A Technical Analysis Framework for Prioritizing Investments in Transportation Control Measures in the Boston Region

by

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B.S., Civil Engineering
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Submitted to the Department of Civil and Environmental Engineering
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Abstract

Transportation Control Measures (TCMs) are programs designed to control mobile source emissions; they consist of a wide variety of strategic and tactical approaches. In addition to their ability to improve long-term and/or short-term regional air quality, TCMs often provide other benefits such as enhanced mobility and accessibility. At a time when Boston is attempting to attain and maintain national air quality standards; is restructuring its transportation planning process; and has committed to implementing over two billion dollars worth of TCMs - improving Boston's method for prioritizing TCM investments is a particularly relevant issue. To this end, the thesis aims to develop a technical analysis framework for prioritizing TCM investments in the Boston region.

In order to achieve this objective, two major research efforts were undertaken. First, the available methods for quantifying the emission and travel impacts of TCMs were surveyed. Second, case studies of five regions with extensive TCM experience were collected. Chapters 3 and 4 present the conclusions from these two endeavors, respectively.

After comparing Boston's current technical analysis activities to the insights found through the research, it became apparent that Boston is aware of, and is dealing with, many of the current issues surrounding TCM analysis. However, Boston's manner of dealing with these issues differs from the approaches adopted by the other case study regions; namely, Boston's approach is much less structured in the sense that it stops short of specifying how exactly technical analysis would be used to facilitate prioritization decisions. Thus, Chapter 5 attempts to develop a framework which structures the interaction of technical analysis with the current TCM prioritization decision-making process. The framework addresses two issues underlying this interaction:

1. Prioritization consists of a continuous sequence of decisions regarding how to define projects and which projects to develop further. *Which of these prioritization decisions should the technical analysis facilitate?*
2. *How exactly should analysis results be used to facilitate decision making?*

Because the research focused on two decisions: (1) which TCMs to consider for inclusion in the SIP, and (2) which TCMs to include in the TIP - only general conclusions could be drawn in regard to the first of the two issues listed above. The research, and therefore the proposed framework, focused largely on the second issue. The core component of the proposed framework is a suggested "Prioritization Methodology," or an idealized system for prioritizing TCM investments. Two underlying theories of the proposed methodology are that (1) approaching the process in a systematic manner is beneficial, and (2) the insights gained by applying the methodology are at least as valuable to the decision-making process as the actual results of the methodology. Chapter 6 tests the proposed methodology by applying it to a simple, hypothetical situation. This trial run results in some minor changes to the methodology and suggests that it be further tested and refined.

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Chapter 1

Introduction

1.1 SUMMARY OF THESIS OBJECTIVE

The objective of this thesis is to develop a technical analysis framework for prioritizing transportation control measures[1] (TCM's) in the Boston region.

Prioritization is viewed as a continuous process; decisions are constantly being made about how to define projects and which projects to develop further. Thus, prioritization occurs on a continuous basis in the sense that if a project is not developed to the point of being construction-ready, it cannot be implemented.

Technical analysis is used to facilitate these prioritization decisions. The proposed technical analysis framework attempts to *structure* the interaction of technical analysis and prioritization decision-making. Namely the technical analysis framework addresses two issues underlying this interaction:

1. Which prioritization decisions to facilitate, and
2. How technical analysis should be used to facilitate them.

However, the second of these two issues is the primary focus of this thesis.

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[1]TCMs are defined in chapter 2.

The thesis attempts to determine how to "best" address these two issues. The *"best"* technical analysis framework would help prioritize TCMs:

- as accurately as possible,
- as inexpensively as possible, and
- as precisely as is necessary.

So that the proposed technical analysis framework could be realistically implemented in the near future:

- it must work within Boston's existing transportation planning process, and
- draw upon the region's existing technical resources and activities.

In order to keep the scope of research manageable, the framework was limited by three main assumptions:

- It is assumed that the overarching regional priority is to meet regional "needs".
- The suggested framework will assume that the region is aware of its "needs" and their relative magnitudes.
- Also, the framework assumes that the region has developed an exhaustive list of potential TCM investments prior to beginning the technical analysis.

1.2 MOTIVATION FOR THESIS OBJECTIVE

The following discussion explains why the prioritization of TCMs is an important issue in Boston currently, and why the technical analysis component of prioritization is focused upon. Stated briefly, prioritization of TCMs is an important issue because of three factors:

1. TCMs are needed to effect a sustainable, long-term improvement in regional air quality, as well as to enhance mobility and accessibility;

2. the transit commitments made in the Memorandum of Understanding between the Conservation Law Foundation and the Massachusetts Executive Office of Transportation and Construction[2]; and
3. Boston's current restructuring of its transportation planning process.

The following paragraphs expand upon these three factors.

1.2.1 TCMs are Needed to Effect a Sustainable, Long-Term Improvement in Regional Air Quality

Many regions worldwide are concerned with their air quality - Boston is one such region. Like these many other regions, Boston may attribute a large portion of its air pollution to motorized vehicle emissions.[3] As transportation's air pollution contribution increases, the question of how to minimize it remains. At the (US) federal level, guidance has been provided by various laws and regulations such as those contained in the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) and the 1990 Clean Air Act Amendments (CAAA). At the state and local levels, additional guidance has been formulated by government, as well as private citizens, businesses, and interest groups.

All of this guidance has resulted in numerous transportation-related actions, and corresponding emission reductions. The bulk of recent emission reductions are attributed to improvements in automobile technology, not TCMs. Unfortunately, these benefits from improved technology may soon be outweighed by the impacts of increased auto use. If this is so, in order to maintain air quality in the long-run, auto use patterns must be targeted for change, not just automobile technology.

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[2] This refers to the Memorandum of Understanding (MOU) between the Conservation Law Foundation (CLF) and Massachusetts' Executive Office of Transportation and Construction (EOTC) which committed the region to numerous mitigation measures aimed at counter-balancing any negative traffic and air quality impacts of the Central Artery/ Tunnel Project. Amongst these commitments were numerous transit projects. Appendix O contains the CLF MOU.

[3] "The Massachusetts 1990 Emissions Inventory indicates that on road mobile sources emit approximately 29% of the total VOCs, 40% of the total NOx, and 61% of the total CO emissions (summer day) in the

As noted in the recent National Travel Census a variety of social and demographic factors could be causing this increasing auto-use pattern. Many of these factors may be out of the control of transportation planners. TCMs are one of the few means transportation planners have to influence the auto-use growth rate. They are a broad range of techniques for altering single-occupant auto-use patterns. Transit projects comprise one category of TCMs.

Though TCMs may be a transportation planner's main means of affecting auto-use patterns, they are not an insignificant means. Although many TCMs often have minimal impacts on air quality and congestion, there are some TCMs that have large potential - such as land-use planning and transportation demand management techniques[4]. However, the effectiveness of TCMs is influenced by how they are planned for. As a result, it would be worthwhile to determine if Boston's TCM planning strategy could be improved and how it could be.

This thesis, however, deals with only a portion of the overall TCM Planning Process: prioritization. Prioritization is a major component of the overall TCM planning process. It is an especially significant portion of the process at this time because about two billion dollars worth of TCMs are at this stage of planning in the Boston region. The extensive package being referred to is also known as "the CLF MOU transit commitments".

1.2.2 The CLF MOU Transit[5] Commitments

A current issue related to air quality planning in the Boston region, is known as "the CLF MOU transit commitments". In a memorandum of understanding (MOU) with the

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state. Mobile source CO emissions on a winter day are approximately 80% of the total statewide CO emissions." - from Boston Document #30, P. 2.

[4] Document No. 8.

[5] The transit commitments affecting the Massachusetts Bay Transportation Authority include a range of bus, subway, commuter rail, and park-and-ride projects. See Appendix O for a more detailed listing of these commitments.

Conservation Law Foundation (CLF), the Governor of Massachusetts agreed to implement about $2 billion of transit projects as mitigation for the Central Artery/Tunnel (CA/T) project.[6] Transit projects are one type of TCM. This rather large transit commitment is still making its way through the planning process.

The CLF MOU commitments have already been through a few phases of the planning process. Whether implicitly or explicitly, the CLF MOU conducted three "planning" actions:

1. It identified the need to mitigate the impacts of the CA/T project.
2. It decided to adopt a transit focus/policy for mitigating these impacts.
3. It chose a set of transit projects.

In addition to these planning actions, the Massachusetts Bay Transportation Authority (MBTA) and Central Transportation Planning Staff (CTPS) have performed an initial, quantitative and qualitative analysis of the original CLF transit commitments.

Thus, the CLF MOU has initiated the "prioritization" process. How so? Selecting a transit focus for the TCM program, indirectly implies that a transit program is "better" than a broad range of alternative TCM strategies. Likewise, choosing a set of specific transit projects implies that those projects better meet the identified needs than other potential projects. However, according to Boston's transportation planning agencies, it is still uncertain if all the original CLF MOU transit commitments are the best project choices.

Two tasks remain before the TCM prioritization process can be completed:

1. The projects committed to in the MOU were selected based on a non-systematic analysis process rather than on a more systematic procedure. The original commitments were selected largely because they were projects which had already been developed and analyzed extensively. However, this analysis did not focus on the air quality benefits of the projects. Additional analysis has been done since the

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[6] The Central Artery / Third Harbor Tunnel Project is described in Chapter 2, the Background chapter.

original commitments were made, finding that all but four of the projects committed to have positive air quality impacts. *The analysis of these original commitments should be finalized.*

2. *Developing a method for identifying new or substitute projects.* In other words, there is a need to develop a store of substitute projects for the existing transit commitments. Substitution of existing commitments might become necessary if financial restrictions makes some of the original commitments unfeasible. (Indirectly, this is equivalent to finding substitute projects which better meet regional needs other than air quality. In the light of limited available funding, the more needs a project serves, the more likely it is to be funded.) Also, identifying possible substitution projects would help clarify if the existing commitments are the best choices.

1.2.3 Boston's Restructuring of its Transportation Planning Process

The third, and final, motivation for this thesis stems from the current restructuring of the Boston planning process. Some examples of what is meant by 'restructuring" is that the Boston region is currently developing a set of "management systems" and reforming its Transportation Improvement Program (TIP)[7] development process. It is important to consider the unique needs of air quality planning when reforming the overall transportation planning structure. Because TCMs are such a large part of transportation's approach to achieving air quality goals, studying the TCM prioritization process provides insight into how the planning process has internalized air quality goals in the past and how it could best do it in the future.

Although Boston's current restructuring of their planning process adds relevance to this research, the thesis does not address this issue.

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[7] Chapter 2 defines TIPs and Management Systems.

1.3 CLARIFICATION AND SCOPE OF OBJECTIVE: WHAT EXACTLY *IS* "A TECHNICAL ANALYSIS FRAMEWORK FOR PRIORITIZING TCMS"

1.3.1 "The TCM Prioritization Process" vs "Prioritization of All Transportation Investments"

This thesis has made a point of focusing on the prioritization of *TCM* projects, rather than on the prioritization of transportation projects in general. The concept of prioritizing transportation investments could be simply described as a process which determines which projects are the most important or cost-effective to implement. TCM prioritization is a subset of this process in the sense that it deals with only a subset of transportation investments: TCMs. While these two processes (TCM prioritization and transportation investment prioritization) overlap, during some portions of the process TCMs may be considered separately from other transportation investments. For instance, this might be the case if certain funds were allocated to TCMs specifically. Another example is the situation when TCMs are being selected to help the region meet air quality goals. Even when TCMs are considered within the same process as other transportation projects, TCMs may be treated in a unique manner. For example, within a TIP scoring scheme, TCMs might be given extra points just for being TCMs. Thus, the path of TCM projects through the planning process is unique.

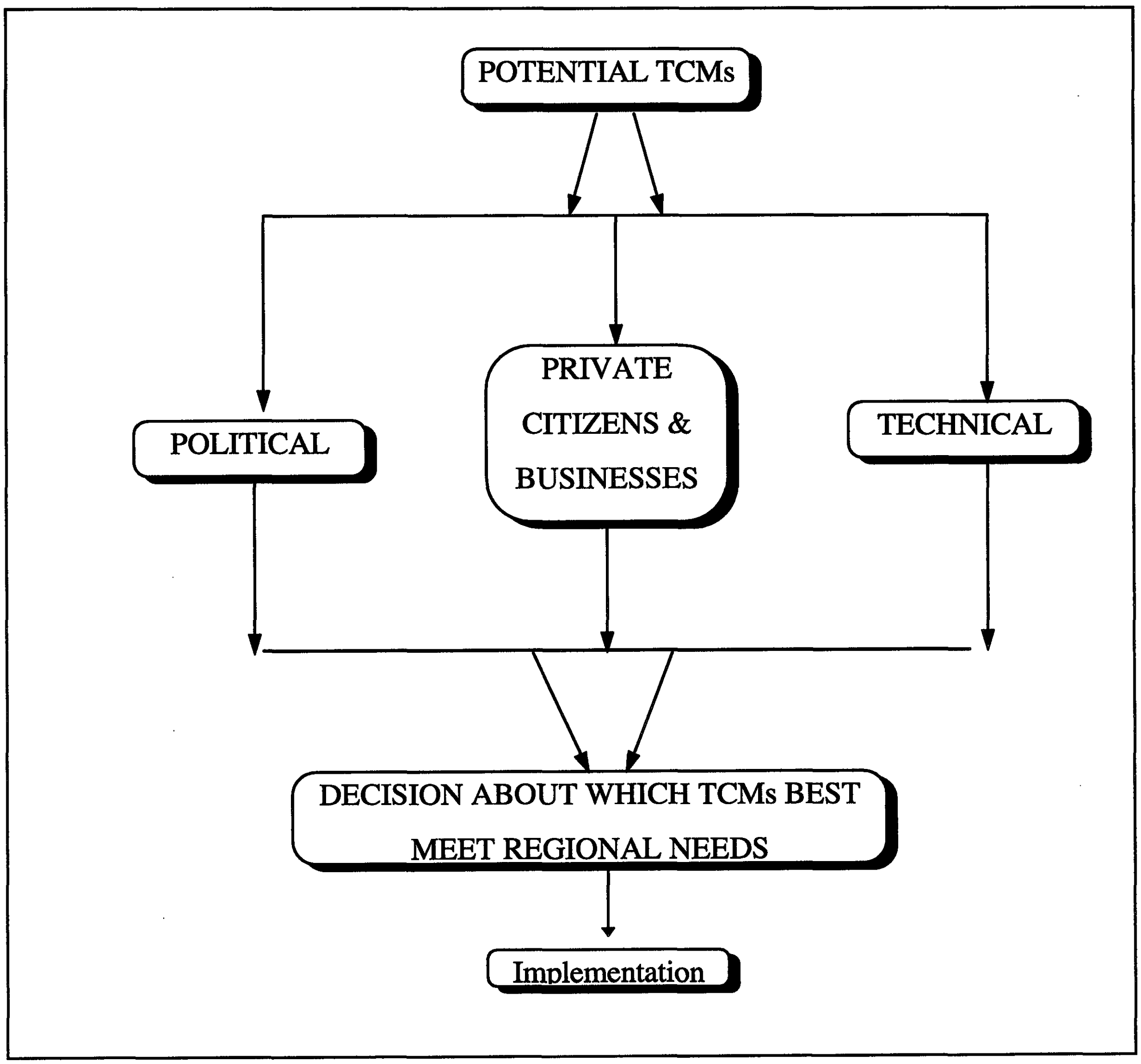
1.3.2 Definition of the TCM Prioritization Process

The "TCM Prioritization Process" refers to the set of tasks which culminate in a decision about which TCMs would best meet regional "needs". (See Figure 1-1) For the purpose of discussion, TCM prioritization could be disaggregated into three components: technical, political, businesses, and private citizens. Each of these components is diverse within itself and could be further disaggregated. However, this breakdown is used to point out the different parties involved in each component and their distinctive perspectives on regional "needs". In particular, for each of the three components - technical, political, private:

- different people are involved,
- different means are used to measure project impacts or system needs, and
- different needs and impacts are focused on or considered.

For example, politicians would be receptive to the wants of their constituents. Public citizens/ businesses are concerned with the impacts to their localities. Technical staff might be focused on their professional responsibilities.

Figure 1-1: The 3 Components of the TCM Prioritization Process



It should also be noted that the three components - technical, political, private- are not completely distinct; in reality these three components are overlapping rather than independent entities. For example, the technical component incorporates input from private citizens and businesses. Politicians try to please there constituents - which are some subset of private citizens/businesses. Also, politicians and technical staff are themselves private citizens. In defining the technical analysis framework, the linkages to private and political processes will be considered.

Combined, these three inputs to the decision-making process (private, political, and technical) work as a system of "checks and balances". They "check and balance" in the sense that what one group is not receptive to, another group may observe. Also they "check and balance" in the sense that if one group incorrectly perceives something, another group may be able to point it out. The next section attempts to define the unique contribution of the technical component to this system of checks and balances.

1.3.3 Defining the "technical component" of TCM prioritization and the scope of the "technical analysis framework"

It is difficult to define exactly what the role of the technical component is within the system of "checks-and-balances" described above. This is partly because it depends on what roles the political and private components play, which is a very variable issue. It varies from region to region. Even within one region, it may vary with time. Probably what makes the technical component's role hardest to determine is that its definition varies with who is defining it. So the question arose of how to develop a technical analysis framework.

There is a goal the TCM prioritization process, as a whole, probably strives for, and which the technical component shares. Simply stated, this goal is to help develop a transportation program which best meets regional priorities in the most cost-effective way possible. Air quality is just one of these regional priorities; mobility and accessibility are other priorities which generally govern the selection of transportation projects. However, meeting air quality goals is often considered the sole responsibility of TCMs, rather than the responsibility of any other category of transportation project.

With this basic goal in mind, the technical component of the TCM prioritization process accomplishes the following. Through one or more project selection and prioritization cycles it reduces the set of all potential TCM investments in Boston, to a ranked subset of these TCMs indicating which projects are the "most consistent" with regional priorities.

In general, the technical component involves traffic engineers, transit analysts, urban planners, environmental analysts, and other such professionals. These parties tend to estimate project impacts and regional needs using mathematical models, case studies from other regions, previous experience, as well as other such tools. The needs and impacts considered in the technical component are multimodal and regional in scale. However, specific agencies, such as the highway department or a local agency, would only be concerned with a subset of these impacts and needs.

This thesis focuses on a portion of the technical component of the TCM Prioritization Process described in Figure 1-1. It develops a technical analysis framework which addresses the question of "how to reduce the initial set of TCMs to a ranked subset".

In order to establish a starting point from which the technical analysis framework for prioritization will progress, three assumptions are made:

- It is assumed that the overarching regional priority is to meet regional "needs".
- The suggested framework will assume that the region is aware of its "needs" and their relative magnitudes.
- Also, the framework assumes that the region has developed an exhaustive list of potential TCM investments prior to beginning the technical analysis.

These three assumptions have several implications on the scope and type of research which was conducted and on the scope of the technical framework eventually suggested.

For instance, the second assumption is not necessarily realistic. It is probably impossible for a region to know exactly what all its needs are and how they are relatively valued. This is partially because defining a region's needs and their relative importance is a highly subjected, and individual-specific issue. Developing a method for identifying regional needs and their relative value is a complex process in itself which should proceed or at least parallel, the relative ranking of transportation projects. Therefore, it is assumed that it has already been conducted, and that the results could be used to facilitate the relative ranking of projects which is undertaken by the technical analysis framework.

The third assumption was made for similar reasons. It is assumed that the region has already developed an exhaustive set of potential TCMs prior to beginning the analysis, because it is a task which should proceed or at least parallel the relative ranking of projects. Developing a set of potential TCMs is an extensive process in itself, and beyond the scope of this thesis. However, it is a very significant portion of the overall planning process and is an indirect participant in the prioritization process. This is true in the sense that a project has indirectly been assigned "low" priority if it is never recognized as a potential project.

1.3.4 Distinction Between Accuracy and Precision

As defined in this thesis, the ***"best" technical analysis framework*** would

1. ***maximize accuracy*** of the final prioritized list,
2. have a ***minimal cost,*** and
3. produce ***sufficiently precise*** results.

The case studies and literature review suggested methods for achieving these three qualities - accuracy, low cost, and precision; Chapters 3 and 4 each identifies issues which affect accuracy, cost, or precision.

As a precursor to this discussion, the meaning of "accuracy" and "precision" are clarified in the following paragraphs. Accuracy and precision as used in everyday speech are practically synonymous, however they refer to two different concepts in the context of this thesis. The distinction between the two goals of accuracy and precision is best illustrated by example.

- *Accuracy*: An agency uses a three tiered ranking system (ranking scheme A) in which projects are either "high priority", "medium priority", or "low priority". An accurate ranking of a project would place it in the right tier.
- *Precision*: Ranking scheme A was just described. Ranking Scheme B provides a continuous ranking of projects. It is based on project scores which range from 0 to 100, 100 being best. Ranking scheme B is more precise than scheme A, because it identifies subtler distinctions between projects.

Notice that as defined in this thesis, the "best" ranking scheme is "as accurate as possible", but only "sufficiently precise". This is because an inaccurately ranked project definitely encourages a bad decision. However, an imprecise ranking is not incorrect, and while it may not point out the best decision it at least would not encourage a bad one. A "sufficiently" precise ranking would be subtle enough to provide decision makers with all the information they need/or would use. It is expensive to increase the precision of technical analysis, and therefore the analysis process should only be as precise as necessary. Precision is expensive to increase because more detailed and time consuming models are needed to produce it. Also, to analyze projects in more detail, additional time must be invested in projects early on in the process. Also, analysts might have to acquire additional data which can be extremely expensive. Thus, only wanting a "sufficiently" precise method is highly related to the issue of wanting to minimize the process' cost.

1.4 APPROACH TAKEN TO ACHIEVE THE THESIS OBJECTIVE - RESEARCH METHODOLOGY

In summary, the objective of this thesis is to develop a technical analysis framework for prioritizing TCM investments in the Boston region. The proposed technical analysis framework attempts to *structure* the interaction of technical analysis and prioritization decision-making. Namely the technical analysis framework addresses two issues underlying this interaction:

1. Which prioritization decisions to facilitate, and
2. How technical analysis should be used to facilitate them.

The thesis attempts to determine how to "best" address these two issues.

In order to achieve this objective, two major research efforts were made. First, the available methods for quantifying the emission and travel impacts of TCMs were surveyed. Second, case studies of five regions with extensive TCM experience were collected.

The first research effort is summarized in Chapter 3 and Appendix B; it consisted of a comprehensive review of the dominant (as defined by the agencies consulted) methodologies available for quantifying the emissions and travel impacts of TCMs as of Spring 1995. A total of ten methods were reviewed in detail. The review of each method answered some or all of the following questions:

1. What TCMs can be analyzed using this methodology and at what level of detail

(a) Level of analysis provided by the methodology

This section identifies what level of analysis is provided by the methodology. Generally, the answer to this will take the form of one of the terms: Screening, Sketch-Planning or Detailed Analysis. The information provided here should give some indication to the reader of how rigorous the methodology is and as such, what level of decisions could be made based on the output.

(b) What TCMs has the methodology been designed to analyze

This section is generally a listing of all the TCMs amenable to analysis using this methodology, in cases where such information was available.

(c) Does the methodology support the analysis of groups of TCMs

In some cases, one may need to analyze a number of TCMs whose impacts are interdependent. In such instances, a methodology which accounts for the effects of interacting measures will be appropriate. This section identifies whether the methodology has the facility to analyze packages of TCMs.

2. Structure, inputs and outputs of the methodology

This section provides a brief overview of the methodology in terms of its structure, input requirements, and resultant outputs. In some cases a methodology will consist of a fully integrated number of modules. These modules may be aimed at analyzing transportation, emissions and cost-effectiveness impacts as well as other impacts. Other methodologies will consist of perhaps only a transportation component. In such cases, estimation of emissions effects and other impacts would require the use an additional method(s). This section highlights what exactly the methodology is made up of, what it is capable of analyzing, and what output it provides.

3. Practical Restrictions

(a) How easy is it to obtain the data required for the methodology

A major element in the decision to use any methodology is whether or not the data is available to actually use it. This section indicates how easy it is to obtain the data required of the methodology and where this information would typically come from. For some methodologies, the data requirements are quite extensive and would thus be very expensive to collect. In other cases, the data may be readily available and so the use of the methodology might be very practical. The decision of which methodology to adopt will also be dependent on the level of analysis required and the seriousness of the decisions which need to be made based on the output.

(b) Computer hardware and software required to use the methodology

This section identifies what the computer requirements (if any) of the methodology are. The potential user will obviously be constrained by the computer resources available to him and this will be an obvious determinant in his choice of methodology.

(c) Technical skills required to operate the methodology

This section indicates the necessary computer experience or skills required to use the various methodologies. Some methodologies are very user-friendly whereas others require programming experience or other expertise.

The review of each method is contained in Appendix B. However, the analysis and conclusions relevant to the subject of this thesis are presented in Chapter 3. Chapter 3 discusses the general approach used to quantify a TCM's travel and emissions impacts. It also discusses the range of methods available, why such a range of methods exists, and what determines which method is "best" for a given application. The chapter concludes by summarizing the implications of the research on the desirable structure of a technical analysis framework.

A second stage of research followed the review of methods described above. It involved the gathering of five detailed case studies of the San Francisco Bay Area, the Puget Sounds Region, the Dallas-Fort Worth Area, the Washington DC area, and the Boston Region. The full case studies are contained in Appendix A. Each one addresses all or most of the following issues:

1. *Why the region was included as a case study*
   - What is special about it: has it had extensive experiences with TCMs, are its experiences well documented, has it had severe air quality problems, how does it relate to the final project objective of developing a methodology for Boston.
   - What is the regions non-attainment status according to EPA standards.
   - Who suggested including the region as a case study.
2. *Brief regional profile*
   - Size of area.
   - Population.
   - Extent of transit, highway, and other components of the transportation system.
   - Unusual characteristics.
   - Impacts of regional characteristics on air quality and congestion.
3. *Description and Status of current TCM related programs*
   - This section lists the TCM programs to be discussed in this case study; it lists specific projects. It may also include a discussion of past TCM programs and other TCM-related programs not described in the case study, since many regions

have developed multiple or ongoing TCM related programs. Not all case studies provide a broad picture of all regional TCM-related processes. Some case studies focus on just one, like a TIP process or a SIP process.

4. *Organizational Structure*
    - The agencies involved in the development of TCM programs, and the responsibilities given to each agency.
5. *Methods used to prioritize and select projects*
    - Process: sequence of events leading to final project selection
    - Qualitative/quantitative methods used to select or prioritize projects. For example, the criteria used to score projects and the methods used to measure these criteria (e.g. if a criteria was "trip reductions" then a travel model may have been used to measure these)
    - Results: how projects were ranked and which projects were chosen.
6. *Analysis of Impacts*
    - Methods (e.g. models) used to estimate the impacts of a TCM or group of TCMs.
    - How applied to measures: what method was used to analyze each TCM. Some example methodologies may be presented - the level of detail of the example depends on the availability of information. An example could include such items as: assumptions made, inputs needed, and calculations made.
    - Degree of accuracy identified: In other words, the ability of the analysis method to successfully predict impacts or relative impacts. Answers to this section are subjective and usually based on a phone interview.
7. *Institutional and Political Issues:*
    - This section is related to the section on organizational structure. It will discuss experiences with coordinating committees, delegating authority, and other such issues. For example, Washington, DC pointed out the need to consult agencies which will be implementing the project to guarantee sufficient resources are available for implementing the project in the way it was defined during the project selection process. For instance, during the project selection process, a project may have been defined as part of a TCM package and thus, as being implemented at a specific time relative to the other projects. This package of TCMs may have then been selected for their synergistic effects. If the responsible agency is unable to implement the project according to the presumed schedule, the synergistic effects may not be captured and the original premise for selecting the TCM package would be false. Thus, the responsible agency should be consulted before the project is selected to ensure that it can be implemented as planned.
8. *Lessons Learned*
    - What did the agencies involved in the process learn from their experiences; what do they think were some strengths and weaknesses of the process they followed, the analytical methods they used, or the decisions they made.
9. *Summary and Conclusions*
    - What was learned from this case study.

The case studies focused on the methods used to systematize the interaction of technical analysis with two critical decisions of the TCM prioritization process:

1. Which TCMs to consider for inclusion in the State Implementation Plan (SIP)[8].
2. Which TCMs to program into the TIP.

The research did not begin with an intention to collect information mainly on these two decisions. Nor, did it begin with a full understanding of what the TCM prioritization process consisted of. Interviewees from regional transportation planning agencies were asked for "methods used to prioritize TCMs" or for information on the "TCM program development process." Interviewees generally responded by describing a TIP or SIP process. Therefore the case studies focus on TIP and SIP processes - which is not a misfortune since these are two critical decision stages of the TCM prioritization process.

However, because of the limited scope of the case studies, their conclusions focus on the second of the two issues the proposed technical analysis framework aimed to address: "how to use technical analysis to facilitate prioritization decisions." Some conclusions were drawn in regard to the first issue: " which prioritization decisions to facilitate," however they are very simple, perhaps even obvious. The analysis and conclusions from these case studies are presented in Chapter 4.

After surveying the available methods for quantifying the impacts of TCMs (Chapter 3), the prioritization methods used by other regions (Chapter 4), in addition to Boston's own planning activities, Chapter 5 ties the research together in order to develop a technical analysis framework for the Boston region. The core component of the proposed framework is a five step "Prioritization Methodology" which addresses the second issue of the framework: "how technical analysis should be used to facilitate decisions." Chapter 5 compares the idealized "Prioritization Methodology" to Boston's existing TIP and SIP planning activities. Because the research focused on two prioritization decisions (TIP and

SIP), only very general conclusions are drawn in regard to the first issue: "which prioritization decisions to facilitate."

Chapter 6 applies the proposed "Prioritization Methodology" to a very simple hypothetical situation in order to clarify the methodology's definition as well as identify any of its shortfalls. One major shortfall is identified by this trial run. As a remedy, two additional steps are added to the original five-step methodology.

Chapter 7 summarizes the thesis by discussing its major conclusions.

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[8] Chapter 2 defines SIPs.

Chapter 2

Background & Definitions

This chapter explains terms and issues of particular relevance to the thesis topic. It begins by explaining what a Transportation Control Measure (TCM) is in Section 2.1 and provides some other useful definitions in section 2.2. The chapter then delves into some less basic issues. Section 2.3 attempts to summarize the nature of the air quality problem. Section 2.4 builds on this by explaining possible solutions to the air quality problem. Section 2.5 presents the general theory behind TCM analysis. Section 2.6 concludes the chapter with a discussion of how effective TCMs are thought to be at reducing emissions.

2.1 WHAT IS A TCM?

TCM's are programs designed to control mobile source emissions, and they consist of a wide variety of strategic and tactical approaches. For example:

1. Supply management techniques incorporate low cost methods for optimizing the capacity of highways and streets. Theoretically, they improve the flow of traffic and reduce high emissions associated with low speeds. Included are actions such as traffic signal optimization, traffic operations improvements and enforcement, as well as various management programs.

2. Demand management strategies are aimed at reducing the number of motor vehicles operating on streets and highways during peak commute periods. Examples of these techniques include public transportation improvements, ridesharing/carpool programs,

employer based programs, and park-and-ride fringe parking programs. Other strategies include trip reduction ordinances, parking management, vehicle use restrictions, and other planning activities.

Also, the Clean Air Act Amendments (CAAA) describes 16 TCM categories (listed in Table 2-1) and suggests their use for mitigating the air quality impacts of the transportation sector.

Table 2- 1 TCMs listed in the CAAA[9]

1. Programs for improved public transit.
2. HOV and bus lanes (construction of and conversion of existing lanes to.)
3. Employer based transportation management plans, including incentives.
4. Trip reduction ordinances
5. Traffic flow improvement programs that reduce emissions.
6. Parking facilities for multiple occupancy vehicle programs or transit service.
7. Vehicle use restrictions in downtown or other high emission areas, especially during peak use periods.
8. Programs providing for all forms of high-occupancy and shared ride services.
9. Programs limiting portions of roads or sections of metropolitan areas to non-motorized vehicular use or pedestrian use (both temporal and spatial restrictions.)
10. Bicycle use incentives in both private and public areas.
11. Idling restrictions.
12. Cold-start emission restrictions (in accordance with Title II.)
13. Employer-sponsored programs to permit flexible work schedules.
14. Programs and restrictions to promote non-single occupant automobile travel as part of the transportation planning and development efforts of a locality (new shopping centers, special events and other centers of vehicle activity included.)
15. Programs for new construction of and major reconstruction of paths, tracks, or areas solely for the use by pedestrian or non-motorized means of transportation when economically feasible and in the public interest.
16. Programs to encourage the voluntary removal from use and the marketplace of pre-1980 model year light duty vehicles and pre-1980 model light duty trucks.

[9] Document No. 5, p. 1-4, table 1-1.

2.2 OTHER USEFUL DEFINITIONS

This section defines several terms which are used frequently in the remainder of the thesis. The terms discussed, and the order they are discussed in, is as follows:

- 1991 Intermodal Surface Transportation Efficiency Act (ISTEA)
- Transportation Plans (TP)
- Transportation Improvement Programs (TIP)
- Metropolitan Planning Organization (MPO)
- Mode, Intermodal, Multimodal,
- Congestion Management and Air Quality Improvement Program (CMAQ)
- 1970 Clean Air Act (CAA)
- Clean Air Act Amendments of 1990 (CAAA)
- State Implementation Plan (SIP)
- 15% Reduction Plan
- Contingency Measures
- Attainment Area and Non-Attainment Area
- National Ambient Air Quality Standards (NAAQS)
- Conformity
- Carbon Monoxide (CO)
- Hydrocarbons (HC)
- Ozone (O_3)
- Particulate Matter (PM and PM_{10})
- National Environmental Protection Act (NEPA)
- Environmental Impact Statement (EIS)
- Central Artery/ Tunnel Project (CA/ T)

2.2.1 The 1991 ISTEA, TPs, & TIPs

The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) is a legislation which imposes requirements, guides, and funds transportation in the US over a six year period. The legislation is divided into eight titles (i.e. subsections):

Title I: Surface Transportation
Title II: Highway Safety
Title III: Federal Transit Act Amendments of 1991
Title IV: Motor Carrier Act of 1991
Title V: Intermodal Transportation
Title VI: Research
Title VII: Air Transportation
Title VIII: Extension of Highway-Related Taxes and Highway Trust Fund

The $151 billion of federal funds ISTEA makes available over the next six years is divided amongst funding programs described throughout the eight titles.[10] One such funding

[10]Document No. 41, p. 240.

program is known as the Congestion Mitigation/ Air Quality (CM/AQ) funds. Under ISTEA, regions may transfer funds between programs in order to best meet regional needs. ISTEA's flexible funding policy distinguishes it from past transportation legislation.

Also unique to ISTEA is its broad statement of policy:

> *"It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner."*[11]

Unlike the interstate highway program, or other past transportation initiatives, ISTEA's policy does not favor one mode and focuses on issues other than establishing mobility. (not to say that it does not support mobility.) Rather, the flexibility of funding allows regions to pursue ISTEA's policy in an unhindered, yet structured manner.

Some structure is provided by the transportation planning requirements mentioned under Title I. These requirements provide a framework within which States and regions could pursue ISTEA's policy. For instance, ISTEA's policy and goal is directly incorporated into the planning process through 15 factors Metropolitan Planning Organizations (MPOs) and 23 factors States must consider while developing long-range plans. Prior to ISTEA, the planning processes of MPO's and state Departments of Transportation (DOTs) often did not address the breadth of concerns included in the ISTEA planning factors.[12]

These 15 MPO and 23 State factors must be considered by MPOs and DOTs, respectively, when they develop their long-range plans. The plans, typically termed Transportation Plans (TP), are also required under ISTEA. They must cover a twenty year planning horizon and be updated periodically. In addition to the 15 regional and 23 state planning factors, ISTEA ensures that TPs reflect ISTEA's policy by imposing three other requirements on the TPs:

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[11]Document No. 41, p. 243.

1. that State TPs are coordinated with MPO TPs,
2. that a reasonable opportunity is provided for the public to comment, and
3. that TPs conform with the SIP. In particular, that transportation control measures (TCMs) mentioned in the SIP are coordinated with the TP.

The first requirement ensures that MPOs and States develop integrated and financially feasible transportation visions. The second has many benefits such as clearing away potential political issues early in the planning process. Meanwhile, the third requirement turns environmental issues into a priority rather than a technicality.

In addition to requiring long-range planning through TPs, ISTEA requires DOTs and MPOs to develop short-term plans called Transportation Improvement Programs (TIPs). TIPs cover a three to five year planning horizon and must be updated every two years. They must contain a financially constrained, prioritized list of projects consistent with the TP and SIP. In particular, TIPs include:

- federally funded projects
- projects which require federal action (like an Army Corps of Engineers permit)
- all significant projects that could effect air quality, and
- all other regionally significant projects.[13]

At minimum, all projects to be implemented in year one may be lumped together as priority 1. Financial constraint must also occur on a yearly basis, at minimum.[14] While some regions have developed TIPs even before ISTEA required them, most regions did not financially constrain their programs. This requirement makes TIPs realistic plans that could even be called the crucial link between planning and implementation. As David Murray of the San Francisco Bay Area's Metropolitan Transportation Commission states, "...with unrealistic financial assumptions, the overall community vision used to develop the

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[12]Document No. 43, p. 44.
[13](Federal Register, 10/28/93. p. 58065) Regionally significant project means, "a project ... that is on a facility which serves regional transportation needs (such as access to and from the area outside of the region, major activity centers in the region, major planned developments such as new retail malls, sports complexes, etc., or transportation terminals...) and would normally be included in the modeling of a metropolitan area's transportation network, including, at a minimum, all principle arterial highway and fixed guideway transit facilities that offer a significant alternative to regional highway travel."

TIP is breached. ... The environmental conformity determination -- the process used to ensure that transportation projects are in sync with clean air laws -- is invalid."[15] Like TPs, TIPs must also undergo public review.

In addition to requiring TPs, TIPs, and the consideration of the planning factors, ISTEA encourages States to develop seven management systems:

1. Pavement Management System (PMS)
2. Bridge Management System (BMS)
3. Highway Safety Management System (SMS)
4. Traffic Congestion Management System (CMS)
5. Public Transit Facilities and Equipment Management System (PTMS)
6. Intermodal Management System (IMS)
7. Traffic Monitoring System for Highways (TMS/H)

These systems are expected to improve the establishment of project funding priorities across modes and the analysis of trade-offs among the range of potential transportation investments being considered.[16]

In conclusion, ISTEA primarily uses four planning requirements to ensure its flexible funds are used in support of its policy objective:

1. 15 regional and 23 state planning factors
2. TP (long-term planning document)
3. TIP (short-term planning document), and
4. Management systems.

Embedded within these are

- public involvement
- financial constraint, and
- conformity

requirements that encourage the development of an integrated (i.e. integrated in the sense that TPs conform with TIPs, that TPs and TIPs conform to the SIP, and that state plans are coordinated with MPO plans) transportation program whose implementation is facilitated by funding availability and public support.

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[14]Document No. 43, p. 63-64.
[15]Document No. 43, p. 62.
[16]Document No. 43, p. 125.

2.2.2 Metropolitan Planning Organization (MPO)

The MPO is the organizational entity designated by law with lead responsibility for developing transportation plans and programs for urbanized areas of 50,000 or more in population. MPOs are established by agreement of the Governor and units of general purpose local government which together represents 75 percent of the affected population or urbanized area.

2.2.3 Mode, Intermodal, Multimodal

A mode is a form of transportation such as automobile, transit, bicycle, or walking. Intermodal refers to the connections between modes. Multimodal refers to the availability of several modal options within a system or corridor.

2.2.4 Congestion Management and Air Quality Improvement Program (CMAQ)

A new categorical funding program created with the 1991 ISTEA. It directs funding to projects that contribute to meeting national ambient air quality standards. CMAQ funds generally may not be used for projects that result in the construction of new capacity available to SOVs (single-occupant-vehicles.)[17]

2.2.5 1970 Clean Air Act (CAA)

This act created the Environmental Protection Agency (EPA) and empowered it to set ambient air quality standards. Required reductions in new automobile emissions were also specified in the act. The act authorized the EPA to require states to formulate implementation plans describing how they would achieve and maintain the ambient air quality standards. In 1971 the EPA promulgated national ambient air quality standards and proposed regulations on State Implementation Plans (SIPs) to meet these standards.

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[17] Taken from the "ISTEA's Planner's Workbook" (i.e. Document No. 24, page156.)

2.2.6 Clean Air Act Amendments of 1990

Of the eleven titles in the act, two directly pertained to transportation in particular. Title 1 addressed the attainment and maintenance of NAAQS. Non-attainment areas were classified for ozone, CO, and particulate matter in accordance with the severity of the air pollution problem. Depending on the degree to which an area exceeded the standard, that area was required to implement various control programs and to achieve attainment of the NAAQS within a specified time period. The areas that were furthest out of compliance were given the longest length of time to achieve the standards. (see Appendix P)

The "conformity" provisions in the 1990 amendments were expanded from the Clean Air Act Amendment of 1977. A conformity determination was required to assure that Federally approved or financially assisted projects or actions conform to a SIP. The 1990 provisions shifted the emphasis from conforming to a SIP to conforming to a SIP's purpose of eliminating and reducing the severity and number of violations of the NAAQS and achieving expeditious attainment of the standards. In addition, no activity could cause or contribute to new NAAQS violations, nor increase the frequency or severity of any existing violations of any standard, nor delay the timely attainment of any required NAAQS. The new provisions still required the state department of transportation and Metropolitan Planning Organizations (MPOs) to make conformity determinations, but they were to be much more dependent on quantitative analysis.[18]

Also, the Clean Air Act Amendments of 1990 expanded the "sanctions" where states failed to carry out requirements of the Act. Previously, sanctions were applied for failing to submit a SIP. Under the new provisions, sanctions could additionally be triggered when EPA disapproved a SIP or a State or MPO failed to implement any SIP provision.

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[18] Definition taken from Document No. 41, pages 232-234.

2.2.7 *SIP, 15% reduction plans, and contingency measures*

State Implementation Plans (SIP) describe a State's plan for attaining, maintaining, monitoring, and enforcing compliance with the National Ambient Air Quality Standards (NAAQS). In order to avoid punitive actions such as sanctions, States develop SIPs which comply with the Clean Air Act and Amendment requirements described in Appendix P. Transportation projects (such as TCMs) may be included in SIPs when they are shown to improve air quality. They may be included as part of the *"15% reduction plan"* or as *"contingency measures"*. The meaning of these two terms is clarified in Appendix P.

2.2.8 *Attainment Areas and Non-Attainment Areas*

An attainment area is considered to have air quality that meets the U.S. Environmental Protection Agency (EPA) health standards used in the Clean Air Act and Amendments. An area may be an attainment area for one pollutant and a non-attainment area for others. Non-attainment areas are areas considered not to have met the NAAQS for designated pollutants.[19] Depending on the severity of the air quality problem, officials in each non-attainment area must take specified actions within a set time frame to reduce emissions and attain NAAQS.[20]

2.2.9 *National Ambient Air Quality Standards (NAAQS)*

Federal standards that set allowable concentrations and exposure limits for various pollutants.

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[19] Taken from the "ISTEA's Planner's Workbook" (i.e. Document No. 24, page154.)

[20] Document No. 23, page 5.

2.2.10 Conformity

Process to assess the compliance of any transportation plan, program, or project with air quality control plans. The conformity process is defined by the Clean Air Act and Amendments.

2.2.11 Carbon Monoxide, Hydrocarbons, Ozone, and Particulate Matter[21]

Carbon Monoxide (CO)

A colorless, odorless, gas that impedes the oxygenation of blood. CO is formed in large part by incomplete combustion of fuel.

Hydrocarbons (HC)

Colorless gaseos compounds originating from evaporation and the incomplete combustion of fossil fuels.

Ozone

Ozone is a colorless gas with a sweet odor. It is not a direct emission from transportation sources. It is a secondary pollutant formed when hydrocarbons (HC) and Nitrogen Oxides (NOx) combine in the presence of sunlight. The ozone is associated with smog or haze conditions. Although the ozone in the upper atmosphere protects humans from harmful ultraviolet rays, ground level ozone produces an unhealthy environment in which to live.

Particulate Matter (PM or PM_{10})

Particulate matter is any material that exists as solid or liquid in the atmosphere. It may be in the form of fly ash, soot, dust, fog, fumes, or some other form. PM_{10} is particulate matter which is less than 10 microns in size and is too small to be filtered by the nose and lungs.

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[21] Document No. 24, pages 153-170.

2.2.12 National Environmental Policy Act of 1969 and Environmental Impact Statements (EIS)

The federal government's concern for environmental issues dated back to the passage of the Air Quality Control Act of 1955, which directed the Surgeon General to conduct research regarding air pollution. Through a series of acts since that time, the federal government's involvement in environmental matters broadened and deepened.

In 1969 an important piece of environmental legislation was passed, the National Environmental Policy Act of 1969 (NEPA). Federal agencies were required under the act to use a systematic interdisciplinary approach to the planning and decision-making that affected the environment. It also required that an Environmental Impact Statement (EIS) be prepared for all legislation and major federal actions that would affect the environment significantly.

An Environmental Impact Statement is a report which details any adverse economic, social, and environmental effects of a proposed transportation project for which federal funding is being sought. Adverse effects could include air, water, or noise pollution; destruction or disruption of natural resources; adverse employment effects; injurious displacement of people or businesses; or disruption of desirable community or regional growth. Also an EIS should contain information on alternatives to the action being studied, the relationship between short-term and long-term impacts, and irretrievable commitment of resources. The federal agency was to seek comments on the action and its impacts from affected jurisdictions and make all information public.[22]

2.2.13 Central Artery/ Tunnel (CA/ T) Project

The Central Artery Project represents a massive investment in the Boston region's highway infrastructure and has been the subject of much scrutiny with regard to its impacts on air quality, congestion and other environmental, economic and community

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[22] Document No. 41, page 82.

impacts. The project consists of approximately 7 miles of new and reconstructed roadways including the following major elements as detailed in the 1990 Final Supplemental Environmental Impact Report (FSEIR.)

- Construction of a widened mostly underground Interstate 93 (I-93) from north of the Central Artery North Area interchange in Charlestown to just south of the Massachusetts Avenue interchange. I-93 is referred to as the Central Artery north of Kneeland Street and as the Southeast Expressway south of Kneeland Street.

- Construction of an I-90 extension via a Seaport Access Highway and Third Harbor Tunnel to Logan Airport in East Boston, with a connection to Route 1A. The I-90 extension will begin at the intersection of the Massachusetts Turnpike (I-90) and the Southeast Expressway (I-93) and proceed eastward, mainly in tunnel, through South Boston, under Boston Harbor, and into Logan Airport. A much improved and expanded high occupancy vehicle (HOV) system also will be incorporated along I-90 and I-93 to link downtown at Kneeland Street and the proposed South Station Transportation Center (SSTC) with Logan Airport and points south and west of Boston.

- Construction of an extended frontage road system parallel to I-93 both northbound and southbound from Causeway Street to just past Southampton Street.

- Construction of a South Boston Bypass Road, most of which will be in an existing railroad right-of-way, connecting the Southeast Expressway (I-93) to the Seaport Access Highway (I-90) and the Commonwealth Flats area in South Boston.

2.3 WHAT IS THE AIR QUALITY PROBLEM?

The consumption and production of energy are major causes of air pollution. The transportation industry uses energy through a range of avenues: vehicle operations, vehicle manufacture, raw material production, vehicle maintenance, infrastructure provisions, and energy generation. Amongst these categories, vehicle operations often consume the largest share of energy, according to a study done in the United Kingdom. For example, as much as 66% of energy consumed by the United Kingdom's land transport system may be attributed to vehicle operations.[23]

Not only do vehicle operations often consume the most energy, but the processes by which they do so produce much pollution and are relatively hard to control. For example, the operation of cars and light duty trucks in California contribute 24% of non-methane hydrocarbon emissions, 27% of NOx emissions, and 55% percent of carbon monoxide emissions statewide. They contribute even larger percentages in urban areas.[24] Catalytic converters offer a means of reducing these emissions; however, not all cars are yet equipped with them. This may be because the vehicle fleet contains some older vehicles which were built before catalytic converters became standard features on automobiles. This may also be because individuals often disable their converters intentionally. In California, random roadside tests of 3742 cars showed that the dirtiest 7% of cars emitted 50% of the emissions in the sample. In contrast, the cleanest 50% of cars emitted only 3% of the emissions.[25]

Thus, the dominant "air-quality problem" as far as transportation is concerned could be seen as the excessive release of hydrocarbons (HC), NOx, carbon monoxide (CO), carbon dioxide (CO_2), particulate matter, sulfur dioxide, lead, and chlorofluorocarbons into the atmosphere by vehicle operations.[26] Of these pollutants, HC, NOx, CO, and CO_2 are the most significant currently in the US. Their significance stems from the health and

[23] Document No. 32, p. 17 and 42.
[24] Document No 33, p. 2-3.
[25] Document No. 33, p. iv.

environmental impacts which result from their excess. These impacts include respiratory disease, acid rain, and global warming.

The excessive emission of these gases by vehicle operations has two primary causes:

1. the incomplete combustion of gasoline, and
2. the excessive vehicle-miles traveled and vehicle-trips made by these gasoline-powered vehicles.

2.4 POSSIBLE SOLUTIONS TO THE AIR QUALITY PROBLEM

In order to reduce the air pollution caused by vehicle operations, both of the aforementioned causes must be addressed. This is because while a significant decrease in pollution may be achieved through technological improvements to the gasoline vehicle, increases in vehicular travel will soon outpace these technological gains. A variety of statistics suggest this given the current circumstances. For instance in the UK:

- Energy use and pollution by transport have continued to increase in the last ten years despite small reductions in energy use and pollution on a per kilometer basis. This is because the number of km (in total) driven by vehicles has increased at a much faster rate. For example, between 1978 and 1988, the energy needed to move 1 passenger 1 km fell by 3%. However, the total number of passenger km rose by 31% to outweigh the small gain in energy *efficiency* (not the same as emissions).
- Technological improvements such as catalyst technology and more energy efficient vehicles are limited because they fail to reduce energy consumption enough to make up for increasing traffic. The Department of Energy forecast that improvements in car *efficiency* (not synonymous to emissions) between 1990 and 2010 would be at most 28%. This contrasts with the lowest increase in car traffic of 41% predicted by the Department of Transport for the same period.

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[26] Document No. 32, p. 33-43.

- Some alternative fuels such as methanol, diesel and gas have the potential to be short-term solutions to the growing pollution from transport. But unless cleaner ways of creating fuels like electricity and hydrogen are developed then growing traffic will also wipe out these gains.[27]

Thus, the two main causes of transportation pollution: (1) incomplete combustion and (2) excessive travel, could be addressed through:

1. Improved Technologies, and
2. Changing Travel Habits and Travel Needs

To achieve an effective solution, however, both avenues must be pursued. Many regions in the US have already implemented such air quality programs, and have achieved varied success in reducing air pollution. ***Transportation Control Measures are a primary means of affecting travel habits and travel needs.***

2.5 GENERAL THEORY BEHIND TCM ANALYSIS

Given a limited budget and a need to reduce emissions, regions often analyze TCMs in order to rank them by their potential to reduce emissions, their cost-effectiveness, or some other measure. To do this, analysts are attempting to understand the interconnections between emissions, travel patterns, and costs. The short-term picture is much simpler than the long-term one. In the short-term, housing location, job location, population, and car ownership are relatively constant. But still, analysis of the short-term situation is not simple. For example, eliminating the need for parents to drive to work does not prevent their children from using the car instead. Although many such short-term and long-term nuances of TCM analysis have yet to be understood, a solid basis has been formed. The following sequence of subsections describes some of these well established "basics".

[27]Document No. 32, p. 3.

2.5.1 What elements of the transportation system cause emissions?

First, it should be noted that this discussion deals mainly with urban transport which excludes inter-city modes such as air and rail. Within this area of focus, diesel and gasoline vehicles are viewed as the major emission producing elements. Thus, pollutants resulting from the production of electricity to run electric vehicles/trains are generally not considered when analyzing the effects of TCMs. However, other elements of the CAA or State Implementation Plans (SIPs) consider these emission sources.

Gasoline and Diesel engines emit pollutants in two manners. Operating the vehicles produces exhaust containing hydrocarbons (HC), nitrogen gases (NOx), carbon monoxide (CO), as well as other substances. Also, gasoline and diesel evaporate, releasing HC into the atmosphere, when the car is at rest, in motion, or refueling. Figure 2-1 provides a detailed description of how pollutants are produced by a petroleum-powered vehicle.

2.5.2 What is the cause-effect relationship between vehicle actions and vehicle emissions?

The amount and type of pollutants released by a vehicle are a function of two things:

- the type of vehicle, and
- the action being performed by a given vehicle.

Many vehicle attributes define its emissions patterns. One example is the mechanics of the vehicle such as the engine. Typically, older cars are less efficient and produce more pollutants. Also, larger vehicles such as trucks and buses, require more energy to move, and would therefore consume more fuel and produce more emissions. In addition to the mechanics of the vehicle, the type of fuel used is a major determinant of emission patterns.

The amount of emissions a certain type of vehicle produces varies with its manner of operation. Some vehicle actions which produce characteristic amounts and types of pollutants include: moving "fast", moving "slowly", starting a cold engine, starting a warm engine, stopping an engine, accelerating, decelerating, idling, and resting. However, because of its complex nature, the emissions process can be categorized only if some simplifying assumptions are made. The complexity arises because:

- The relation between a pollutant and a vehicle action (such as speed) is not always linear.
- The relationship between a vehicle action and pollutant A does not always parallel the relation between the vehicle action and pollutant B.
- Sources define the relationships between vehicle actions and pollutants slightly differently.
- Relationships vary for different engine types.

Looking closely at the relations between vehicle speed and emissions, shows how complex categorizing the emissions process can become. According to Document No. 5, between the speeds of 0 and 20 mph, the amount of NOx, HC and CO released in vehicle exhaust decreases sharply. However, between 20 and 50 mph, the release of NOx increases, while the release of HC and CO continues to drop off. Also, the amount of HC which evaporates during vehicle operations diminishes consistently with increasing speed.[28] It should be noted that Document No. 2 makes slightly different generalizations. It states that the emission of HC and CO between the speeds of 20 and 55 mph, is relatively stable. Emissions of these two gases increases as speeds decrease below 20 mph and increase above 55 mph. Between 5 and 45 mph, NOx emissions decrease with increasing speed. Above 45 mph NOx emissions increase with increasing speed.[29]

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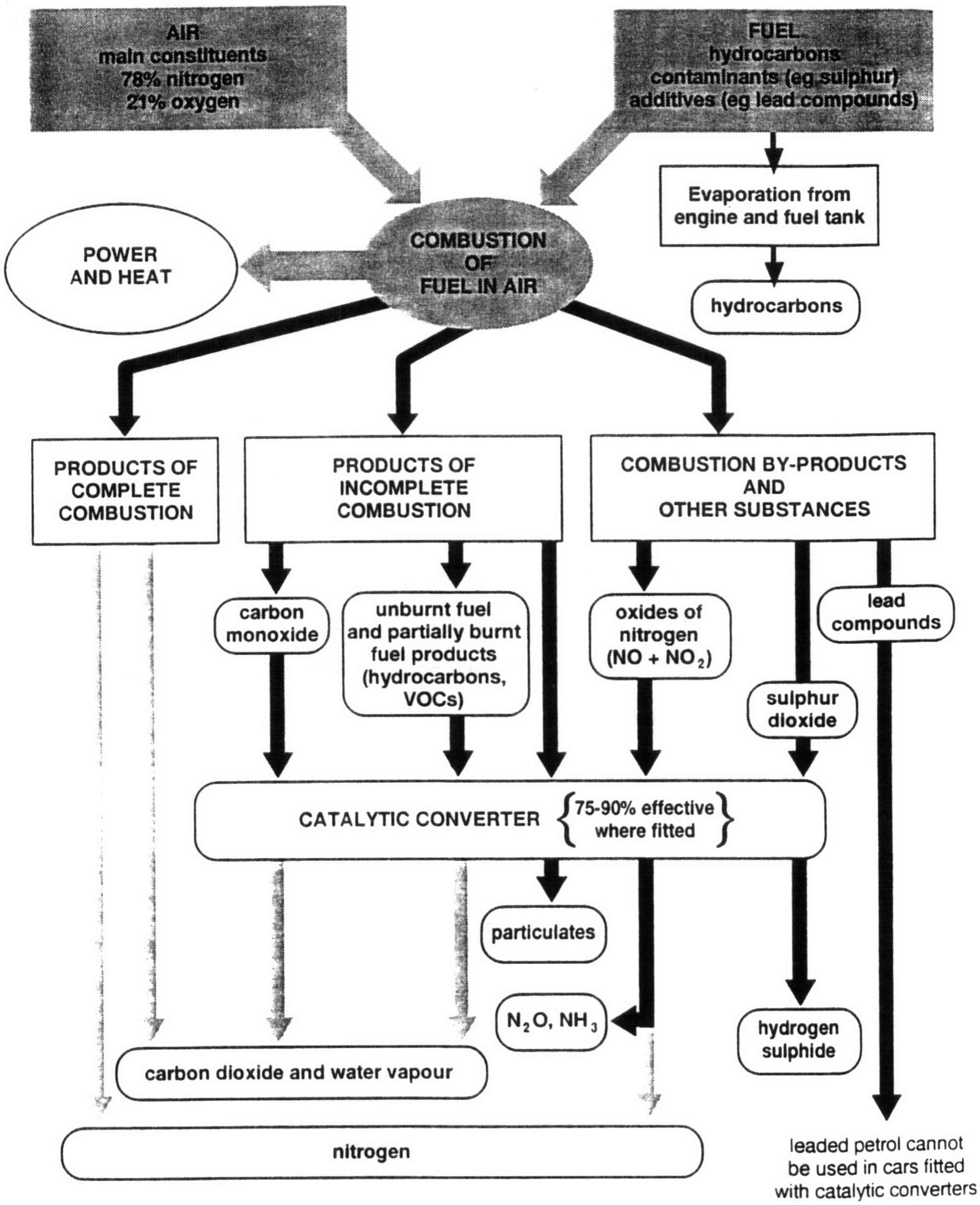
[28] Document No. 5, p 3-5.
[29] Document No. 2, p 13.

Figure 2- 1 Pollutants Emitted by Petroleum-Powered Vehicles

(Source: reproduction from Document No. 22, p. 22)



2.5.3 TCMs are used to eliminate some of the previously mentioned causes of emissions.

In the previous section the amount and type of emissions were shown to be characteristic of vehicle type and vehicle use pattern. Certain vehicle types and vehicle use patterns produce less pollutants than others. TCMs may be used to replace or eliminate the highly polluting combinations by altering the vehicle fleet mix, the existing vehicle use patterns, and the vehicle fleet size. For example, "buy-back"[30] programs may be used to remove less efficient old vehicles from the vehicle fleet. Parking restrictions and the availability of auto-alternatives could reduce the desirability of auto ownership, and thus reduce the vehicle fleet size. Zoning and congestion pricing could alter origin-destination patterns and thereby reduce the length or number of vehicle trips. The three effects of TCMs commonly noted are change in number of trips, change in vehicle miles traveled (VMT), and changes to travel speeds.

Unfortunately for the analyst, ranking TCMs is difficult because many TCMs have both positive and negative effects. For instance, improved traffic signal timing will improve the efficiency of a road network and thereby increase its attractiveness. By diminishing the need to stop and start, improved signal timing may reduce idling, acceleration, and deceleration, and may increase average speed. All of these changes could reduce the emissions produced by a given vehicle trip. However, improving the road network's efficiency may increase the attractiveness of auto-travel and therefore generate new trips. Thus, improved signal timing could increase the number of cold or hot starts, as well as re-congest the roadways. Since cold starts can account for as much as 50% of emissions resulting from an entire vehicle trip, and since idling will occur if roadways are re-congested, the negative effects of this TCM may negate the positive ones.

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[30] "Buy-back" programs are when older, high-emission vehicles are bought from the owners by the government in order to reduce the air pollution in a given region. The concept is also known as "cash for clunkers."

2.5.4 What are the costs and benefits of a TCM program?

Many factors make up the benefits and costs of a TCM program. The goals of a given region may make some of these irrelevant. Some costs which have been identified include:

- construction and capital costs
- maintenance and administrative costs
- social costs
- stifled economic growth
- reduced mobility
- environmental costs.

Some benefits include:

- improved mobility
- reduced pollution
- regional growth and development.

2.6 HOW EFFECTIVE ARE TCMS AT REDUCING EMISSIONS?

There have been studies which estimate the "average" effectiveness of TCMs. Because these averages are neither region-specific nor project-specific, they may be highly variable. For instance, a congestion pricing measure analyzed by Washington, D.C., was predicted to increase emissions rather than largely decrease them as estimates found in the literature would suggest.[31] Such discrepancies occur for two primary reasons. First, the effect of a TCM depends on how it is implemented and how people respond. For instance, a five mile HOV lane would have less of an impact than an entire system of HOV lanes. Furthermore, a well-enforced HOV system in a highly congested city would attract more users than the opposite situation. The second reason is related to the analysis methods and measures used. Different methods and measures each have a unique set of assumptions imbedded within.

Nevertheless, these "averages" are worth noting. The results of two studies are described below: (1) a General Accounting Office (GAO) report, and (2) a report prepared by Apogee Research, Inc.

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[31] Washington No. 1, preface.

According to a recent report by the General Accounting Office (GAO)[32] *projections* of the impact of TCMs on reducing regional hydrocarbon and carbon monoxide emissions generally range from less than 1 percent to 5 percent.

Apogee Research, Inc. has developed a listing of "average" impacts to be expected by certain TCMs. Apogee's report, Document No. 8, describes the generalizing assumptions they used to convert results of various regions into a uniform set of units; this made the results comparable. In this manner, the Apogee report on costs and effectiveness of TCMs calculated typical travel and emissions impacts based on its literature review. These impacts: percent reduction in daily VMT, percent reduction in daily trips, and percent reduction in HC emissions, are presented in Table 2- 3.

Apogee also produced a ranking of TCMs according to their ability to reduce HC emissions and their cost per ton of HC emissions eliminated. This is presented in Table 2-2 and Table 2- 4.

Table 2- 2 TCMs Ranked by Their Ability to Reduce HC Emissions[33]

STRONG (HC Reduction >2%)	WEAK (HC Reduction <1.1%)	SPECULATIVE
• Congestion Pricing • Parking Pricing • Smog/VMT Tax • Buy-Backs of Older Cars	• HOV Lanes • Incident Management • Employer Trip Reduction • Transit Improvements • Signal Timing • Area-wide Ride-sharing • Park-and-Ride Lots • Bike and Walk Facilities	• Land Use Planning • Telecommuting • Compressed Work Week

[32]Document No. 21. (GAO Report)
[33] Document No. 8, p. i. (Apogee's Report)

Table 2- 3 Results of Apogee TCM Literature Review: Estimated Travel & Emission Impacts[34]

TCM	PERCENT REDUCTION IN DAILY VMT	PERCENT REDUCTION IN DAILY TRIPS	PERCENT REDUCTION IN HC EMISSIONS
Employer trip reduction	0.96	0.8	0.9
Area-wide ride-sharing	0.4	0.33	0.35
Transit Improvements	1.0	0.83	0.9
HOV lanes	1.4	0.5	1.1
Park-and Ride Lots	0.45	0	0.3
Bike and walk facilities	0.03	0.04	0.03
Parking Pricing			
work	3.0	2.5	2.8
non-work	4.2	5.4	4.6
Congestion Pricing	5.0	3.8	8.2
Compressed Work Week	0.8	0.7	0.7
Telecommuting	1.1	1.0	1.0
Land Use Planning	5.4	5.4	5.4
Signal Timing	-0.02	-0.02	0.41
Incident Management	-0.08	-0.07	0.92
Smog/VMT Tax	0.4	0.7	4.1
Buy-backs of Older Cars	N/A	N/A	3.0

Table 2- 4 TCMs Ranked by Cost-Effectiveness[35]

HIGH (< $25,000/ton of HC)	MODERATE ($25,000 - $100,000/ton of HC)	LOW (> $100,000/ton of HC)	UNKNOWN, but likely to be HIGH
• Smog/VMT Tax • Buy-backs of Older Cars • Area-wide Ridesharing • Signal Timing	• Parking Pricing • Congestion Pricing • Incident Management	• HOV Lanes • Park-and-Ride Lots • Transit Improvement • Employer Trip Reduction • Bike and Walk Facilities	• Compressed Work Week • Telecommuting • Land Use Planning

[34] Document No. 8, p. 20. (Apogee's Report)
[35] Document No. 8, p. ii. (Apogee's Report)

Chapter 3

Methods Available for Quantifying the Travel & Emission Impacts of TCMs

At the core of any technical analysis framework are the actual estimates of a TCM's potential emission and travel impacts. Thus, this chapter discusses what is the "best" quantification method for estimating impacts. In Chapter 1 the "best" method was defined as the method which would:

1. ***maximize accuracy*** of the final prioritized list,
2. have a ***minimal cost,*** and
3. produce ***sufficiently precise*** results.

The analysis and conclusions presented in this chapter are based on an extensive review of the methods available for quantifying the emission and travel impacts of TCMs. The chapter begins by discussing the scope of the review in Section 3.1. Ten methodologies were covered in detail, however many more exist. After Section 3.1 makes clear that a range of methods are available, Section 3.2 describes some basic similarities amongst the methods. In essence, it describes how most methods attempt to quantify the emissions and travel impacts of TCMs. Section 3.3 then discusses why such a range of methods exists, and what defines a "best"[36] method. Section 3.4 concludes the chapter by summarizing its implications on the desirable structure of a technical analysis framework.

Table 3-1 provides some summary facts on each of the ten methodologies covered. The table is discussed in Section 3.1. Also, Appendix B contains the full summary and analysis of the ten methodologies covered in detail.

3.1 SCOPE OF RESEARCH

This chapter provides a comprehensive review of the dominant (as defined by the agencies consulted), methodologies available for quantifying the emissions and travel impacts of TCMs as of Spring 1995. The literature review covered ten methods used to analyze TCMs in the US which were:

1. 4-Step Regional Travel Model
2. TCM Tools
3. CM/AQ Evaluation Model
4. EPA-SAI Methodology
5. Pivot Point Model
6. TRIPS
7. COMSIS TDM Model
8. SMAQMD Methodology
9. AQAT-3
10. SAI-CARB Methodology

Each of these ten methods were reviewed in a uniform manner; for each method some or all of the following questions are answered in Appendix B:

[36] "Best" method is defined as the method which (1) maximizes accuracy, (2) minimizes cost, and (3) is sufficiently precise.

1. What TCMs can be analyzed using this methodology and at what level of detail

(a) Level of analysis provided by the methodology

This section identifies what level of analysis is provided by the methodology. Generally, the answer to this will take the form of one of the terms: Screening, Sketch-Planning or Detailed Analysis. The information provided here should give some indication to the reader of how rigorous the methodology is and as such, what level of decisions could be made based on the output.

(b) What TCMs has the methodology been designed to analyze

This section is generally a listing of all the TCMs amenable to analysis using this methodology, in cases where such information was available.

(c) Does the methodology support the analysis of groups of TCMs

In some cases, one may need to analyze a number of TCMs whose impacts are interdependent. In such instances, a methodology which accounts for the effects of interacting measures will be appropriate. This section identifies whether the methodology has the facility to analyze packages of TCMs.

2. Structure, inputs and outputs of the methodology

This section provides a brief overview of the methodology in terms of its structure, input requirements, and resultant outputs. In some cases a methodology will consist of a fully integrated number of modules. These modules may be aimed at analyzing transportation, emissions and cost-effectiveness impacts as well as other impacts. Other methodologies will consist of perhaps only a transportation component. In such cases, estimation of emissions effects and other impacts would require the use an additional method(s). This section highlights what exactly the methodology is made up of, what it is capable of analyzing, and what output it provides.

3. Practical Restrictions

(a) How easy is it to obtain the data required for the methodology

A major element in the decision to use any methodology is whether or not the data is available to actually use it. This section indicates how easy it is to obtain the data required of the methodology and where this information would typically come from. For some methodologies, the data requirements are quite extensive and would thus be very expensive to collect. In other cases, the data may be readily available and so the use of the methodology might be very practical. The decision of which methodology to adopt will also be dependent on the level of analysis required and the seriousness of the decisions which need to be made based on the output.

(b) Computer hardware and software required to use the methodology

This section identifies what the computer requirements (if any) of the methodology are. The potential user will obviously be constrained by the computer resources available to him and this will be an obvious determinant in his choice of methodology.

(c) Technical skills required to operate the methodology

This section indicates the necessary computer experience or skills required to use the various methodologies. Some methodologies are very user-friendly whereas others require programming experience or other expertise.

The review of each method is contained in Appendix B. However, the analysis and conclusions relevant to the subject of this thesis are presented in this chapter. Also Table 3-1 provides a summary of the information contained in Appendix B. For each of the ten methodologies contained in the appendix, Table 3-1 describes who developed the methodology, what case study regions discussed in Chapter 4 made use of this methodology, whether the methodology is designed for a specific region or is broadly applicable, what modules comprise the methodology, what level of analysis the methodology provides, whether the methodology supports the analysis of TCM packages, in addition to other unique points of the methodology.

The literature review did not cover some TCM analysis methods which existed or were being developed at the time research was conducted. These methods were excluded because (1) they were region-specific and several region-specific methods had already been included, (2) they were outdated, or (3) they were still being developed. Some of the region-specific methods referred to were developed by regions in California. Some examples include:

- Los Angeles Metropolitan Area
- San Francisco / Bay Area (covered in companion report)
- San Luis Obispo

Several regions in Texas have also developed methods:

- NCTOG (North Central Texas Council of Governments) Method, used in Dallas- Fort Worth Area (included in companion report) for TIP programming (developed in 1992)
- H-GAC (Houston-Galveston Area Council) method used in H-GAC's 1993 TIP programming (developed in 1992)
- TxDOT (Texas Department of Transportation) method (developed in 1993)

as have several other agencies and consulting firms:

- NCHRP Report 263
- Turnbull Method used in Minneapolis, Minnesota (developed in 1990)
- CM/AQ Evaluation Methodology designed for Pennsylvania by COMSIS
- TDM Evaluation Methods being developed by JHK & Associates

Table 3-1 Summary of Analysis Methods Covered in this Report

Name of Methodology	*Who Developed It*	*Case Studies Available in Chapter 4 & Appendix A*	*Is It Region-Specific*	*What Modules It Contains*	*Level of Analysis It Provides*	*Does It Analyze TCM Packages*	*Other Unique Points (if applicable)*
4-Step Regional Travel Model	Software packages (such as UTPS, MinUTP, Transplan, EMME/2, TransCAD, or System 2) which must be calibrated by each region	Washington, DC Dallas-Fort Worth San Francisco Seattle Boston	The software package is not, but it must be calibrated using regional data	Travel	More Detailed than any other method	Yes	Not Applicable
TCM Tools	Sierra Research, Inc., with support from JHK & Associates	Seattle (has also been used in CA, AZ, Delaware, TX)	No	Travel Emissions Cost-Effectiveness	Screening	Yes	Originally developed for SANDAG in 1991, and has since been tailored for national use.
CM/AQ Evaluation Model	JHK & Associates	None (has been used in CA, AZ, Delaware, TX)	No	Eligibility Travel Emissions Cost-Effectiveness Criteria Weighting	Screening	Information Not Available	Designed with the CM/AQ funding program in mind
EPA-SAI Methodology	Systems Applications International	None	No	Travel Emissions	A Sketch-Planning Method Designed for Screening	Yes	It is the second generation of the SAI CARB methodology Research conducted by TTI found it to be superior to TCM Tools

Table 3-1 Continued

Name of Methodology	*Who Developed It*	*Case Studies Available in Chapter 4 & Appendix A*	*Is It Region-Specific*	*What Modules It Contains*	*Level of Analysis It Provides*	*Does It Analyze TCM Packages*	*Other Unique Points (if applicable)*
Pivot Point Model	Cambridge Systematics	None	No	• Travel	screening/ sketch-planning	Info. Not Available	Not Applicable
TRIPS	Information Not Available	None	Yes	• Travel • Emissions • Fuel Consumption • Residential Location	screening/sketch planning/ or detailed analysis	Information Not Available	Not Applicable
COMSIS TDM Model	COMSIS Corporation	Washington, DC	No	• Travel	screening/ sketch planning/ or detailed analysis	No	Designed specifically for the analysis of TDMs, and provides examples for 7 measures. JHK should be developing a similar TDM analysis tool
SMAQMD Methodology	Sacramento Air Quality Management District	None (used by SMAQMD)	Yes	• Travel • Emissions • Cost-Effectiveness	screening and detailed analysis	Yes	Not Applicable
AQAT-3	California Air Resources Board	None	Yes	• Travel • Emissions	screening	Information Not Available	Uses URBREMIS, EMFAC, CALINE4, & PIVOT POINT
SAI-CARB Methodology	Systems Applications International	None	Yes	Travel Emissions	sketch planning method used for screening	Yes	Original version of the EPA-SAI method mentioned earlier

3.2 WHAT IS THE GENERAL METHODOLOGY USED TO QUANTIFY EMISSION AND TRAVEL IMPACTS OF TCMS.

Analysis of the emission and travel impacts of TCMs can naturally be subdivided into two phases: estimation of travel impacts, and estimation of emission impacts; they must be conducted in that order because a TCM's emission impacts are a function of its travel impacts as will be described in section 3.2.2. Not all methodologies address both the estimation of travel impacts and the estimation of emission impacts. For instance, a regional travel model only estimates travel impacts. The EPA/SAI methodology addresses travel and emissions impacts. Some methodologies include a third component; in addition to estimating the travel and emission impacts of TCMs, some methods also develop a cost-effectiveness measure. A commonly used method which includes this third component is called "TCM Tools". The following two subsections describe how methodologies generally approach quantifying the travel and emission impacts of TCMs.

3.2.1 Estimating Travel Impacts

The implementation of any particular TCM will have an effect on the transportation network and/or on travelers. For example, the addition of a new transit line adds a link to the existing network, as well as perhaps causing changes in the travel patterns or mode choice of certain travelers. Some examples of traveler response include:

- Choosing not to travel as much
- Changing from single to multiple-occupant vehicles
- Changing travel time from the peak period to the off-peak period
- Changing travel route
- Changing mode of travel e.g. from auto to transit
- Changing destination in the form of relocating residence or workplace in order to have a shorter commute.

In order to predict *traveler response* the analyst must make some assumptions. For example, if a ride-sharing program is to be promoted in all large businesses, the analyst will need to know how many large businesses there are, how many employees each business has, and the rate of participation in the program, in order to estimate the number of work trips eliminated. Data on the first two figures might be available or collectible, but the third figure would have to be estimated based on previous experience or professional judgment. In addition, assumptions would have to be made about the probable use of an auto which was left at home rather than driven to work because the worker chose to ride-share; in other words, assumptions would have to be made about the potential for the ride-sharing program to produce new trips.

Predicting the effects of a TCM on the *transportation network* seems more straightforward, but actually requires a variety of assumptions as well. In particular, link speeds are dependent on link volumes, which are in turn dependent on traveler response. Thus, adding a new transit line not only adds a new link to the system, but may also alter speeds on other links by eliminating auto trips.

Generally, TCM analysis tools quantify traveler and network impacts through three measures: change in vehicle miles traveled (VMT), change in speed, and change in trips. These three measures are desirable because they can be easily converted into emissions impacts.

3.2.2 Estimating Emission Impacts

Estimating emission impacts of the TCM is the second step of a methodology. Emission impacts are generally presented as percent reduction of hydrocarbons (HC), carbon monoxide (CO), nitrogen gases (NOx), or some other category of pollutants. In order to calculate these percent reductions, emission factors are calculated using a program such as MOBILE5a and then multiplied by the travel changes. A simple sample calculation is:

trip reductions = 5 cold started trips of a light duty gas vehicle (LDGV)

emission factor = 2.48 grams HC per cold started trip of a LDGV

*HC reductions = 5 * 2.48 = 12.40 grams*

Vehicles continuously emit pollutants. However, the type and amount of pollutant emitted varies by vehicle type and use. For example, a truck driving ten miles will emit more exhaust than an auto driving ten miles under similar conditions. Moreover, certain types of automobiles will emit more exhaust than others. Also, starting a cold engine produces more emissions than starting a warm one. For these reasons, emission factors are usually specific to vehicle class and emission categories. MOBILE5a provides emission factors for each of the following 9 vehicle classes and 7 emission categories:[37]

VEHICLE CLASSES	EMISSION CATEGORIES
1. Light-duty gasoline vehicle	1. Exhaust
2. Light-duty gasoline trucks less than 6000 lbs	2. Hot Soak
3. Light duty gasoline trucks more than 6000 lbs	3. Diurnal
4. Light -duty gasoline trucks, the total composite of the above two.	4. Crankcase
5. Heavy-duty gasoline vehicles	5. Running Losses
6. Heavy-duty diesel vehicles	6. Resting Losses
7. Light-duty diesel vehicles	7. Refueling
8. Light-duty diesel trucks	
9. Motorcycles	

Document No. 5 provides the following detailed descriptions of the 7 emission categories:

Exhaust: Vehicle tailpipe HC, NOx, and CO emissions which occur during vehicle operation. Exhaust emissions are further categorized (according to the operating conditions of the vehicle) into start-up emissions (cold and hot) and warmed-up stabilized emissions. These are commonly referred to as cold-start, hot-start and hot-stabilized emissions, respectively.

[37] Document No. 5, p. 3-3.

Hot Soak: HC emissions which consist of the evaporation of emissions from the engine and fuel lines immediately following the end of a trip.

Diurnal: Evaporative HC emissions resulting from temperature fluctuations occurring when the vehicle is not in use. These are categorized into partial-day, full-day and multiple-day diurnal according to the period of vehicle non-operation.

Crankcase: HC emissions from the vehicle crankcase during operation, significant only for older model-year vehicles.

Running Losses: HC evaporative emissions which occur during the operations of the vehicle.

Resting Losses: HC emissions resulting from permeation of non-metallic evaporative emission control equipment occurring at all times (when a vehicle is in-use and when it is not in-use).

Refueling: HC emissions resulting from vapor displacement from the vehicle gasoline tank and from gasoline spillage during vehicle refueling.

EMFAC7E and BURDEN7C, common analysis models used in California, use five similar emission categories: running emissions, starting emissions, evaporative running emissions, evaporative hot soak emissions, and diurnal emissions. Detailed descriptions similar to those provided for MOBILE emission categories are present on p. 12 of Document No. 2.

In summary, each emission factor produced by MOBILE, or another similar program, is specific to

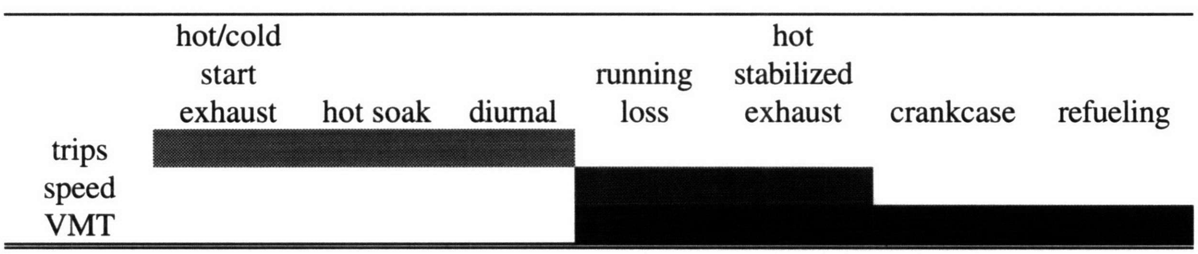
- Pollutant Type: for example CO, NOx, or HC.

- Emission Category: for example, exhaust or hot soak.
- Vehicle Class: for example light duty gas vehicle or heavy-duty gas vehicle.

The units of an emission factor might be, for example, grams of HC per mile, or grams of HC per trip. Multiplying these emission factors by travel impacts such as changes in VMT, trips, or speed, provides an estimate of the change in emissions.

In order to do this, assumptions are made about how travel impacts translate into emissions changes. These cause-effect relationships may be summarized in Figure 3-1. For example, the first cell of Figure 3-1 states that a change in the number of vehicle trips corresponds to a change in the number of times engines are started (either hot or cold started engines), which in turn changes the amount of pollution which may be attributed to the exhaust produced by the starting of hot or cold engines. As a second example, consider the cell common to "speed" and "hot soak". This cell is not shaded which indicates that a change in the speed of travel does not change the amount of pollution which may be attributed to the hot soak of engines.

Figure 3-1 How Travel Impacts Translate Into Emission Changes (shaded squares indicate the presence of a relationship) [38]



Also, Document No. 2 points out that a change in trips effects changes in speed and VMT.[39] Thus, changes in trips has the most potential to reduce emissions because it affects all emission categories. In particular, it is the one type of travel impact which may

[38] Document No. 5, p3-6.
[39] Document No. 2, p12.

reduce hot and/or cold starts. This is very significant because starting a cold engine produces a considerable amount of emissions, compared to the other emission categories listed in Figure 3-1.

Not all methodologies analyze the emissions process to the same level of detail. Although methodologies using more detailed representations of the emissions process may provide more accurate estimates of emission reduction, they also require more detailed inputs. When these inputs are unavailable the analyst must estimate their values to use the methodology. Two examples of inputs which must frequently be approximated are:

- *Vehicle Fleet Mix*: Because emission factors vary by vehicle type, assumptions about the vehicle fleet mix will have a direct effect on the estimated emissions impact of the TCM.
- *Cold Start/Hot Start Ratio*: Because the emissions from a hot and cold start differ, assumptions must be made about the proportion of hot to cold started vehicle trips eliminated by a TCM.

3.3 WHY THERE ARE SO MANY METHODS AVAILABLE, & WHICH ONE IS BEST

The literature review covered ten methods used to analyze TCMs in the US today. Table 3-1 provides some summary facts. As the table makes apparent, a few agencies are responsible for most of the existing methods. Namely, COMSIS, Sierra Research, JHK & Associates, SAI, and Cambridge Systematics have developed several analysis tools. Also, many of the methodologies are updated versions of other methods or are based on other methods. Thus, TCM analysis has been continuously evolving in recent years. Some of this "evolution" has resulted in improved methods and estimates of TCM impacts. However, this "evolution" has also resulted in a *range* of methods, none of which is universally better than the others. Rather, some methods better suit a given set of analysis needs than other methods do.

Chapter 1 defined the ***"best" method*** as the method which would:

1. ***maximize accuracy*** of the final prioritized list,
2. have a ***minimal cost,*** and
3. produce ***sufficiently precise*** results.

There are a few reasons why none of the available quantification methods is universally "best":

- Even the results of the "most accurate" methods are regarded with skepticism, according to the literature.
- Any technical analysis framework must balance its accuracy, cost, and precision. This is because increasing accuracy often increases cost or decreases precision. Similarly, increasing precision may also increase cost. So the most accurate method is not always the least expensive or the most precise.
- The ideal balance of accuracy, precision, and cost depends on the requirements of the specific application.

Thus, while there is no universal "best", there might be a method (or methods) which "best" suits the needs of a given application. The needs of a given application can be grouped into two categories:

- Region Specifics, and
- Legislative Requirements.

The "best" tool for a given application will have characteristics which match these needs. Subsection 3.3.3 summarizes the characteristics of a tool which must be matched to the needs of a given application. Subsections 3.3.4 and 3.3.5 discuss the various "region-specific" and "legislative" needs of a given application. But first subsection 3.3.1 presents some general comments on the accuracy of available methods. Of all the available methods, regional models have the most potential to produce accurate estimates. Section 3.3.2 presents some general comments on regional-model based versus non-regional-model based methods.

3.3.1 Accuracy of Results

Some authorities suggest that a general consensus on appropriate TCM modeling assumptions is being reached. An analyst from the Los Angeles Metropolitan Transportation Authority (LAMTA) pointed out that analyses of the same project by different methods produced similar results. Also, the analysis of the same situation by two methods, TCM Tools and EPA-SAI, produced similar output, according to research conducted by the Texas Transportation Institute (TTI).[40]

Although analysis techniques are converging and different methods are producing similar results, it is still uncertain how accurate these results are. Quantitative results produced by existing methodologies are generally regarded with skepticism. The literature points out that because of this uncertainty, *current methodologies may best serve as 'learning tools' through which the analyst familiarizes himself with the relative effects of TCMs.*

Just as there is little evidence to prove the results are accurate, there is also little evidence which proves they are inaccurate. The lack of before/after monitoring, and the tendency of projects not to be implemented as they were modeled, makes it difficult to determine how accurate predictions are.

Although there are no conclusions regarding the ability of existing quantification methods to accurately predict reality, some conclusions may be drawn regarding the theoretical accuracy of the available methods. From a theoretical perspective, some methods might produce more accurate estimates because they make a better attempt to capture the complexities of travel behavior, and the details of travel behavior which are relevant to air quality. These details of travel behavior were discussed in section 3.2. But, in summary, the travel impacts relevant to estimating emission changes are

- change in vehicle miles traveled (VMT)

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[40] Document No. 17, p. 85. This document presents a comparative evaluation of the EPA-SAI methodology to TCM Tools and concludes that the SAI method is superior although the two methods produce similar results.

- change in speed, and
- change in trips.

Moreover it is important which portion of the vehicle fleet is affected (i.e. high-emission vehicles or low-emission vehicles), whether the changes in trips affect "hot-started" or "cold-started"[41] trips, as well as other such details.

The relationships between travel and emission categories are illustrated by Figure 3-1. (which was presented and discussed a few pages ago in Section 3.2.2) Document No. 2 states that a change in trips effects changes in speed and VMT.[42] *Thus, changes in trips has the most potential to reduce emissions* because it affects all emission categories. Changes in trips are also a very effective means of reducing emissions because they are the one type of travel impact which may reduce cold starts.

In addition to the above considerations, the literature emphasized some other issues a more accurate method should address such as:

1. Consistency Within and Amongst Methods

Many TCM analysis needs revolve around comparing options. Because analysis results are questionable, this may be the best use of them because *by using results in a comparative manner, inaccuracies may negate themselves.* However, comparing results from inconsistent methods (e.g. methods which are based on differing assumptions) could compound the errors. Thus, the need for consistent methods, and consistency within a given methodology was considered in the development of most recent quantification methods.

2. TCM Packages vs. Individual TCMs

Another analysis need which has received increasing attention in recent methodologies, is the analysis of TCM packages. Methods for conducting such

[41] Starting an engine when it is cold produces more emissions than starting an engine when it is "warm".
[42] Document No. 2, p.12.

analysis have not fully matured. However, it is commonly accepted that the impacts of TCMs are not additive. Rather, they often have synergistic or overlapping effects.

3. Regional vs. Local

Pollutants and the mobile sources of pollutants tend to cross local boundaries; thus, conducting analysis on a regional level increases the chances of capturing all of a TCM's impacts on emissions. However, TCMs are often very local level/ small scale projects and target a specific subset of the region's population. When this is the case, the impacts of the TCM are often too small to be captured by regional-level analysis - since regional-level models tend to aggregate regional characteristics and analyze impacts at a grosser level.

4. Multimodal

As mentioned earlier, changes in vehicle trips has the most potential to reduce emissions. Reducing the number of vehicle trips made in a region involves influencing inhabitants:

- not to travel as much, or
- to choose a different mode of travel.

A traveler's choice of travel mode depends on the relative attractiveness of the available modes, more than on the attractiveness of any given mode. Conducting analysis on a multimodal level enables the analyst to determine a TCMs affect on the relative attractiveness of modes, and thus a TCMs ability to change the number of vehicle trips made in the region.

5. Long-term vs. Short-term

Projects which improve air quality in the short-term do not necessarily improve it in the long-term, and vice versa. For example, an improvement to traffic flow may not only reduce emissions from existing vehicle traffic or improve the quality of bus service, but may also increase the capacity of the roadway system. If, in the long-term, this increased capacity is filled with new vehicle trips and the roadway is returned to its original congested state, the "traffic flow improvement" will facilitate a net increase in vehicle emissions in the long-term, rather than the decrease experienced in the short-term. However, if the increase in vehicle trips would have occurred even if the roadway had not been improved, then the roadway improvement would have even larger benefits in the long-term than it would in the short-term.

6. Transportation System vs. Urban System

A transportation project is not a completely independent entity; it interacts with the rest of the urban environment and especially with other transportation projects. In order to produce the most realistic and accurate estimate of a project's impacts, its impacts on the rest of the transportation system and urban structure are often considered. This is particularly important in the estimation of a project's long-term impacts. The short-term picture is much simpler than the long-term one because in the short-term housing location, job location, population, and car ownership are relatively constant.

This discussion only begins to touch on the many issues related to accurately estimating the travel and emission impacts of TCMs. Amongst these issues are concerns related to estimating impacts of transportation projects in general; this is a very lengthy and developed subject beyond the scope of this thesis. However, professionals experienced in the field of impact analysis, and familiar with the range of issues involved, suggest that, *of all the available methods, regional models have the most potential to produce accurate predictions*. This is partly because they model reality more closely than other methods and are calibrated with region-specific data. They are regional and multimodal in scale, have the ability to analyze TCM packages, and are consistent within themselves. Some regional modeling systems have the ability to consider the impacts on urban-structure.

Although the regional travel model provides the most accurate estimates, and is perhaps the oldest of all the methods identified, other methods have emerged. This has three explanations. One, regional models can not model all TCMs. Two, like some other methods reviewed, regional models only analyze the travel impacts. Since the emission impacts of TCMs are the main issue, the analyst must use the regional model in conjunction with another methodology to fully analyze TCMs. Third, accuracy of results is not the only issue when selecting a methodology. Not all applications require the level of detail provided by a regional model. Also, they are one of the more time consuming and data intensive methods. Thus, a variety of TCM analysis tools have developed to suit a variety of TCM analysis needs.

3.3.2 Regional-Model Based vs. Non-Regional Model-Based Methods

In general, TCMs can be analyzed using either regional models (entirely or parts thereof) or by using non-regional model-based approaches. Regional models were not developed specifically for the analysis of TCMs, but it is the case that many of the changes brought about by TCMs can be determined using these models. TCMs amenable to analysis using a regional model would include any measure whose effects can be reflected by the variables contained in the model. The effects of all TCMs cannot necessarily be illustrated using this type of model because many TCM effects are too small to be captured by this means.

There are other approaches to analyzing TCMs that do not involve the use of regional models. Many of these analysis methodologies are discussed in this summary. These are generally applied in situations where the regional model is either non-existent, not sensitive enough to the TCM under consideration, or too time consuming an approach to be worthwhile. These Screening or Sketch-Planning approaches are sometimes more easily applied, faster and cheaper than the full regional model. They do not require the same quantity of data input and are designed to be specific to TCM analysis as opposed to the more gross level analysis inherent in the use of regional models.

3.3.3 Characteristics of Quantification Methods

As mentioned in the previous section, not all quantification methods produce equally accurate and precise results, or cost the same amount to use. Moreover, a method which is most accurate or costs the least for one application, might be the most expensive and inaccurate method for another application. Listed below are the characteristics which determine if a given quantification method "best" serves a given application:

- Is the quantification method region specific or broadly applicable (Section 3.3.3.1 discusses this in more detail.)
- Which TCMs the quantification method can analyze.
- Which TCMs the quantification method has been designed to analyze.
- Does the methodology support the analysis of groups of TCMs (i.e. TCM packages.)
- How rigorous the quantification method is and as such, what level of decision could be made based on the output.
- Structure, inputs, and outputs of the method.
- What type of data is required to use the method.
- What type of technical skills, hardware, and software are needed to use the method.

Appendix B presents the 10 quantification methods covered by the literature review and describes the above characteristics of each method. Table 3-1 presents an overview of the ten methodologies covered in Appendix B.

In order to determine the "best" quantification method for a given application, the characteristics listed above should match:

1. the characteristics of the region in which the method will be used, and
2. the legislative requirements which stimulated or guide the particular application.

In other words, the method should match the application and vice versa. Section 3.3.4 and 3.3.5 discuss the characteristics which define a given application.

But first, the next subsection discusses one of the characteristics of quantification models in more detail.

3.3.3.1 Was the Quantification Method Designed for a Specific Region or is it Broadly Applicable

The more accurately a methodology accounts for the specifics of a region, the more accurately it may estimate the impacts of a TCM. Aspects such as city-structure, existing travel habits, regional culture, climates, and geography all affect a TCM's potential to reduce emissions and alter travel behavior. These aspects are reflected in the quantitative results through elasticity estimates and other default inputs. Some methodologies were developed for a specific region and provide default values which require extensive resources to replace; other regions would have difficulty calibrating such a method based on their own region-specifics. However, many methodologies attempt to facilitate the process by prompting the user for region-specific replacements.

Also, many methodologies are region-specific in the sense that they have been designed to suit the data, software, hardware, and staffing resources available to a specific region. For instance, methodologies developed for regions in California rely on EMFAC and BURDEN emission models, rather than the EPA's MOBILE emission model which is used in most other states. Although the models are similar, care must be taken when interchanging the models to ensure that units and other such details correspond.[43]

3.3.4 Characteristics of a Specific Region

Some characteristic of a region which influence which method is the best for a given application are listed below.

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[43] Document No. 5, p3-2.

The dominant region-specific characteristic regards what role the region has assigned technical analysis in its overall planning process. Earlier in the thesis (chapter 1) the overall planning process was broken down into three components: technical, political, and private citizens and businesses. All three components influence the final decision making process in their own unique way; together they form a system of checks-and-balances. How technical analysis is expected to facilitate decision making within this system of checks-and-balances would largely determine how accurate it needs to be, how precise, and how much money the region would be willing to spend on producing these technical results.

Aside from this major region-specific, the ideal balance of accuracy, cost, and precision also depends on region-specifics such as:

1. *Data availability.* Each quantification method requires certain data inputs before it can produce output. Most regions collect data to facilitate analysis. Either the region chooses a quantification method which does not require more data than it typically collects or would have to collect for other purposes, or the region chooses to collect the data required for the chosen quantification method. The later case might prove more expensive than the former, while the former might limit the range of methods available.
2. *At what point in the planning process are projects defined in detail.* Projects begin as ideas, and are gradually specified in more and more detail. It is difficult to estimate the impacts of a project which has not yet been clearly defined. Quantification methods require project-specific inputs before they may produce impact estimates. Thus, certain methods may only be applicable after the point in the planning process at which sufficient project-specific inputs are available.
3. *Which TCMs the region would like to analyze.* This has two implications on the choice of quantification method. First, certain quantification methods cannot analyze the full range of TCMs. Second, given that the quantified impact estimates will eventually be used to rank TCMs relative to one

another, it is important that the estimates are produced in a comparable fashion.

4. *Organizational structure of regional planning agencies.* Quantifying the impacts of TCMs or TCM packages often involves coordination across modes or localities. For example, if a regional-level technical staff analyzes TCMs while mode-specific agencies will be responsible for implementing them, the technical staff might coordinate with the modal agencies to ensure that TCMs are modeled as they might be realistically implemented. The structure of regional planning agencies influences a region's ability to coordinate TCM analysis in this and other ways.
5. *The region's technical capabilities.* In other words, the trained staff, hardware, and software the region already possesses. The region could always increase its technical capabilities, but this generally has cost implications. The region's technical capabilities would match the technical requirements of the "best" method.
6. *Financial restrictions.* How much money the region has decided to spend on quantifying the impacts of TCMs would limit the set of quantification methods available.
7. *Timing restrictions.* How much time the region has available for conducting the analysis influences its choice of analysis method since certain methods are more time-consuming than other methods.

3.3.5 Legislative Requirements

Oftentimes analysis is conducted to help determine which projects to include in a federally mandated document such as the Transportation Improvement Program (TIP) or a State Implementation Plan (SIP). Including projects in such documents commits the region to implementing them. The case studies focused on TIP and SIP processes, and Chapter 4 analyzes the implications of their legislative requirements on the choice of quantification methods, as well as prioritization methods.

In addition to the TIP and SIP, regions are also governed by a variety of federal, state, or even regional level legislative requirements which influence their project selection process. For example, planning regions in California are subject to the unique requirements of the California Clean Air Act. Also, the Puget Sounds Region (which includes Seattle) is subject to Washington State's regional growth-management act.

3.4 CONCLUSIONS: IMPLICATIONS ON HOW TO BEST DEVISE A TECHNICAL ANALYSIS FRAMEWORK

One of the main conclusions of this chapter is that TCM analysis has been continuously evolving in recent years. Some of this "evolution" has resulted in improved methods and estimates of TCM impacts. However, this "evolution" has also resulted in a *range* of methods, none of which is universally "better" than the others. Rather, some methods better suit a given set of analysis needs than other methods do.

Chapter 1 defined the ***"best" method*** as the method which would:

1. ***maximize accuracy*** of the final prioritized list,
2. have a ***minimal cost,*** and
3. produce ***sufficiently precise*** results.

There are a few reasons why none of the available quantification methods is universally "best":

- Even the results of the most accurate methods are regarded with skepticism, according to the literature.
- Any technical analysis framework must balance its accuracy, cost, and precision. This is because increasing accuracy often increases cost or decreases precision. Similarly, increasing precision may also increase cost. So the most accurate method is not always the cheapest or the most precise.
- The ideal balance of accuracy, precision, and cost depends on the requirements of the specific application.

Thus, while there is no universal "best", there might be a method (or methods) which "best" suit the needs of a given application. The needs of a given application can be grouped into two categories:

- Region Specifics, and
- Legislative Requirements.

The "best" tool for a given application will have characteristics which match these needs. It is a two-way matching process which determines the best method for a given application in the sense that not only must the method suit the application, but also the application must suit the method. Not only does a range of quantification methods exist, but there are also a range of application approaches. In particular, it should be noted that many region-specifics may be altered in the long run. Regions can choose to

- acquire new data, hardware, or software
- develop a new quantification method for themselves
- reorganize their planning structure, or
- alter the role impact estimates play in the decision-making process

in order to improve their impact estimates and/or the quality of their overall decision-making process. Figure 3-3 illustrates the two-way matching process which determines the best match of method and application.

The previous discussion leads to the second main conclusion of this chapter: The literature points out that because of their uncertainty, current quantification methods may best serve as 'learning tools' through which the analyst familiarizes herself with the relative effects of TCMs. This limits the potential applications of analysis results; in other words, because of their limited accuracy, impact estimates can only contribute so much to the decision-making process.

Just as there is little evidence to prove that impact estimates are accurate, there is also little evidence which proves they are inaccurate. This is the third main conclusion of this chapter. The lack of before and after monitoring, and the tendency of projects not to be implemented as they were modeled, makes it difficult to determine how accurate predictions are.

Although there are no conclusions regarding the ability of existing quantification methods to accurately predict reality, some conclusions may be drawn regarding the theoretical accuracy of the available methods. From a theoretical perspective, some methods might produce more accurate estimates because they make a better attempt to capture the complexities of travel behavior, and the details of travel behavior which are relevant to air quality. Professionals experienced in the field of impact analysis, and familiar with the range of theoretical issues involved, suggest that, *of all the available methods, regional models have the most potential to produce accurate predictions.*

Accuracy is not the only consideration when choosing a quantification method. Sometimes other methods are more appropriate. The most appropriate method for a given application is determined by the two-way matching process previously described and illustrated by Figure 3-3.

The fourth and final major conclusion drawn by this chapter is that analyzing the methods used to quantify emission and travel impacts of TCMs revealed a few basic insights regarding the type of methods most likely to accurately estimate a TCM's impacts on emissions. These insights were discussed fully in section 3.2. But, in summary, the travel impacts relevant to estimating emission changes are

- change in vehicle miles traveled (VMT)
- change in speed, and
- change in trips.

Moreover it is important which portion of the vehicle fleet is affected (i.e. high-emission vehicles or low-emission vehicles), whether the changes in trips affect "hot-started" or "cold-started"[44] trips, as well as other such details.

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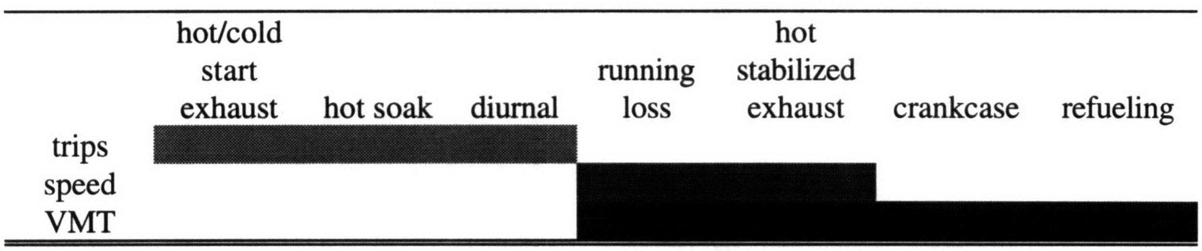
[44] Starting an engine when it is cold produces more emissions than starting an engine when it is "warm".

The relationships between travel and emission categories are illustrated by Figure 3-2 (which was also included as Figure 3-1 and discussed in Section 3.2.2). Document No. 2 states that a change in trips effects changes in speed and VMT.[45] *Thus, changes in the number of vehicle trips has the most potential to reduce emissions* because it affects all emission categories. Changes in trips are also a very effective means of reducing emissions because they are the one type of travel impact which may reduce cold starts. Starting an engine cold produces a considerable amount of emissions, compared to the other emission categories listed in Figure 3-2.

Figure 3- 2 How Travel Impacts Translate Into Emission Changes (shaded squares indicate the presence of a relationship)[46]



In addition to the above considerations, the literature emphasized some other issues that a more accurate method should address such as:

1. Consistency within and amongst methods;
2. TCM packages vs. individual TCMs;
3. Regional vs. local;
4. Long-term vs. short-term; and
5. Transportation system vs. urban system.

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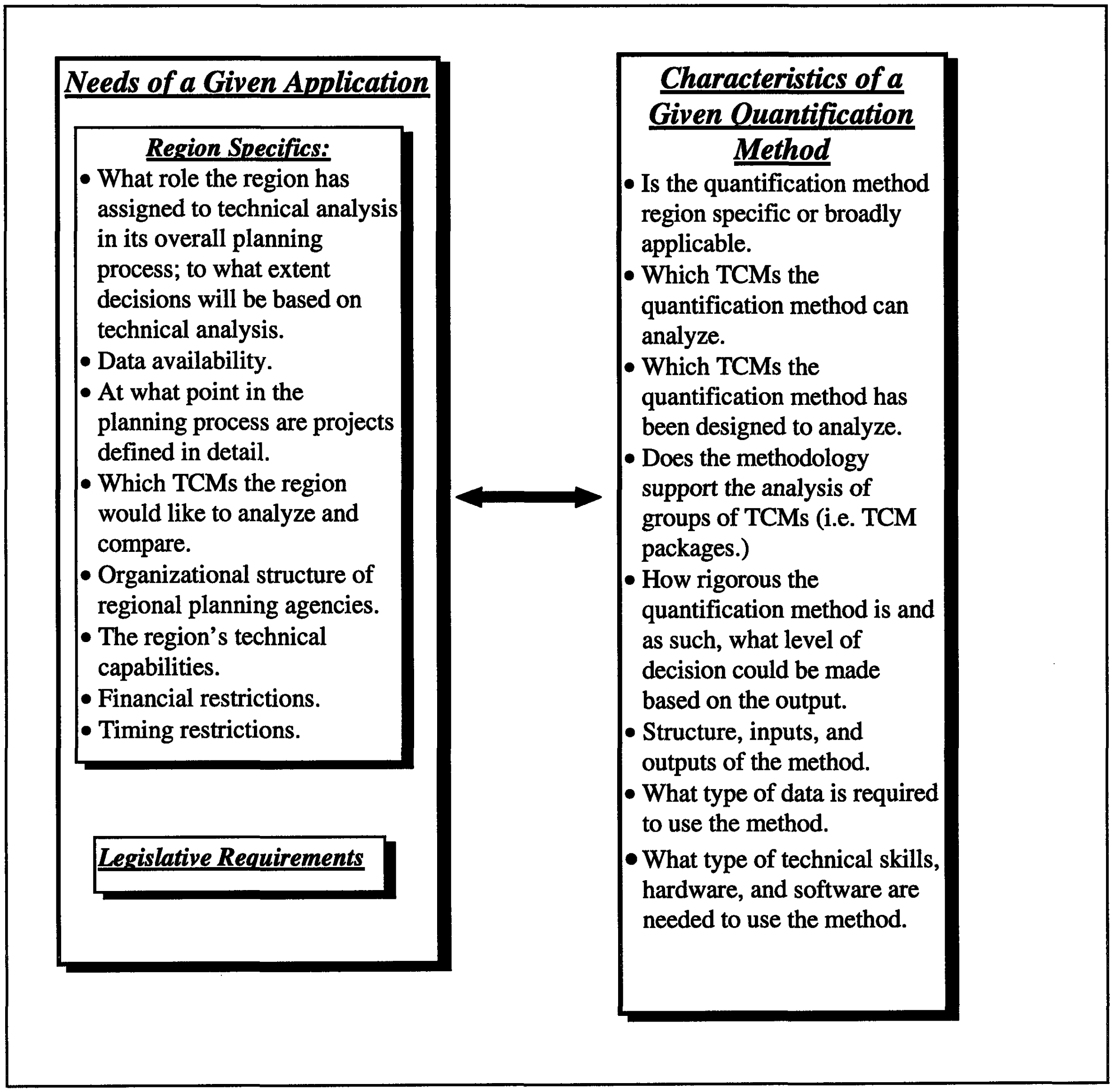
[45] Document No. 2, p.12.

[46] Document No. 5, p3-6.

Figure 3- 3 Characteristics of the Quantification Method Should Match the Needs of the Given Application, and Vice Versa



The above discussion summarizes some of the issues which were highlighted in the literature; however, estimating travel and emission impacts is a very complicated subject consisting of many more issues than were highlighted by this thesis (many of these issues were not highlighted because they have already been resolved or are well-accepted.) The issues highlighted by this chapter are not only relevant to the choice of quantification method, but also to the choice of prioritization method, and the organizational structure within which analysis is conducted. Thus, these insights are carried into the next chapter which discusses the prioritization methods and organizational structures currently being used by five case study regions.

Chapter 4

Findings from the Case Studies

Chapter 3 discussed how to choose a quantification method which best meets the demands of a given application. However, the choice of quantification method is only a subset of a much broader issue: how to use technical analysis to facilitate prioritization decisions. To explore this broader issue, five detailed case studies were collected (including Boston) and the methods they used were observed. This chapter summarizes the findings from the case studies. The full case studies are contained in Appendix A and Figure 7-2 presents an overview of the case studies. (The implications of this table will be discussed in Section 4.2)

This chapter begins with a discussion of which regions were studied in Section 4.1 and a discussion of the scope of the case studies in Section 4.2. In particular, Section 4.2 describes the format used to conduct each case study and the type of information gathered from each one.

After these introductory sections, the chapter begins to summarize the findings from the case studies. Section 4.3 discusses the methods regions used to estimate the impacts of TCMs. Section 4.4 discusses the methods used to prioritize and select projects in the processes covered by the case studies. Section 4.5 describes how regions chose to structure their overall project selection processes. In particular, it describes how regions chose to mix and match the methods discussed in sections 4.3 and 4.4. Then Section 4.6 discusses the legislative requirements specific to TIP and SIP processes; these requirements often govern the structure of a project selection process and the types of methods employed within the structure. Section 4.7 presents some general organizational and institutional issues raised by the case studies.

Section 4.8 concludes the chapter with a summary of its main points. In particular, it summarizes how the case study regions used technical analysis to facilitate prioritization decisions.

4.1 WHICH REGIONS WERE STUDIED

Information was collected from the ten regions listed in Table 4-1. Of these regions, five were pursued in detail: Boston, Dallas-Fort Worth, Seattle, San Francisco, and Washington, DC. Each of the five detailed case study regions have been classified as non-attainment areas by the USEPA. Appendix A provides an in depth description of how the case study regions were selected and why they were selected.

Table 4-1: List of regions studied and type of information obtained from each. (regions printed in bold were studied in detail)

REGIONS in/ including	*PHONE INTERVIEW*	*DOCUMENTATION*
Boston Region	**yes**	**yes**
Los Angeles, CA	yes	yes
Houston, TX	yes	no
New Jersey	no	yes
State of Pennsylvania	no	yes
Seattle, WA	**yes**	**yes**
San Diego, CA	yes	yes
San Francisco, CA	**yes**	**yes**
Dallas-Fort Worth, TX	**yes**	**yes**
Washington, DC	**no**[47]	**yes**

[47] A telephone interview was not conducted for Washington, DC because the documentation available was detailed and specific enough to the purposes of the research.

4.2 SCOPE OF CASE STUDIES

The five detailed case studies present some specifics on the current-state-of-practice as regards TCM Program Development. In the context of this report, *'TCM Program Development'* refers to the processes through which TCMs are selected and brought towards implementation. It consists of four primary steps:

1. Identification of an air quality problem during a SIP or EIS-related analysis.
2. Identification of TCMs which could relieve the air quality problem. These TCMs may be grouped into a 'TCM program' as part of the SIP, or may be included as mitigation measures in an EIS.
3. Incorporating these commitments into the Transportation Plan (TP), the region's long-range transportation plan.
4. Programming these commitments into the Transportation Improvement Program (TIP), the region's short-term transportation plan. Including a project in the TIP entails defining the project specifically (relative to the level of detail required by the SIP) and identifying a funding source (such as CM/AQ).

Due to the lengthy and complex nature of this development process, individual case studies do not discuss all four of its stages with uniform detail. Rather, individual case studies may focus on one or two stages. For example, they may focus on (1) the selection of TCMs for the SIP 15% reduction plan or contingency plan, (2) programming TCMs into the TIP, or (3) the assignment of funding (such as Congestion Mitigation/Air Quality (CM/AQ) funds) to TCM projects during the TIP programming. However, as a unit, these case studies provide insight into all stages of the TCM program development process. To guide the reader towards this macro-perspective on TCM program development, Table 4-2 has been provided. It summarizes the information presented by each case study. Details of the five case studies are in Appendix A.

Table 4-2: Summary of the Five Detailed Case Studies

Region	Non-attainment Status	Case Study Focus[48]	Lead Agency[49]	Process Overview *(refers to case study focus)*	Issues Discussed in Detail *(refers to case study focus unless otherwise noted)*	Other Issues *(if applicable)*
Washington DC	Serious for O_3 Moderate CO	TCM Program for 1993 SIP	Transportation Planning Board (TPB) (Washington, DC's MPO)	Initial list of potential projects Screening/scoring Quantitative testing Further screening; packaging Project selection	All stages of process described in detail Quantitative analysis methods; which method is right for which TCM Analysis results and projects selected Lessons learned	Not applicable
Dallas-Fort Worth	Moderate for O_3	1995 CMAQ scoring methodology and project selection	North Central Texas Council of Governments (NCTCOG)	Survey used to select criteria 5 evaluation criteria selected and assigned weights Methodologies for quantifying criteria were developed ~1000 project proposals from public/private agencies received , scored, and ranked Transportation council of elected officials made final project selection	Development of scoring methodology (selection of criteria, criteria weighting, calculation of criteria) Project scores and project selection Status of 1994 tip commitments	1993 TIP Process 1995 TIP Process SIP
Seattle (Puget Sound)	Marginal for O_3 Moderate CO Moderate PM_{10}	Regional 1995 TIP Project Review/ Evaluation Process (There are also county-level processes)	Puget Sound Regional Council (PSRC)	FIRST STAGE Project sponsors submit 2-3 page project proposals Technical and qualitative screening of proposals SECOND STAGE Detailed analysis; projects are scored and reviewed	Computation of air quality score (one component of total project score): measures used, analytical tools used, conversion of raw measures into point scores.	Conformity analysis TCMs in the SIP

[48]Portion of the TCM Development Process the case study focuses on.
[49] Agency which lead the process discussed in the "Process Overview" column.

Region	Non-attainment Status	Case Study Focus[50]	Lead Agency	Process Overview (refers to case study focus)	Issues Discussed in Detail	Other Issues
San Francisco / Bay Area	Moderate for O_3 Moderate CO *(current status - not necessarily the same in 1990)*	1990 Transportation Control Measure Plan (TCMP) *(for the SIP and California CAA)*	Metropolitan Transportation Commission (MTC)	Defining a set of possible TCMs. Screening: Identifying individual measures with significant emission reduction potential. Integrating feasible TCMs into a region-wide control plan (TCMP). Detailed Analysis: Analyzing the combined effect of measures in the TCMP. Assessing the institutional feasibility of potential TCMPs.	Analytical tools used for screening. Analytical tools used for detailed analysis. Calculation of cost-effectiveness. Measures included in selected plan and analysis results.	TIP Project Review Process Bay Area Partnership.
Boston	Serious for O_3 Moderate CO	Development of the Program for Mass Transportation (PMT), and the TIP	The Massachusetts Bay Transportation Authority lead the PMT Process The Boston Metropolitan Planning Organization (MPO) lead the TIP process	*PMT: Evaluation of a Project consists of:* Project Definition. Determination of project characteristics. Calculation of performance measures; qualitative ranking. Interpretation of data. Conclusions. *TIP Process:* Project proposals submitted to the MAPC. Screening: projects ready for implementation. Screening: financial constraint Remaining projects put in draft TIP. Public review. Final TIP.	All stages of PMT process described. CA/T mitigation commitments. TCM analysis methods; which method is appropriate for which TCM. Advancement of projects from the TP to the TIP.	Development of the TP. Recent updates to the Boston Regional Transportation/ Land Use Model.

[50]Portion of the TCM Development Process the case study focuses on.

Also, it should be noted that the research did not begin with an intention to collect information mainly on TIP and SIP processes. Nor, did it begin with a full understanding of what the TCM prioritization process consisted of. Interviewees from regional transportation planning agencies were asked for "methods used to prioritize TCMs" or for information on the "TCM program development process." Interviewees generally responded by describing a TIP or SIP process. Therefore the case studies focus on TIP and SIP processes - which is not a misfortune since these are two critical decision stages of the prioritization process.

Each of the five detailed case studies included in Appendix A uses a similar format attempting to address some or all of the following nine issues:

1. *Why the region was included as a case study*
    - What is special about it: has it had extensive experiences with TCMs, are its experiences well documented, has it had severe air quality problems, how does it relate to the final project objective of developing a methodology for Boston.
    - What is the regions non-attainment status according to EPA standards.
    - Who suggested including the region as a case study.
2. *Brief regional profile*
    - Size of area.
    - Population.
    - Extent of transit, highway, and other transportation system components.
    - Unusual characteristics.
    - Impacts of regional characteristics on air quality and congestion.
3. *Description and Status of current TCM related programs*
    - This section lists the TCM programs to be discussed in this case study; it lists specific projects. It may also include a discussion of past TCM programs and other TCM-related programs not described in the case study, since many regions have developed multiple or ongoing TCM related programs. Not all case studies provide a broad picture of all regional TCM-related processes. Some case

studies focus on just one, like a CMAQ process, a TIP process, or an SIP process.

4. *Organizational Structure*

   - The agencies involved in the development of TCM programs, and the responsibilities given to each agency.

5. *Methods used to prioritize and select projects*

   - Process: sequence of events leading to final project selection.
   - Qualitative and quantitative methods used to select and prioritize projects. For example, the criteria used to score projects and the methods used to measure these criteria (e.g. if a criteria was "trip reductions" then a travel model may have been used to measure these.)
   - Results: how projects were ranked and which projects were chosen.

6. *Methods Used to Estimate the Impacts of TCMs*

   - Methods (e.g. models) used to predict the effects of a TCM or group of TCMs.
   - How applied to measures: what method was used to analyze each measure. Some example methodologies may be presented - the level of detail of the example depends on the availability of information. An example could include such items as: assumptions made, inputs needed, and calculations made.
   - Degree of accuracy identified: In other words, the ability of the analysis method to successfully predict impacts or relative impacts. Answers to this section are subjective and usually based on a phone interview.

7. *Institutional and Political Issues:*

   - This section is related to the section on organizational structure. It will point out experiences with coordinating committees, delegating authority, etc. For example, Washington, DC pointed out the need to consult agencies which will be implementing the project to guarantee sufficient resources are available for implementing the project in the way it was defined during the project selection process. For instance, during the project selection process, a project may have been defined as part of a TCM package and thus, as being implemented at a specific time relative to the other projects. This package of TCMs may have then been selected for their synergistic effects. If the responsible agency is unable to implement the project according to the presumed schedule, the synergistic effects may not be captured and the original premise for selecting the TCM package would be false. Thus, the responsible agency should be consulted before the project is selected to ensure that it can be implemented as planned.

8. *Lessons Learned*
   - What did the agencies involved in the process learn from their experiences; what do they think were some strengths and weaknesses of the process they followed, the analytical methods they used, or the decisions they made.
9. *Summary and Conclusions*
   - What did we learn from this case study.

The first two of the nine issues contain background information on the case study regions. These two issues are:

- Why the Region was Included as a Case Study
- Brief Regional Profile

The third of the nine issues, "Description and Status of Current TCM Related Programs," addresses one of the assumptions which limit the scope of this thesis. Namely, in Chapter 1 of this thesis it was assumed that "the region has developed an exhaustive list of potential TCM investments prior to beginning the technical analysis." The third issue listed above often confirms this assumption by identifying the initial list of TCMs which were to be ranked and prioritized by the case study region.

The remaining six issues are relevant to the main subject of this thesis: developing a technical analysis framework for prioritizing TCM investments in the Boston region. These six issues are:

- Organizational Structure
- Methods Used to Prioritize and Select Projects

- Methods used to Estimate the Impacts of TCMs
- Institutional and Political Issues
- Lessons Learned
- Summary and Conclusions

The next few sections of this chapter (sections 4.3 through 4.7) present the conclusions from these six issues.

4.3 METHODS USED TO ESTIMATE THE IMPACTS OF TCMS

Chapter 3 describes the range of quantitative methods available for analyzing the emission and travel impacts of TCMs. In addition to the numerous mathematical methods described in that chapter, there is also the option of using qualitative analysis for measuring a project's impacts. Of course many of the quantitative methods, are based on qualitative analysis. For example, analyzing the impacts of a ride-share program might require an assumed participation rate as input. This assumed rate would be chosen based on previous experience or professional judgment.

The case study regions contained in this report used a combination of quantitative and qualitative analysis. When adopting a quantitative approach one or more of three methods were generally used:

1. detailed regional travel model
2. pre-packaged sketch-planning technique such as TCM Tools or COMSIS TDM
3. a sketch-planning method designed to analyze a specific type of measure for that region.

Table 4-3 summarizes the particular quantitative methods used in each case study region.

Table 4- 3 Quantitative Analysis Methods Employed By Each Case Study Region In Project Selection Process

Case Study Region	*Analysis Tools*	*How Tools Were Used*
Washington, DC	• Regional Mode-Choice Model • COMSIS TDM Evaluation Model • Sketch-planning methods devised by the region	After screening, 59 measures remained and were analyzed in detail using these methods.
Dallas-Fort Worth	• Appendix E describes the hand-computation method used to estimate impacts.	These methodologies were used to score about 1000 projects during D-FW's 1995 TIP Process (assignment of CMAQ funds).
Seattle	• TCM Tools • User Defined measure within TCM Tools	Seattle used these methods to analyze air quality impacts and score projects during its 1995 TIP Project Review/Evaluation Process.
San Francisco	*Screening:* • STEP • LOCATE • CHAIN • Inference based on elasticities • Inference based on case study data *Detailed And TCM-Package Analysis:* • MTC regional travel forecast model system	San Francisco used these tools during the development of its 1990 TCM Plan.
Boston	Boston has a range of methods available for analyzing TCM impacts as described in Appendix N. In general they fall into three categories: regional model-based, partially regional model-based, and non-regional model-based.	These methods were used during the 1994 PMT (Program for Mass Transportation) development process. Also, the Clean Air Task Force[51] used these methods in 1993 to develop their recommendations regarding strategies for attaining and maintaining air quality in the state (SIP related process).

The implications of the information summarized above on the desirable structure of a technical analysis framework are described by the next two sections (4.3.1 and 4.3.2). The first section expands on the conclusions drawn in Chapter 3 regarding the factors which determine if a particular method is "better" than another method. Section 4.3.2

[51] See Chapter 5 for a more detailed description of the Clean Air Task Force and their relation to the SIP development.

then discusses some recurring issues found in the case studies with regard to the estimation of TCM impacts.

4.3.1 Factors which Determine if a Particular Analysis Method is Better Than Any Other Analysis Method

The factors which determine which quantification method is best for a given application were discussed in detail by Chapter 3. The discussion is summarized by Figure 3-3. However, the case studies added some depth to this discussion. First, they expanded the range of available methods for estimating a TCM's impacts to include qualitative methods, not just quantitative ones. Second, they provided some "real-world" examples of the issues raised in Chapter 3. Some of these "real-world" examples are discussed in the next subsection, subsection 4.3.2. Third, the case studies clarified the types of legislative requirements which affect the choice of method for estimating TCM impacts. Section 4.4 addresses this issue.

4.3.2 Recurring Issues Found In The Case Studies.

A few issues on the subject of impact analysis arise repeatedly in the case studies: (1) how to package TCMs in order to capture synergistic effects, (2) when to start analyzing TCM packages, (3) analyzing measures using methods which produce comparable results, (4) the appropriate use of detailed travel models vs. sketch planning techniques, (5) when to invest time in conducting technical analysis, (6) the usefulness of quantified impact estimates, (7) the importance of considering land-use impacts, and (8) sometimes qualitative analysis is more accurate than a quantitative approach. Many of these issues were initially brought up by Chapter 3, but the examples found in the case studies add a new depth to the discussion as the following paragraphs will show.

(1) How To Package TCMs In Order To Capture Synergistic Effects

In Chapter 3 it was mentioned that the literature suggested that more accurate impact estimates tend to consider TCM packages. Washington, DC and the San Francisco Bay Area (SFBA) both suggested packaging schemes. Washington, DC considered packaging TCMs:

- by mode
- by date of effect and/or benefit
- by degree of difficulty or implementation
- by economic factors such as market based, combined public-private approach, and public investment
- by underlying life style values and preferred outcomes.

Eventually Washington, DC packaged 14 TCMs into five groups: (1) Public Information Campaign, (2) Traffic Engineering/Advanced Technology, (3) Employer Trip Reduction (support), (4) Transit and HOV Incentive, and (5) Employer Commute Option Program. The San Francisco Bay Area eventually grouped 21 measures into 7 similarly titled packages: (1) Employer-Based Measures, (2) Mobility Improvements, (3) Traffic Operations Management, (4) User Incentives, (5) Alternative Revenue Concepts, (6) Transit/Land Use Integration, and (7) Implementation Support.

(2) When To Start Analyzing TCM Packages

Analyzing TCM packages is one means of capturing synergies in the impact estimates. As the prioritization process progresses, the number of potential projects becomes increasingly smaller, as does the number of potential TCM packages. Thoroughly analyzing the numerous possible TCM packages available early on in the prioritization process would be labor intensive and possibly fruitless. If TCM packages were to be analyzed at this early stage of the process, only selected ones would be targeted most likely. Dealing with the issue later in the prioritization, when many projects have been screened out, fewer potential packages exist and they may indeed be the better ones, depending on how the initial screening stages were conducted. Washington, DC took this approach in its SIP TCM prioritization process. Initially about 164 TCMs were screened partly based on a rough score. One of the scoring criteria was the projects "synergistic effects" measured on a high-medium-low scale. When only 59 measures remained, Washington, DC attempted to group TCMs so as to capture synergistic effects.[52]

By dealing with the packaging issue late in the process, TCMs with small individual benefits but large "synergistic" potential might be overlooked. The results of San Francisco's analysis exemplify this concern. The sum of individual impacts they selected was less than the cumulative impacts of all measures. This may occur because certain TCMs have "overlapping" effects (e.g. target the same market group) as opposed to synergistic benefits. (This is not to say that San Francisco packaged TCMs too late in the process, just that their results show how impacts are not necessarily additive.)

Another drawback of packaging TCMs later rather than earlier is that time is often scarce later in the process, and analyzing synergistic effects might be neglected. Such was the case in Washington, DC who abandoned their efforts to package TCMs due to time constraints.

(3) Analyzing Measures Using Methods Which Produce Comparable Results

This was also an issue raised by Chapter 3. Since impact estimates are often used to rank projects relative to one another, impact estimates should be of comparable accuracy and precision to produce an equitable ranking. In order to ensure this, Seattle employed the same method, TCM Tools whenever possible. Although using one method to analyze all

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[52] Washington No. 1, p. 5-10.

projects does not ensure comparable results, it does ensure a certain degree of uniformity if the method was devised with comparability in mind (e.g. assumptions used to analyze different TCMs might be consistent). In contrast to Seattle, Washington, DC used a variety of methods to perform its analysis. Rather than comparability, Washington, DC seemed to stress the use of the most accurate analysis tool for each measure. Thus, Seattle and Washington, DC adopted varied approaches to balancing accuracy and comparability of analysis results.

(4) The Appropriate Use Of Detailed Travel Models Vs. Sketch Planning Techniques

As was discussed in Chapter 3, more detailed and therefore accurate analysis methods consume more human, as well as hardware, time. Sketch-planning methods such as TCM Tools (which Seattle used) and the COMSIS TDM model (which Washington, DC used) are less labor intensive than regional travel models (not considering training time), and they offer reasonably accurate results, according to several case study regions.[53]

(5) When to Invest Time in Conducting Technical Analysis

Each region invested time into analysis to different degrees and at different stages of the decision-making process. To illustrate this variation, compare the cases of San Francisco and Washington, DC's SIP processes. After the initial screening, Washington, DC conducted detailed analysis on about 59 measures, using a combination of techniques: COMSIS TDM, detailed travel model, and regionally-devised methods. San Francisco used a combination of region-specific models to perform screening-level analysis and used their detailed regional travel model when a few TCMs remained and could be combined into control plans.

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[53] Interview No. 9.

(6) The Usefulness of Quantified Impact Estimates

Although each region employed analysis methods differently, most case study regions agreed on the usefulness of having quantified results to aid in project selection. In particular, members of Los Angeles, Seattle, and Dallas-Fort Worth agencies all mentioned this point. Although this general issue is agreed upon, exact opinions vary even within a given agency. For example, while one individual from LA mentioned the lack of effective analysis methods, another found results from existing methods to be useful and at least "better than nothing."

(7) The Importance of Considering Land-Use Impacts

In general, model systems which include a land-use component or feedback loops between components - do a better job of capturing induced impacts[54] than models which do not include these elements. Washington, DC noted that a weakness of its technical analysis for congestion pricing and other market measures was the lack of a land-use feed back (i.e. the analysis used a fixed trip table that did not account for distribution effects).[55] Many regions possess modeling systems that include land-use components and feedback loops. For example, Boston itself recently integrated a land-use allocation model with its transportation models. Now, not only can the impacts of population and employment on transportation be forecasted, but also the impacts of transportation on population and employment.[56] However, regions do not always use their detailed models to produce impact estimates. Often they use more "rough" sketch-planning methods because they better suit the overall analysis needs than the more detailed models.

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[54] Induced impacts are indirect impacts of a transportation project. Some examples of induced impacts include, changes to the urban structure, an individual changing their employment or residential location, an individual changing the number of cars they own, or diverting congestion to a component of the transportation system not associated with the project at hand.
[55] Washington No. 1, p. 10-11.

(8) Sometimes Qualitative Analysis Is More Accurate Than A Quantitative Approach

Because insufficient data can lead to inaccurate estimates, it is good to match data availability with analysis tool, and available time. In the light of insufficient data, one possible solution might be to use qualitative measures rather than producing really inaccurate quantitative ones. Regions often adopted this approach earlier on in the decision-making process. For example, Washington, DC based its initial project scores on impact estimates which were derived largely from qualitative analysis.

4.4 METHODS USED TO PRIORITIZE AND SELECT PROJECTS

In the case studies, project rankings were derived from a mixing and matching of three types of methods:

1. screening,
2. scoring, and
3. raw evaluation measures.

These three methods were combined in a variety of ways to produce ranking schemes. Some examples of ranking schemes include:

- ***Screening:*** Sometimes regions ranked projects based purely (i.e. no scoring is used) on screening criteria. An example of a "pure" screening criteria is: "TCMs committed to in the SIP automatically pass the screen and are given top priority". Boston's TIP project selection process uses this screening criteria. Other examples of "pure" screening criteria are contained in Table 4-4. (p. 108)
- ***Scoring:*** None of the processes focused on by the case studies ranked projects based solely on their total project scores.
- ***Screening and Scoring:*** Some regions combined screening and scoring as follows. They ranked projects through screening; however, one of the screening criteria was related to a project's score. This screening technique was

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[56] Boston No. 2, p. B-3.

used by both Washington, DC and Dallas-Fort Worth as is described in Table 4-4. (see page 108)

- ***Raw Evaluation Measures and Qualitative Analysis:*** Some regions ranked projects based on qualitative analysis supported by some quantitative "raw evaluation measures." A few regions used this method at some point in their project selection processes. This was the only ranking method used in the development of Boston's PMT. Washington, DC used this method at some points of its project selection process, but used other types of ranking schemes at other points in its process. The range of ranking methods Washington, DC used in its project selection process is discussed further by Section 4.5 of this chapter.

The next three sections (4.4.1 through 4.4.3) discuss the three possible components of any ranking scheme: screening, scoring, and raw evaluation measures. Section 4.4.1 describes some of the screening schemes found in the case studies. Examples of "pure" screening schemes and screening schemes which use project scores are both given. Section 4.4.2 describes the scoring schemes found in the case studies. Although project scores were never the sole basis for ranking projects in any of the case study examples, they often comprised a significant portion of the ranking scheme and are therefore discussed in detail. Section 4.4.3 discusses some of the raw evaluation measures used by case study regions as a basis for project ranking.

4.4.1 Screening

Devising a screening scheme involves

- Selecting some screening criteria.
- Sometimes a system for determining whether a project complies with a given criteria is specified, but not always. An example of a very systematic measure of compliance is project scoring. The use of project scores is systematic in the

sense that most scoring schemes found in the case studies ensure that competing projects are scored in a consistent manner.

- Specifying what a project must do in order to pass the screening process. For example, perhaps a project must comply with all of the screening criteria in order to pass. Or, perhaps a project must meet at least two of the three criteria in a certain screening scheme in order to pass. Examples of this will be provided a few paragraphs from here.

A screening scheme produces a very rough project ranking in the sense that the projects are broken down into only two categories:

1. projects are top rank if they passed the screening process
2. projects are low rank if they did not pass the screening process.

Thus, screening is generally used to trim a large set of TCMs into a smaller set. The use of screening in four of the case studies is summarized in Table 4-4. In order to help the reader synthesize the information contained in Table 4-4, some of its implications are described below.

- *Screening Criteria can be either qualitative or quantitative*

  All of the criteria used in Seattle's screening scheme are highly qualitative, although some of them could be amenable to quantitative analysis. In contrast, both Dallas-Fort Worth and Washington, DC included a numerical scoring measure as one of their screening criteria. In the case of Washington, DC this scoring scheme, though numerical was based largely on qualitative analysis. However, in the case of Dallas-Fort Worth the scoring scheme was based in part on quantitative analysis.

- *Qualitative and Quantitative analysis are compatible in a screening scheme*

  As is displayed by the screening schemes used by Dallas-Fort Worth and by Washington, DC, both qualitative and quantitative screening criteria may be included in a single screening scheme without any need to convert the qualitative and quantitative measures into a single unit. This contrasts, the requirements of a scoring scheme. In scoring schemes all criteria measures must be converted into a single unit so that they may be summed to form a total project score. (This is discussed by Section 4.4.2.)

- *The use of "measures" and "standards" to determine if a project complies to a given screening criterion*

  Some screening criteria specify very precisely what a project must do to prove that it complies with the criteria. For example, one of Washington, DC's screening criteria is "project score of 16 or above". The analysis team specified a method for developing the project score. The project score is the "measure" of how well a project complies to the given screening criterion. Also, the screening criterion specifies how high a score must be in order for a project to comply with this screening criterion (i.e. it specifies that a project's score must be above 16). Thus, a "standard" has been specified indicating how good is good enough.

  On the opposite end of the spectrum, are the screening criteria used by Seattle. No guidelines were provided on how to determine conformity to the criteria in Seattle's screening scheme. In other words, no "measures" or "standards" were specified.

- *What determines if a project passes a screen varies amongst screening schemes.*

  For example, in order for a project to pass Washington, DC's screening process, it must meet one of the three screening criteria listed in Table 4-4: "implementable by 1996." Also, a project must meet one of the other two criteria: "a numeric score of 16 or above" or " five or more 'must include' votes." In contrast, in order to pass Dallas-Fort Worth's screening process, a project must meet all three of the criteria listed in Table 4-4.

Table 4-4 The Use of "Screening Criteria" During TIP or SIP Project Selection Processes

Case Study Region	*Screening Criteria*	*Stage of Process at which Projects Were Screened*
Washington, DC	• a numeric score of 16 or above • project implementable by 1996 • five or more "must include" votes[57]	Screening was used to trim a list of 164 measures. Fifty-nine measures remained after screening and proceeded on towards detailed analysis. Project scores used during screening were based largely on rough qualitative analysis, since projects had not yet been analyzed in detail.
Dallas-Fort Worth	• project scores • if funding caps are violated • construction feasibility[58]	Once projects have been scored and ranked, they are presented to a council of elected officials who will select which projects to include in the TIP. Project selection is based partially on the three screening criteria listed here.
Seattle	• Some of the screening questions considered in the first stage are listed as a footnote.[59]	To identify which project proposals will proceed to "phase two" during which projects are scored and analyzed in detail.
Boston	• may be feasibly implemented within the TIP planning horizon • funding availability	These two broad screening measures are the two major prerequisites for inclusion of a project in the TIP.

[57] Mentioned on page 20.

[58] Mentioned on page 51.

[59] Screening criteria (taken from the 1995 Policy Framework for Seattle's 1995 ISTEA TIP Process)

1. Does the project improve system performance? Performance can be measured in a variety of ways, such as congestion levels for highway projects, ridership per hour for transit, etc. Who benefits from the improvement should be identified.
2. Does the project reduce reliance on single-occupant vehicles?
3. Does the project help sustain and promote economic vitality through improved mobility for people or freight and goods?
4. Does the project improve or provide multimodal or intermodal access to ports, airports, or centers?
5. Does the project support air quality goals? VMT and emissions reductions are required by federal law for CMAQ funded projects.
6. How does the project support Growth Management Act/ Vision 2020 (long term regional development plan) / comprehensive plans?
7. Does the project provide greater system efficiencies or effectiveness? This may include considering improved connectivity with other elements of the transportation system or within the same system elements for improved person throughput. Examples: completion of the state HOV system; identifying missing roadway links; creating improved multimodal connections between bus, rail, ferry, and pedestrian elements.

- *Screening was used for a range of purposes.*

  Towards the beginning of its project selection process, Washington, DC used a screening scheme to trim a set of 164 measures down to a set of 59 measures. Similarly, Seattle used a set of highly qualitative screening criteria early in its project selection process in order to determine which projects should proceed to the second phase of the process. In contrast, Boston and Dallas-Fort Worth used screening towards the end of their project selection processes in order to make their final decisions about which projects to incorporate in their TIPs.

- *Using Screening in Order to Combine Technical and Political Inputs to the Decision-Making Process*

  It is usually during the ranking process that the results of technical analysis are combined with input from politicians, private citizens, and private businesses in order to produce a final decision. The screening schemes used by Washington, DC and Dallas-Fort Worth illustrate how this may be done. Dallas-Fort Worth ranks projects based on three screening criteria:

  1. project scores
  2. if funding caps are violated
  3. construction feasibility

  One of these three criteria (project scores) summarizes the results of the technical analysis, while the other two are largely political issues.

  Washington, DC uses a similar set of screening criteria to rank projects:

  1. a numeric score of 16 or above
  2. project implementable by 1996
  3. five or more "must include" votes

  Notice that one of the screening criteria summarizes the technical analysis (project scores), while the other two reflect political concerns. In the case of Washington, DC the ranking produced by this screening process was not used to make the final decision about which TCMs to include in the SIP, but was used to trim the set of potential TCMs during the initial stages of the project selection process.

4.4.2 Scoring

Most project selection processes identify a few criteria upon which projects will be analyzed and compared. Some processes systematize this comparison by devising a scoring scheme which converts total project impacts into a unitless point scale. Converting impacts into this unitless measure involves three steps:

1. *Estimating project impacts*
2. *Developing "criterion scores":* For example, if a criterion such as air quality had to be scored, all air quality impacts would need to be aggregated and converted into the unitless point scale.
3. *Adding up criteria scores to produce a "total project score":* This involves weighting the criterion scores. For example, consider a scoring scheme in which total project scores range from 0 to 100 points and reflect two criteria: mobility improvement and air quality improvement. Fifty points might be allotted to the mobility criteria, and fifty to the air quality criteria; or, 40 might be allotted to mobility and 60 to air quality. Each of these scenarios has certain implications and internalizes assumptions into the "total project score".

In fact, many aspects of a scoring scheme imbeds assumptions within the "total project scores". Scoring schemes, and their assumptions, vary on three main points:

1. Criteria included,
2. Points assigned to each criterion, and
3. How to measure each criterion.

These three points are expanded on below.

POINT #1: Criteria Included

- The criteria included in a particular scoring scheme is usually *a function of both regional-priorities and legislative requirements.*

- The criteria included in a scoring scheme also depends on *the ability to measure certain criteria.* For example, a criteria such as "a project's long-term impacts on city structure" might not be included in certain scoring schemes because it is hard to measure and estimate.

- Sometimes *criteria which are interdependent or redundant* are both included in a scoring scheme. This causes the scoring scheme to "double-count" (i.e. count more than once) certain project impacts. The meaning and significance of "double counting" is best illustrated by an example such as the following one. The Dallas-Fort Worth region employed a 100 point scoring scheme in its 1995 TIP/CMAQ Project Selection Process. The scoring scheme could be broken down as follows:[60]

CRITERIA	***POSSIBLE POINTS***
Current Cost Effectiveness	20
Local Cost Participation	20
Air Quality/ Energy Conservation	20
Congestion Management Plan/ Transportation Control Measures	20
Intermodal/Multimodal/Social Mobility	20
TOTAL	***20***

In this scoring scheme, projects improving air quality could receive priority through three avenues: the 20 points allotted to "air quality/ energy conservation", the 20 points allotted to "congestion management plan/ TCMs", or through the 20 points allotted to "intermodal/multimodal/ social mobility" projects. In this sense, the air quality benefits of a project could be "double counted" or literally triple

[60] Texas No. 4, p. 1.31.

counted within this scoring scheme. *However, the three air quality related criteria are not identical, and the implications of this "double counting" is not equivalent to giving projects up to 60 points directly for their "air quality" benefits.* For instance, the criterion "congestion management plan/ TCMs" gives priority to TCMs in the SIP, but not necessarily to other TCMs not committed to in the SIP.[61] Also, the criterion "intermodal/ multimodal/ social mobility" basically gives 20 points to any project which does not favor the single-occupant-vehicle mode; many, but not all TCMs, fall into this category. So this criterion, like the last one, only gives additional priority to certain types of TCMs.

In summary, "double counting" can be a good technique for factoring in the complexities of regional priorities, but could also imbed false implications in a weighting scheme if not used carefully.

***POINT #2: Points Assigned to Each Criterion*:**

- The number of points assigned to each criterion relative to the other criteria depends on the *relative importance of each criterion.* (Ideally 1 point of mobility benefit and 1 point of air quality benefit should be of equal "value" to society, for example.)

- The number of points assigned to each criteria is also influenced by the need to convert the measures of different criteria into a common unit. Impact estimates of competing criteria are usually in different units, when in their raw form. To use these raw estimates in a scoring scheme they must all be converted into one unit. Depending on how this conversion is made, impact estimates may be distorted, or certain assumptions may be built into the final project score.

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[61] Texas No. 2.

Sometimes rough approximations for conversion factors are made. This seems to be the case in Seattle's air quality scoring scheme for its 1995 TIP process. During the 1995 TIP process, air quality impacts of proposed projects were estimated for the year 2005. The eventual conclusion of the process was a single number representing the air quality impact of a given project. This single number was computed in the following manner. As a start, four measures of air quality impacts were created using the TCM Tools software package:

- Vehicle trip reductions
- Vehicle miles traveled (VMT) reductions
- Pollutant reductions in carbon monoxide (CO), ozone precursors -- hydrocarbons (HC) and nitrogen oxides (NOx) and particulate matter (PM_{10})
- Cost-effectiveness for CO, HC, NOx, and PM_{10} reductions[62]

The above four measures were used to score each project. Each of the four measures: 1) trip reductions, 2) VMT reductions, 3) pollutant reductions, and 4) cost-effectiveness for pollutant reductions, received equal weight in the final score. Within measures (3) and (4), reductions of each pollutant carried equal weight.

There were two assumptions in Seattle's scheme which seem to be rough approximations. First, all four impact estimates were given equal weight. Second, the four pollutant types were given equal weight within measures (3) and (4).

- Third, the number of points assigned to each criteria reflects how precise the analysis was. This is an important detail since assuming a higher degree of precision than exists can produce an inaccurate ranking. Scoring schemes can

[62] Taken directly form Seattle No. 2, p I-2 and I-3.

accommodate variable degrees of precision amongst impact estimates by adjusting the number of points assigned to each criteria and the gradations at which points are assigned.

Less precise analysis results might only allow projects to be broken down into three ranks: low, medium, and high. However, more precise analysis might allow projects to be broken down into five ranks, ten ranks, or even more (if the analysis is really precise).

It is most straight forward to reflect a three-tiered ranking on a 3-point integer scale (1 point = low, 2 points = medium, and 3 points =high). However, it could also be reflected through a 20 point scale (0 points = low, 10 points = medium, 20 points = high), a 50 point scale or a number of other scales. The main advantage to using a scale with more points is that it could accommodate variable degrees of precision.

To illustrate this point an example is given from Dallas-Fort Worth's 1995 TIP-CMAQ scoring scheme. As described previously this scoring scheme offered each project a maximum of 100 points through five criteria, each worth 20 points. However, not all criteria were measured with equal precision as can be scene from how they were scored. The criterion called "air quality/energy conservation" was scored in 5 point gradations, while the criterion called "project commitment/local cost participation" was broken down into finer gradations. The scoring of these two competing criteria are described in the next two tables.

$/lb of Volatile Organic Compound Emission Reduction	***Score***
>=100.0	0
50.0 - 99.99	5
10.0 - 49.99	10
5.0 - 9.99	15
<=4.99	20

% of Funds Provided by Non-CMAQ (e.g. Local or Private) Funds	Score
0 - 20	0
21 - 25	3
26 - 30	7
31 - 35	10
36 - 40	13
41 - 45	17
>=46	20

POINT #3: How to Measure Each Criterion

- It should be noted that *naming* a measure is only a first step. The exact meaning of a measure is defined by how it is calculated. Take as an example quantifying mobility benefits of transit and highway expansion projects using "number of vehicle-hours reduced" as the measure. There are two interpretations of "vehicle-hours reduced": (1) the vehicle hours saved by the travelers which opt for using the new facility, or (2) the hours saved by all users of the transportation system due to the new project. The second interpretation might favor transit projects. Transit projects may convert highway commuters into transit commuters and thus alleviate congestion in the system overall. However, new users of the transit system may not experience significant time savings by switching from single-occupant-vehicles (SOVs) to transit. They may have been motivated to switch to transit because it offered a journey of comparable length accompanied by a welcome break from congested roadways.

As a second example consider how to measure the total air quality benefits of a project. There are numerous ways to do this; there is no commonly accepted measure of total air quality impact. Several issues must be considered in devising an air quality measure. For instance, the emissions of various pollutants must be weighted against one another and aggregated somehow. This raises questions like:

is a 1 ton reduction in HC emissions of comparable environmental value to a 1 ton reduction in CO or NOx. An example of these issues is provided by a scoring scheme used by Seattle which was described a few paragraphs ago.

- Another issue related to defining measures is whether measures should be identical for all project types (e.g. highway, rail, pricing) within a given criterion.

The above discussion provided some illustrative examples. Table 4-5 provides some more examples of how the scoring schemes found in the case studies addressed two of the three points discussed above:

1. Criteria included in the scoring scheme
2. Points assigned to each criteria

The third point, "how to measure each criteria," could not be summarized briefly in a table. Providing a list of measures would be misleading since a measure *name* does not capture the measure's exact meaning, since a measure's true meaning is a function of the many assumptions made when calculating it. Appendix A, which describes the case studies in full, contains some detailed examples of the measures used by regions. Also, Chapter 3 is largely devoted to explaining the methodology used to develop measures such as "VMT reduced," "trips reduced," and "amount of pollutant emissions reduced."

In addition to providing more examples of the first two points listed above, Table 4-5 summarizes how regions used scoring to aid in project selection. A few observations may be drawn from this table. For example:

- In the case studies, scores were used in a variety of contexts. For instance, regions used scoring schemes to aid in the initial phases of project selection, as well as in final selection decisions. Washington, DC used a scoring scheme of low precision early on its project selection process before projects had been analyzed in detail. In contrast, Seattle scored projects once they had passed into phase two of the project selection process and had been analyzed in detail.

- Oftentimes, as in the case of Washington, DC, project scores were not the sole criteria considered in project selection. In Washington, DC scores were part of a screening process which included two other screening criteria, in addition to project scores: "5 or more must include votes" and "implementable by 1996".

- Scoring schemes need not be based on highly quantitative analysis, even though they are communicated numerically. The primary example of this is found in the Washington, DC case study. Washington, DC developed numerical (i.e. a project score was indicated by a number) project scores based largely on qualitative analysis, before any detailed quantitative analysis had been done.

Table 4-5 Scoring Schemes Used by the Case Study Regions

Case Study Region	*Scoring Criteria*	*Scoring Scale*	*What Scoring Was Used For*
Washington, DC	• Travel Reduction Potential • Cost • Speed of Implementation • Political Acceptability • Synergistic Effect • Cost effectiveness (cost/ travel reduction potential) • other benefits (e.g. revenue generation, quality of life, reduction of energy demand)	A project could attain a maximum of 3 points for each criteria, except in two criteria ("cost" and "travel reduction potential") which were double weighted (i.e. worth a maximum of 6 points). Thus, each project was scored as "low", "medium", or "high (3 points) in each category. Summing the seven criteria scores could produce a maximum project score of 27 points.	Used during the analysis of TCMs to be included in the SIP. Scores were used in conjunction with two other criteria to screen measures in the early stages of analysis. The screening determined which projects merited detailed analysis.
Dallas-Fort Worth	• Current Cost Effectiveness • Local Cost Participation • Air Quality/Energy Conservation • Congestion Management Plan / TCM • Intermodal/ Multimodal/ Social Mobility	A project could attain a maximum score of 100 points. Each criteria was worth 20 of these 100 points. More details on the scoring scale appear on pages 40 - 43 of Appendix A.	This scoring scheme was used to assign CMAQ funds to projects during the 1995 TIP project review/evaluation process. A similar scoring scheme was used to assign STP funds. About 1000 proposals for CMAQ funds were received and scored before they were presented to a council of elected officials which would select projects. Project scores were one of several criteria considered during project selection.
Seattle	• Maintenance and Preservation • Traffic Congestion • Safety • Efficiency • Accessibility • Connectivity • Reliability and Convenience • Environmental Benefits • Cost/Affordability	Air quality constituted about 23% of a project's total score during the 1993 process. It was suggested that this be increased to 33% during the 1995 process. More details on the computation and scaling of air quality scores are presented on pages 61-62 of Appendix A.	This coring scheme was used by Seattle during its 1995 regional TIP Project Review/Evaluation Process. Once projects have passed an initial screening they are analyzed in detail, scored, and reviewed.
San Francisco	See Appendix S because it is too lengthy to summarize in this table.	See Appendix S because it is too lengthy to summarize in this table.	This scoring scheme was used in their FY 1994 RTIP and 1995 TIP Project Review process.
Boston	scoring not used		

4.4.3 Raw Evaluation Measures

Raw Evaluation Measures are often used to compare the impacts of competing projects. Projects are sometimes ranked based on this type of comparison. Raw evaluation measures may be either qualitative or quantitative. There are a few advantages and disadvantages to the use of raw measures:

- The main downfall of this ranking technique, is that the basis for ranking is not clear; it is often not clear why a high priority project is better than a low priority project. Thus, anyone other than the individuals which developed the ranking, might regard it with skepticism - even if it is extremely accurate, precise, and based on extensive analysis. This is an unusual point to be making since it is related to intangible concepts like communication and trust. Yet, it is mentioned because it was a recurring issue in several of the phone interviews conducted with individuals involved in regional planning processes.
- All raw evaluation measures do not have the same units and are therefore hard to compare. For instance, "vehicle miles traveled" and "tons of hydrocarbon eliminated" are two measures which are not intuitively comparable. Thus, it is difficult to weigh different project impacts (e.g. mobility vs. air quality) against each other in a consistent manner for all projects using raw evaluation measures.
- Certain measures are redundant. For example, "VMT reductions" and "tons of HC reduced" are dependent on one another. Considering such measures separately, may lead a decision maker to double count the impacts of a given project.
- On the flip side, because raw measures leave model estimates in a relatively "pure" form, they are less likely to distort them. For example, converting all impacts into dollar values would entail the use of various conversion factors (e.g. value of time) which are themselves surrounded by many assumptions and a certain degree of inaccuracy.

Given these pros and cons, a few regions have ranked projects based on qualitative analysis supported by raw evaluation measures. Two regions stated explicitly that this was the technique they would use: Washington, DC and Boston. During Phase IV of its process, Washington, DC used this technique to trim a set of 48 measures down to a set of 40. Boston used this technique to develop its final recommendations for the PMT. The "raw evaluation measures" which these two regions calculated and documented are listed in Table 4-6. As was mentioned in a previous section, a listing of measure *names* (such as the one provided by Table 4-6) can be misleading, since the exact meaning of a measure depends on how it is calculated. More detailed descriptions of these measures is provided in Appendix A and Appendix J.

Table 4-6 Examples of Raw Evaluation Measures Used to Compare Projects

Case Study Region	***Evaluation Measures Calculated***
Washington, DC	Vehicle-Trips Reduced, Vehicle-Miles-Traveled Reduced, VOC Reduced in tons per day, cost vs VOC reduced table
Boston	*Utilization* Total New Trips, New Transit Trips, Riders/Vehicle Service Hour, Riders/Vehicle Service Mile *Cost-Effectiveness* Farebox Ratio, Investment/New Daily Transit User, Annualized Cost/ New Daily Transit User, Annualized Cost/Hour of Travel Time Savings, Annual Operating Subsidy *Air Quality Impacts* Percent Emission Reduction, Capital Cost/ kg VOC Eliminated *Service Quality & Coverage* Improved Connections, System Accessibility, Distribution of Service, Unmet Needs, Travel Time Savings, Safety/ Security, Comfort/ Convenience, Crowding *Impact on System* Preservation of Existing System, Preservation of Future Options, Efficiency/Effectiveness *Economic Impacts* Economic Development Potential, Potential for Private-Sector Participation *Land Use Impacts* Supports Urban Core, Supports Suburban Compact Development

4.4.4 Implications on the Desirable Structure of a Technical Analysis Framework

In the case studies, project rankings were derived from a mixing and matching of three types of methods:

1. screening,
2. scoring, and
3. raw evaluation measures.

Tables 4-4 through 4-6 summarize the examples of these methods found in the case studies. Table 4-7 lists the examples presented in those tables.

Table 4- 7 Examples of Screening, Scoring, and Raw Evaluation Measures Found in the Case Studies and Discussed in this Section ("X" indicates that the method was used by the given region)

	Washington, DC	*San Francisco Bay Area*		*Dallas-Fort Worth*	*Seattle*	*Boston*	
	(SIP)	*(SIP)*	*(TIP)*	*(TIP)*	*(TIP)*	*(PMT)*	*(TIP)*
Screening	X	X		X	X		X
Scoring	X		X	X	X		
Raw Evaluation Measures	X					X	

These three methods were combined in a variety of ways to produce ranking schemes. Namely, the case studies based project ranking on: (1) screening; (2) screening and scoring; or (3) qualitative analysis supported by raw evaluation measure. In the processes focused on by the case studies, project scores were never the sole criterion upon which projects were ranked.

The case study regions used both systematic and non-systematic methods for ranking projects. Screening and scoring schemes catered to systematic ranking processes, whereas "raw evaluation measures" catered to non-systematic ranking processes. While screening and scoring were more systematic than "raw evaluation measures," not all screening and scoring schemes were equally systematic. Some screening schemes, such as Seattle's (the one described in Table 4-4) were very vaguely specified. On the other hand, the scoring scheme used by the San Francisco Bay Area in its TIP process (described in Table 4-5 and Appendix S) was much more systematic.

Thus, Section 4.4 has lead to one of the major conclusions of this thesis: that some regions have found it beneficial to use systematic ranking schemes. A second major conclusion, related to the first major conclusion, is that a systematic ranking scheme need not be highly quantitative or numerical. For example, at the onset of Washington, DC's project selection process a highly systematic ranking scheme which combined screening and scoring was used. However, this ranking scheme was based largely on qualitative analysis. This ranking scheme is summarized in Tables 4-4 and 4-5.

The third, and final, major conclusion brought forth in this section (4.4) regards the general composition of a systematic ranking scheme. Based on the examples found in the case studies, it may be concluded that developing a systematic ranking process generally involves the following components:

INPUTS:

- ***Criteria -*** Choosing the criteria upon which project ranking will be based.
- ***Measures and Standards -*** Determining measures and standards which will be used to determine if a project complies to the above criteria.
- ***Calculations -*** Determining the value (qualitatively or quantitatively) of these measures and standards.
- ***Weight Criteria -*** Determining the relative importance of the above criteria.

"PROCESSOR":

- Choosing a ranking process such as screening; screening and scoring; or some other method. The ranking process should specify what characteristics a project must have in order to obtain a particular rank. For example, the ranking process could specify that projects which meet all of the screening criteria are ranked as "high priority," and that all other projects are ranked as "low priority." Or a ranking process could specify that projects with scores between 0 and 30 are ranked as "low priority," projects with scores between 30 and 70 are ranked as "medium priority," and that projects with scores between 70 and 100 are ranked as "high priority."

OUTPUT:

- The output of a highly systematic ranking process not only indicates what a project's rank is, but why it was ranked that way. For example, if a project was ranked as "low priority" because its score was very low, this explanation should be available somewhere in the documentation.

The components listed above are not unique to systematic ranking schemes - any ranking scheme must contain the above inputs, outputs, and "processor." What distinguishes a systematic approach from a non-systematic one, is how explicitly and specifically the above components are defined. Since not all examples found in the case studies were equally systematic, they did not all define and document the above components to the same level of detail.

Also, it should be noted that the components listed above are not discrete, they are interdependent. For example, it is best to choose measures whose values can be calculated by existing methods (whether they be qualitative or quantitative methods.) Similarly, if one criterion is much more important than any of the other criteria, the ranking process could be defined to reflect this. In particular, the first step of the ranking process might involve screening projects based solely on this one very important criterion. This would reduce the time spent on analyzing projects which could easily be identified as infeasible.

4.5 STRUCTURE OF PRIORITIZATION PROCESSES FOUND IN THE CASE STUDIES

This section discusses the structure of the various project selection processes encountered in the case studies. The major conclusion brought forth by this section is that the project selection processes focused on by the case studies often rank projects in "cycles." In other words, they prioritize projects in stages. They begin by ranking projects roughly so as to reduce the number of potential projects. Once the potential list of projects has been reduced to a point at which more detailed analysis of all the remaining projects is a feasible endeavor (i.e. would not consume too much money and time) projects may be ranked more precisely.

Thus, a given project selection process often makes use of several types of ranking schemes (these were described in section 4.4) and analysis methods (these were described in section 4.3); different ones are used at different stages of a given project selection process. Table 4-8 provides a general description of the types of methods employed at various stages of the processes focused on by the case studies. To aid the reader in synthesizing and understanding the information contained in the table a few of its implications are discussed below.

1. When regions chose to use various types of ranking schemes.

Washington, DC developed project scores at the beginning of the process when only rough qualitative analysis was available. Subsequent ranking processes were based largely on "raw evaluation measures." In contrast, Seattle scored projects in the later part of its process when detailed analysis had been conducted. Seattle used a technical and qualitative screening process during the earlier stage of its process.

2. When regions chose to perform detailed analysis.

As can be scene from the Seattle, Washington, DC, and San Francisco Bay Area case studies, regions tended to conduct detailed analysis in the later parts of the process when the number of potential projects had been trimmed substantially.

3. When regions attempted to package TCMs.

None of the TIP related processes encountered in the case studies addressed the issue of packaging TCMs. However, both of the SIP related processes did. Both Washington, DC and the San Francisco Bay Area considered TCM packaging towards the end of their project selection processes when the set of potential TCMs had already been trimmed substantially and detailed analysis of individual projects had been conducted. Washington, DC only analyzed individual TCM impacts. In contrast, the San Francisco Bay Area analyzed the combined impacts of a few TCM packages.

4. How the initial set of TCMs was derived

It was assumed in Chapter 1 that regions have developed an exhaustive set of potential TCMs before beginning the "technical analysis process."[63] The table confirms the feasibility of this assumption; the table points out that the first step in all processes was defining an initial list of projects.

However, the nature of this initial list varied between TIP and SIP related processes. The Washington, DC and San Francisco Bay Area case studies both focused on SIP related processes, and both processes began with the analysts defining an in initial set of TCMs. In contrast, the other three case studies which focused on TIP related processes, began with a set of potential projects which was generated by sponsoring agencies (i.e. sponsoring agencies proposed projects to be considered for inclusion in the TIP).

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[63] This assumption was made in order to limit the scope of the technical analysis framework to be developed.

Table 4- 8 Structure of Project Selection Processes Found in Case Studies

Case Study Region	Case Study Focus[64]	Process Overview *(refers to case study focus)*
Washington DC	TCM Program for 1993 SIP	• Initial list of potential projects • Screening/scoring • Quantitative testing • Further ranking based on qualitative analysis and raw evaluation measures; packaging • Project selection
Dallas-Fort Worth	1995 CMAQ scoring methodology and project selection	• Survey used to select criteria • 5 evaluation criteria selected and assigned weights • Methodologies for quantifying criteria were developed • ~1000 project proposals from public/private agencies received , scored, and ranked • Transportation council of elected officials made final project selection
Seattle (Puget Sound)	Regional 1995 TIP Project Review/ Evaluation Process (There are also county-level processes)	FIRST STAGE • Project sponsors submit 2-3 page project proposals • Technical and qualitative screening of proposals SECOND STAGE • Detailed analysis; projects are scored and reviewed
San Francisco/ Bay Area	1990 Transportation Control Measure Plan (TCMP) *(for the SIP and California CAA)*	• Defining a set of possible TCMs. • Screening: Identifying individual measures with significant emission reduction potential. • Integrating feasible TCMs into a region-wide control plan (TCMP). • Detailed Analysis: Analyzing the combined effect of measures in the TCMP. • Assessing the institutional feasibility of potential TCMPs.
Boston	Development of the Program for Mass Transportation (PMT), and the TIP	*PMT: Evaluation of a Project consists of:* • Project Definition. • Determination of project characteristics. • Calculation of performance measures; qualitative ranking. • Interpretation of data. • Conclusions. *TIP Process:* • Project proposals submitted to the MAPC. • Screening: projects ready for implementation. • Screening: financial constraint • Remaining projects put in draft TIP. • Public review. • Final TIP.

[64] Portion of the TCM Program Development Process the case study focuses on.

4.6 LEGISLATIVE REQUIREMENTS

As mentioned in previous sections and in Chapter 3, legislative requirements influence the choice of analysis approach. The case studies emphasize two critical decisions of TCM prioritization:

1. Which TCMs to consider for inclusion in the SIP
2. Which TCMs to program into the TIP.

Each of these decisions is governed by a unique set of legislative requirements; namely, the first decision is governed by the requirements placed on the SIP, and the second decision is governed by the requirements placed on the TIP. The next few subsections describe the conclusions regarding TIP and SIP processes which were drawn from the case studies.

4.6.1 How a SIP, EIS, TP, or TIP Incorporates TCM Programming Into Its Overall Structure

State Implementation Plans, Environmental Impact Statements, Transportation Plans, and Transportation Improvement Programs are four planning documents which serve four very different functions:

SIP: The SIP is a state level plan for achieving air quality standards. It considers all sources of air pollution, not just transportation. It identifies the sources of air pollution and devises a plan for reducing/eliminating their impacts. The development of the SIP is the point when TCMs are first chosen and committed to. Commitments at this stage are more impact-specific than project-specific.

EIS: An EIS analyzes environmental impacts of a proposed project and project alternatives. Air quality is just one of the environmental impacts considered. The EIS suggests or requires the implementation of mitigation measures which could negate the environmental impacts of the proposed projects. Mitigation measures for a transportation projects need not be transportation projects themselves.

TP: A TP documents a region's or state's long-range (20 year), financially feasible, transportation vision.

TIP: A TIP documents a region's or state's short-term (3 to 5 years), financially constrained, prioritized agenda of transportation projects. TIP Programming is the point by which general SIP commitments must be translated into specific project commitments; projects are assigned funding sources, and projects are programmed for implementation. Commitments at this stage are more project-specific than impact-specific.

A TCM passes through at least three [SIP-TP-TIP or EIS-TP-TIP] of these documents on its path from conception to implementation. Thus, the processes used to construct a SIP, EIS, TP, or TIP must each address the issue of TCM programming in their own way. The case studies presented in this report describe how SIPs and TIPs incorporate TCM programming into their overall structure. Table 4-9 summarizes this.

4.6.2 Distinction Between How TIPs & SIPs Incorporate TCM Programming Into Their Overall Project Selection Processes

Prioritization/Selection processes encountered in the case studies fall into two groups: (1) processes used to devise TCM Plans for the SIP, and (2) processes used to select projects for the TIP. Both types of processes would be used to narrow down a broad list of candidate measures to a few measures to be considered seriously. However, the two processes must address slightly different issues since the TIP and SIP are subject to different finance, project detail and air quality regulations. These distinctions are described in more detail below.

Table 4-9 How Case Study Regions Incorporated TCM Programming into their Overall SIP or TIP Structure

Case Study Region	Case Study Focuses on SIP or TIP	How TCMs Fit Into Overall SIP or TIP Structure
Washington, DC	SIP	The degree of non-attainment was identified and attributed to various sources. Transportation being a primary mobile source of emissions, a plan was devised to mitigate its impacts. As part of this effort, TCMs were considered for inclusion in the '15% reduction plan' and the 'contingency plan' of the SIP. To decide which TCMs to include, a lengthy analysis of potential TCMs was conducted. An initial list of 200 TCMs was reduced to a list of 14 TCMs to be seriously considered. One of the 14 was included in the '15% reduction plan' and the rest would be considered for the 'contingency plan'.
Dallas- Fort Worth	TIP	D-FW uses a scoring system (amongst other methods) to streamline its TIP programming process. TCMs committed to in the SIP or an EIS must compete with other projects through this scoring system. About a fifth of the point scores are dependent on a project's air quality impacts. The scoring system used to assign CMAQ funds differs slightly from the system used to assign STP funds. For instance, in the CMAQ system TCMs receive bonus points which account for a fifth of the total project score.
Seattle	TIP	TCMs must compete with other projects during the TIP project review/evaluation process. Projects which pass the screening stage, are scored and analyzed in detail before they are reviewed. TCMs receive priority in this system through three mechanisms. First, "travel demand management/ system management' projects which address congestion and environmental objects are one of the four project categories which receive priority in the TIP policy framework. Second, one of the screening criteria explicitly refers to air quality goals. Lastly, during the 1993 TIP process air quality constituted 23% of a project's total score. It was suggested to increase this to ~33% in the 1995 process.
San Francisco	SIP	Very similar to Washington, DC. However, SFBA had to meet requirements of both the federal and state Clean Air Acts and Amendments. Also, SFBA used different methods to transform its large list of potential TCMs into a reduction plan and a contingency plan.
Boston	TIP	In general, Boston includes projects in the TIP as long as they are sufficiently ready for implementation within the TIP planning horizon and can be funded. TCMs receive funding priority. However, this does not mean they are the first TIP projects to be implemented.

SIP Requirements Relevant to TCM Prioritization:

- *Finance:*

  Although it would be unwise to devise a TCM Plan that was financially infeasible, funding need not be addressed in the SIP. Because SIP commitments are not project-specific, a detailed funding plan would be hard to devise.

- *Project Detail:*

  Because projects included in the SIP require much commitment, the more general project specifications are, the more flexibility the region will have in the future. Thus, the tendency is to consider only "categories" of measures during a SIP-related project selection process. For example, "HOV lanes" would be considered, rather than "2 miles of HOV lane on I-80".

- *Air Quality:*

  Since the SIP is the State's plan for attaining air quality standards, projects included within it are selected primarily for their air quality benefits, in theory. This is not to say that air quality is the sole consideration in selecting projects. Rather, it is the primary purpose of the plan, so a project with negative air quality benefits would not be included most likely - even if it affected other system characteristics in remarkably positive ways.

TIP Requirements Relevant to TCM Prioritization:

- *Finance:*

  Due to the financially constrained nature of the TIP and funding programs such as CMAQ, project finance is a major concern in project selection.

- *Project Detail:*

  Also due to the financially constrained nature of the TIP, projects included in the TIP must be specifically defined. This is because projects must be well defined before their costs (and impacts) can be estimated accurately or precisely.

- *Air Quality:*

  According to legislation governing the TIP, air quality need only be a secondary concern in selecting projects, although regional priorities may make it otherwise. Projects with negative air quality impacts may be selected if they effect other system characteristics positively (for instance, if they improve mobility or stimulate economic development.)

  Air quality issues may influence TIP project selection through three avenues. First, the cumulative effects of TIP projects cannot conflict with air quality goals according to conformity requirements. Also, CMAQ projects, as the title implies, are supposed to mitigate congestion as well as improve air quality. Third, general commitments made in the SIP must be translated into specific projects which are programmed into the TIP.

These three distinctions (finance, project detail, and air quality) between the motivating forces for SIP TCM programs and the TIP, are reflected in the project selection processes used for each as described above. However, these distinctions have several indirect effects on the structure of a TIP or SIP project selection process. For example:

- "Project detail" limits how detailed the analysis may be. If a project is defined only generally, only its general impacts may be estimated.
- In order to define a project in detail, its sponsoring agency should be consulted.
- The need to consider financial constraints and air quality impacts influences the project selection criteria used. It may also influence the relative weighting of these criteria.

4.6.3 Conclusions Regarding the Desirable Structure of a Technical Analysis Framework

Conclusion #1:

Some distinctions between TIP and SIP processes were noted in a previous section (4.5). This section (4.6) begins to explain the source of these distinctions. SIP and TIP related processes differ because of the distinctive legislative requirements placed on each. SIP and TIP processes must meet different requirements as regards the level and type of detail of projects contained within them, the air quality benefits of the projects contained within them, and the type of financial commitment imposed on the projects contained within them. Section 4.6.2 discussed these three distinctions and their repercussions on the structure of a project selection process, and the methods used within the process.

Conclusion #2:

The decisions made at the SIP and TIP level are very critical portions of the TCM analysis process. The SIP process is critical because, a region is required to implement projects included in the SIP or projects with equally great air quality benefits. The TIP process is critical because, if projects are included in the TIP, they have been assigned a funding source.

4.7 ORGANIZATIONAL & INSTITUTIONAL ISSUES

This section consists of two sets of conclusions. The first set of conclusions regard the general sequence of events comprising the TCM prioritization process. This has implications on the type and depth of technical analysis which would be most suitable at various stages of the prioritization process. The second set of conclusions regards some recurring institutional and organizational themes found in the case studies.

4.7.1 Usual Sequence of Events in a Technical Analysis Framework for Prioritizing TCMs

The case studies implied that the technical component of the TCM prioritization process may be broken down into three "sieves", as pictured in Figure 4-1. This figure tries to point out a few conclusions drawn from the case studies.

- *SIEVE 1:* SIP level commitments tend to be very general, as described in previous and subsequent sections. Therefore SIP TCM selection processes often analyze general categories of TCMs, rather than specific projects. Also, at the point in time when SIP TCMs are analyzed, specific projects have not yet been defined usually. This is why Figure 4-1 begins with a set of "TCM categories." There are numerous TCM categories (e.g. improved signal timing, HOV lanes, park-and-ride lots) which a region may originally wish to consider. Only a few of these TCM categories will pass through "Sieve 1." Sieve 1 generally does not produce specifically defined projects since SIP commitments need only be impact-specific, not project-specific. Although SIP commitments may remain general, projects must be defined to some degree of detail for analysis purposes (i.e. to facilitate their analysis and produce a sufficiently precise ranking.) A region is committed to implementing projects committed to in the SIP; thus, some regions prefer to keep SIP commitments general because it offers them more flexibility in the long run. This is also a reason why Sieve 1 only deals with TCM categories, and not specific TCM projects.
- *SIEVE 2:* SIP commitments must be developed into specific projects, if this has not already been done prior to the SIP. Project development is a very broad and significant portion of the prioritization process; if TCMs are not developed into "construction-ready" projects, they cannot be implemented. By the time a TCM leaves Sieve 2 it has been defined in enough detail so that it might begin construction within the TIP planning horizon (3 - 5 years usually). TCMs from the SIP are only one type of transportation project which proceeds through Sieve 2.
- *SIEVE 3:* The TIP project selection process is the final planning stage projects must proceed through in order to be implemented.

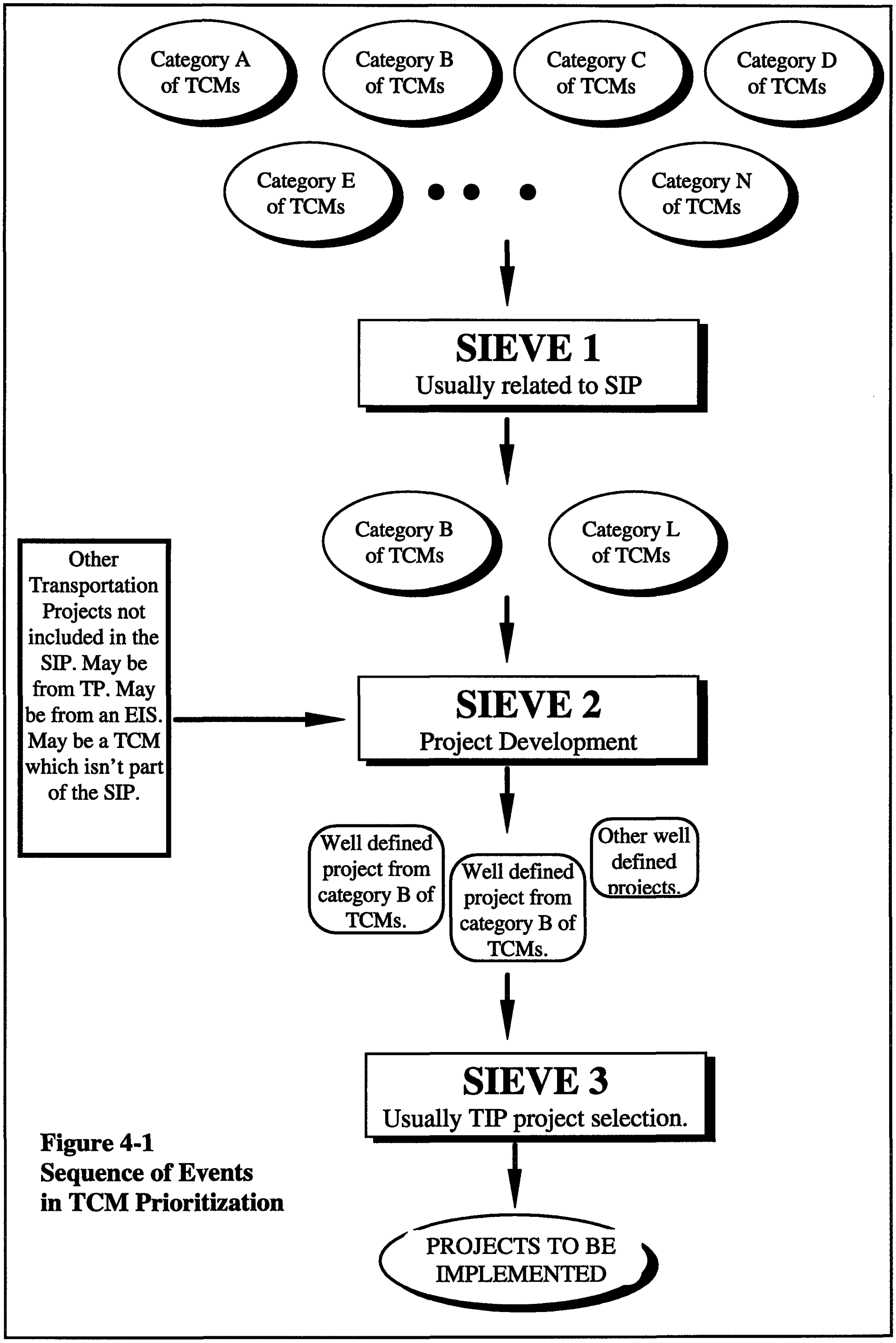

Figure 4-1
Sequence of Events
in TCM Prioritization

4.7.2 Recurring Institutional & Organizational Themes

The case studies display a few recurring institutional and organizational themes which are discussed below.

Who has Control Over Funds

This can either help or hinder an agency in creating a successful TCM Plan. The political climate and structure in the region seem to determine who has control over funds. In Seattle, control over certain funds was delegated to local agencies (from the regional one) in order to facilitate planning for local needs. The San Francisco agency mentioned its lack of sufficient authority to implement most TCMs during its 1990 TCMP process. Since then it has formed the "Bay Area Partnership" (in 1992) which consists of top managers from 31 transportation related agencies in the region. Also, the Houston agency suggested that too much authority had been allocated to State agencies. As a result projects may have been delayed in Houston due to withheld funds.

The Roles of Elected Officials, Interest Groups, General Public, & Local Agencies

The case study region's involved elected officials, interest groups, the public, and local agencies at some point in their project selection processes. A board of elected officials generally participates in final selection of projects aided by the analysis and screening processes carried out by technical staff. The Washington, DC case study discusses in detail their experiences with incorporating a variety of parties in the project selection process. These issues are too lengthy to list here, but are discussed in detail in Appendix A.

Timing

Processes often start with a broad, large range of candidate TCMs which must be narrowed down. For instance Washington, DC considered some 200 TCMs and selected only 14. One of the 14 TCMs was included in the 15% reduction plan, and the rest were considered for inclusion in the contingency plan.[65] The San Francisco Bay Area selected 21 of the numerous TCMs it initially considered.

Regions often trim their initial list of TCMs in cycles. Organizational structures must consider when (in which cycles) to include the following:

- input from technical staff, private parties, and elected officials,
- detailed analysis,
- certain selection criteria, and
- analysis of TCM packages.

Deciding how to time the above actions often involves trading off speed for thoroughness and vice versa. For example, conducting detailed analysis early in the process reduces the chance of ruling out good options due to inaccurate analysis. However, conducting detailed analysis early in the process is very time consuming because there are more TCMs to analyze at this point in the process, relative to later points in the process. On the other hand, conducting rough analysis early in the process and detailed analysis later in the process involves analyzing certain projects twice. Thus, it might prove swifter to analyze projects in detail earlier rather than later, in some situations.

Deadlines

The process structure may specify deadlines by which certain phases must be completed. In retrospect, Washington, DC mentions that having had specific deadlines could have improved their process.

The MPO as an Umbrella Agency Or as a Central Planner

This is perhaps the basic issue from which many of the above issues stem. At one extreme, MPOs act as "umbrella agencies" by consolidating projects selected by various local, transit, or other transportation agencies rather than conducting an extensive

[65] The meaning of contingency plan and 15% reduction plan are clarified in Appendix P.

selection process of their own. At the other extreme, MPOs act as "central planners" by conducting and defining the entire project selection process, rather than sharing these powers with local agencies. In most case studies, regional MPOs have adopted a middle ground between these two roles. For instance:

- Regional agencies in San Francisco, Boston, Dallas-Fort Worth and Seattle all collected project proposals from various levels of government and private agencies during their TIP processes.
- Some MPOs delegate authority to county or city level agencies so that local needs may be better addressed. For instance, the San Francisco Bay Area used a self-scoring TIP project application for the 1995 project selection process. Seattle delegates some funding control to county level agencies. Both San Francisco and Boston provide localities with "bid targets"[66] to help them devise a feasible set of project proposals.
- While MPOs delegate some authority to sub-regional agencies, they also set certain regional or state standards within which these agencies must work. "Bid targets" are one such standard. Screening criteria are another technique used to set standards project proposers know they must work within. Other examples include Washington State's "Growth Management Act", California's "California Clean Air Act", and Los Angeles County's "Congestion Management Program".

4.7.3 Conclusions Regarding the Desirable Structure of a Technical Analysis Framework

Conclusion #1

Some distinctions between TIP and SIP processes were noted in a previous section (4.5). This section (4.7) explains a source of these distinctions. On one level, these differences occur because TIP and SIP processes generally occur at different stages of the TCM prioritization process (as picture in Figure 4-1). Namely, SIP processes usually occur prior to the "Project Development" sieve and TIP processes occur after it. Thus, the projects being ranked at the SIP level usually have not yet been defined in great detail, which limits the level of detail at which their impacts may be estimated. Also, the range and number of TCMs being ranked at the SIP level usually far exceeds the number being ranked at the TIP level. Although numerous projects are ranked at the TIP level, most of these projects are not TCMs.

Conclusion #2:

The decisions made at the SIP and TIP level are very critical portions of the TCM analysis process. Namely, they begin and end the process as can be scene in Figure 4-1. All transportation projects, including TCMs, must pass through the TIP. However, not all TCMs which pass through the TIP and are eventually implemented, originate in the SIP. Some TCMs are committed to in Environmental Impact Statements, and some originate in the project development process simply because they are good transportation projects. (In addition to their air quality benefits, the other transportation benefits of many TCMs are substantial.

Conclusion #3:

This section pointed out some recurring institutional and organization themes which were:

- Who has control over funds
- The role of elected officials, interest groups, general public, & local agencies
- Timing
- Deadlines
- The MPO as an umbrella agency or as a central planner

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[66] Bid targets are estimates of how much funding the locality is likely to receive. The locality may use this information to develop a financially feasible set of projects to propose for inclusion in the TIP.

4.8 SUMMARY OF CONCLUSIONS DRAWN IN THIS CHAPTER IN REGARD TO THE DESIRABLE STRUCTURE OF A TECHNICAL ANALYSIS FRAMEWORK

This thesis aims to develop a framework which *structures* the interaction of technical analysis and TCM prioritization decision-making. Namely the technical analysis framework should address two issues underlying this interaction:

1. Which prioritization decisions to facilitate, and
2. How technical analysis should be used to facilitate them.

The case studies intended to explore the second issue listed above: how to use technical analysis to facilitate TCM prioritization. They drew several conclusions in regard to this issue. These conclusions are summarized by sections 4.8.1 through 4.8.4.

In the course of exploring the second issue, the case studies brought fourth the first issue: which prioritization decisions should technical analysis be used to facilitate. Namely, from examining the case studies it became apparent that TCM prioritization was not an isolated event; it was a continual process which spanned many agencies, many planning documents, and many years. It consisted of numerous "decisions." However, because this only became apparent after the case studies were collected the case studies did not explore the issue explicitly; the conclusions they draw in regard to the first issue are very simple, perhaps even obvious. These are summarized in the upcoming sections (4.8.1 through 4.8.4).

Sections 4.8.1 through 4.8.4 summarize the findings from the case studies which relate to the main objective of this thesis: developing a technical analysis framework. These findings could be grouped into five categories:

1. Methods Used to Estimate the Impacts of TCMs
2. Methods Used to Prioritize and Select Projects
3. Structure of Project Selection Processes
4. Legislative Requirements

5. Institutional & Organizational Issues

These categories were discussed in detail by sections 4.3 through 4.7 of this chapter.

4.8.1 Methods Used to Estimate the Impacts of TCMs (Conclusions from Section 4.3)

The factors which determine which quantification method is best for a given application were discussed by Chapter 3 in detail. The discussion is summarized by Figure 3-3. However, the case studies added some depth to this discussion. First, they expanded the range of available methods for estimating a TCMs impacts to include qualitative methods, not just quantitative ones. Second, they provided some "real-world" examples of the issues raised in Chapter 3. Some of these "real-world" examples are discussed in subsection 4.3.2. Third, the case studies clarified the types of legislative requirements which affect the choice of method for estimating TCM impacts. Sections 4.4 through 4.7 address this issue.

A few issues on the subject of impact analysis arise repeatedly in the case studies: (1) how to package TCMs in order to capture synergistic effects, (2) when to start analyzing TCM packages, (3) analyzing measures using methods which produce comparable results, (4) the appropriate use of detailed travel models vs. sketch planning techniques, (5) when to invest time in conducing technical analysis, (6) the usefulness of quantified impact estimates, (7) the importance of considering land-use impacts, and (8) sometimes qualitative analysis is more accurate than a quantitative approach. Many of these issues were initially brought up by Chapter 3, but the examples found in the case studies add a new depth to the discussion as Section 4.3.2 shows.

4.8.2 Methods Used to Prioritize and Select Projects (Conclusions from Section 4.4)

In the case studies, project rankings were derived from a mixing and matching of three types of methods:

1. screening,
2. scoring, and
3. raw evaluation measures.

Tables 4-4 through 4-6 summarize the examples of these methods found in the case studies. Table 4-7 listed the examples presented in those tables, and is reprinted here as Table 4-10.

Table 4- 10 Examples of Screening, Scoring, and Raw Evaluation Measures Found in the Case Studies and Discussed in Section 4.4 ("X" indicates that the method was used by the given region)

	Washington, DC	*San Francisco Bay Area*		*Dallas-Fort Worth*	*Seattle*	*Boston*	
	(SIP)	*(SIP)*	*(TIP)*	*(TIP)*	*(TIP)*	*(PMT)*	*(TIP)*
Screening	X	X		X	X		X
Scoring	X		X	X	X		
Raw Evaluation Measures	X					X	

These three methods were combined in a variety of ways to produce ranking schemes. Namely, the case studies based project ranking on: (1) screening; (2) screening and scoring; or (3) qualitative analysis supported by raw evaluation measure. In the processes focused on by the case studies, project scores were never the sole criteria upon which projects were ranked.

The case study regions used both systematic and non-systematic methods for ranking projects. Screening and scoring schemes catered to systematic ranking processes, whereas "raw evaluation measures" catered to non-systematic ranking processes. While screening and scoring were more systematic than "raw evaluation measures," not all screening and scoring schemes were equally systematic. Some screening schemes, such as Seattle's (the one described in Table 4-4) were very vaguely specified. On the other hand, the scoring scheme used by the San Francisco Bay Area in its TIP process (described in Table 4-5 and Appendix S) was much more systematic.

Thus, Section 4.4 lead to one of the major conclusions of this thesis: that some regions have found it beneficial to use systematic ranking schemes. A second major conclusion, related to the first major conclusion, is that a systematic ranking scheme need not be highly quantitative or numerical. For example, at the onset of Washington, DC's project selection process a highly systematic ranking scheme which combined screening and scoring was used. However, this ranking scheme was based largely on qualitative analysis. This ranking scheme is summarized in Table 4-4 and 4-5.

The third, and final, major conclusion brought forth in Section 4.4 regards the general composition of a systematic ranking scheme. Based on the examples found in the case studies, it may be concluded that developing a systematic ranking process generally involves the following components:

INPUTS:

- ***Criteria*** **-** Choosing the criteria upon which project ranking will be based.
- ***Measures and Standards*** **-** Determining measures and standards which will be used to determine if a project complies to the above criteria.
- ***Calculations*** **-** Determining the value (qualitatively or quantitatively) of these measures and standards.
- ***Weight Criteria*** **-** Determining the relative importance of the above criteria.

"PROCESSOR":

- Choosing a ranking process such as screening; screening and scoring; or some other method. The ranking process should specify what characteristics a project must have in order to obtain a particular rank. For example, the ranking process could specify that projects which meet all of the screening criteria are ranked as "high priority," and that all other projects are ranked as "low priority." Or, a ranking process could specify that projects with scores between 0 and 30 are ranked as "low priority," projects with scores between 30 and 70 are ranked as "medium priority," and projects with scores between 70 and 100 are ranked as "high priority."

OUTPUT:

- The output of a highly systematic ranking process not only indicates what a project's rank is, but why it was ranked that way. For example, if a project was ranked as "low priority" because its score was very low, this explanation should be available somewhere in the documentation.

The components listed above are not unique to systematic ranking schemes - any ranking scheme must contain the above inputs, outputs, and "processor." What distinguishes a systematic approach from a non-systematic one, is how explicitly and specifically the above components are defined. Since not all examples found in the case studies were equally systematic, they did not all define and document the above components to the same level of detail.

Also, it should be noted that the components listed above are not discrete, they are interdependent. For example, it is best to choose measures whose values can be calculated by existing methods (whether they be qualitative or quantitative methods.) Similarly, if one criterion is much more important than any of the other criteria, the ranking process could be defined to reflect this. In particular, the first step of the ranking process might involve screening projects based solely on this one very important criterion. This would reduce the time spent on analyzing projects which could be identified as infeasible based on minimal analysis.

4.8.3 Structure of Project Selection Processes (Conclusions from Section 4.5)

The major conclusion brought forth by this section is that the project selection processes focused on by the case studies often rank projects in "cycles." In other words, they prioritize projects in stages. They begin by ranking projects roughly so as to reduce the number of potential projects. Once the potential list of projects has been reduced to a point at which more detailed analysis of all the remaining projects is a feasible endeavor (i.e. would not consume too much money and time) projects may be ranked more precisely.

Thus, a given project selection process often makes use of several types of ranking schemes (these were described in section 4.4) and analysis methods (these were described in section 4.3); different ones are used at different stages of a given project selection process. Table 4-8 provides a general description of the types of methods employed at various stages of the processes focused on by the case studies. The table has several implications in regard to:

1. When regions chose to use various types of ranking schemes.
2. When regions chose to perform detailed analysis.
3. When regions attempted to package TCMs.
4. How the initial set of TCMs was derived

Section 4.5 expands on these topics.

4.8.4 Legislative Requirements, Institutional Issues & Organizational Issues (Conclusions from Sections 4.6 and 4.7)

Conclusion #1

Some distinctions between TIP and SIP processes are noted in Section 4.5. Sections 4.6 and 4.7 explain a source of these distinctions. On one level, these differences arise because TIP and SIP processes generally occur at different stages of the TCM prioritization process (as picture in Figure 4-1). Namely, SIP processes usually occur prior to the "Project Development" sieve and TIP processes occur after it. Thus, the projects being ranked at the SIP level have not yet been defined in great detail, which limits the level of detail at which their impacts may be estimated. Also, the range and number of TCMs being ranked at the SIP level usually far exceeds the number being ranked at the TIP level. Although numerous projects are ranked at the TIP level, most of these projects are not TCMs.

Also, SIP and TIP processes must meet different requirements as regards the level and type of detail of projects contained within them, the air quality benefits of the projects contained within them, and the type of financial commitment imposed on the projects contained within them. Section 4.6.2 discussed these three distinctions and their repercussions on the structure of a project selection process, and the methods used within the selection process.

Conclusion #2:

The decisions made at the SIP and TIP level are very critical portions of the TCM prioritization process. The SIP process is critical because, a region is required to implement projects included in the SIP or projects with equally great air quality benefits. The TIP process is critical because, if projects are included in the TIP, they have been assigned a funding source.

The SIP and TIP begin and end, respectively, the TCM prioritization process as can be scene in Figure 4-1. All transportation projects, including TCMs, must pass through the TIP. However, not all TCMs which pass through the TIP and are eventually implemented, originate in the SIP. Some TCMs are committed to in Environmental Impact Statements, and some originate in the project development process simply because they are good transportation projects. (In addition to their air quality benefits, the other transportation benefits of many TCMs are substantial.

Conclusion #3:

Section 4.7.2 pointed out some recurring institutional and organization themes which were:

- Who has control over funds
- The role of elected officials, interest groups, general public, & local agencies
- Timing
- Deadlines
- The MPO as an umbrella agency or as a central planner

This concludes Chapter 4. The range of conclusions brought forth in this chapter, coupled with the conclusions discussed in Chapter 3, form the basis of the technical analysis framework which will be developed and tested in chapters 5 and 6.

Chapter 5

A Technical Analysis Framework for Prioritizing TCM Investments in the Boston Region

This chapter addresses the main objective of this thesis: developing a technical analysis framework for prioritizing TCM investments in the Boston region. In this thesis prioritization is viewed as a continuous process; decisions are constantly being made in regard to how to define projects and which projects to develop further. Thus, prioritization occurs on a continual basis in the sense that if a project is never developed to the point of being ready for construction, it cannot be implemented.

Technical analysis is often used to facilitate these prioritization decisions. The proposed technical analysis framework attempts to *structure* the interaction of technical analysis and prioritization decision-making. Namely, the technical analysis framework addresses two issues underlying this interaction:

1. Prioritization consists of a continuous sequence of decisions regarding how to define projects and which projects to develop further. *Which of these prioritization decisions should the technical analysis facilitate?*
2. *How exactly should analysis results be used to facilitate decision making?*

The chapter focuses on the second of these two issues. It adopts the following approach for developing a framework which addresses these two issues.

The chapter begins by providing some background on Boston's conceptual framework for prioritizing transportation investments in Section 5.1. Then Section 5.2 discusses how TCM prioritization fits into this overarching planning framework. This background is relevant because the proposed technical analysis framework should work within Boston's existing planning structure and should capitalize on Boston's existing technical resources, according to the scope of this thesis.

After comparing Boston's current technical analysis activities to the insights found through the research, it became apparent that Boston is aware of many of the current issues surrounding TCM analysis. These issues are discussed in Section 5.3 of this chapter.

While Boston is aware of the many issues surrounding TCM analysis and prioritization, it should be noted that Boston's manner of dealing with these issues differs from the approaches adopted by the case study regions. One major contrast appears: Boston's approach is much less structured than the approaches adopted by the case study regions. In Boston's approach, clearly decisions are made and technical analysis is conducted; however Boston's process stops short of specifying exactly how technical analysis will be used to facilitate decisions. By drawing on the approaches found in the case studies, Section 5.4 recommends a methodology for better structuring the interaction of technical analysis with the (TCM) decision-making process in Boston. This prioritization methodology is the core component of the technical analysis framework suggested by this thesis.

In Sections 5.5 and 5.6, the proposed "Prioritization Methodology" is applied to two critical decisions of Boston's TCM prioritization process:

1. Which TCMs to consider for inclusion in the SIP. The methods used by the Clean Air Task Force are discussed, and
2. Which TCMs to include in the TIP. The 1996-1998 TIP prioritization process are discussed.

In the case of TIP and SIP processes, direct comparisons could be made to the approaches used by the case study regions, since the case studies focused on these processes. The comparative analysis conducted in these two sections identified which components of Boston's existing analysis activities could be used in the proposed "Prioritization Methodology." Conversely, the analysis identified how Boston would need to enhance its analysis activities in order to follow the proposed "Prioritization Methodology."

Thus Sections 5.1 though 5.6 are devoted to the main conclusion of this chapter: that Boston's approach is less structured relative to the case study regions and could be improved through the use of the recommended "Prioritization Methodology." Section 5.7 discusses a second conclusion of this chapter. There was one issue brought forth by both Boston and the other four case studies, which neither addressed fully: TCMs which reduce emissions greatly in the long-run must *change* travel behavior. A web of factors govern an individual's travel behavior. Considering this web of factors when prioritizing TCMs involves a high degree of coordination amongst transportation agencies, as well as other public agencies, developers, politicians, businesses, and private citizens. In order to facilitate this high level of coordination, the technical analysis could be used to streamline and tie the various prioritization decisions together. A method for doing this is formulated in Section 5.7.

Finally, Section 5.8 concludes the chapter with a summary of its main points.

5.1 BOSTON'S CONCEPTUAL FRAMEWORK FOR PRIORITIZING TRANSPORTATION INVESTMENTS

All transportation projects in the Boston region are prioritized through the process described by Figure 5-1. This is the structure of the Transportation Plan for the Boston Region. The Metropolitan Planning Organization (MPO)[67] intends for the Transportation

[67] The MPO represents 101 cities and towns in the Boston region. It consists of six state and regional signatory agencies: the Executive Office of Transportation and Construction (EOTC), the Massachusetts

Plan to eventually be a guide of projects that the MPO intends to construct, projects which are undergoing comprehensive evaluations, and those projects which are in early stages of the planning process. The Plan has not yet reached this degree of "clarity".[68]

The Transportation Plan's project selection framework, summarized by Figure 5-1, groups projects into six time and/or need specific categories: ongoing, current, level 1 (awaiting implementation), level 2 (short-term), level 3 (long-term), and level 4 (future projects). The following is a more detailed description of these six categories:

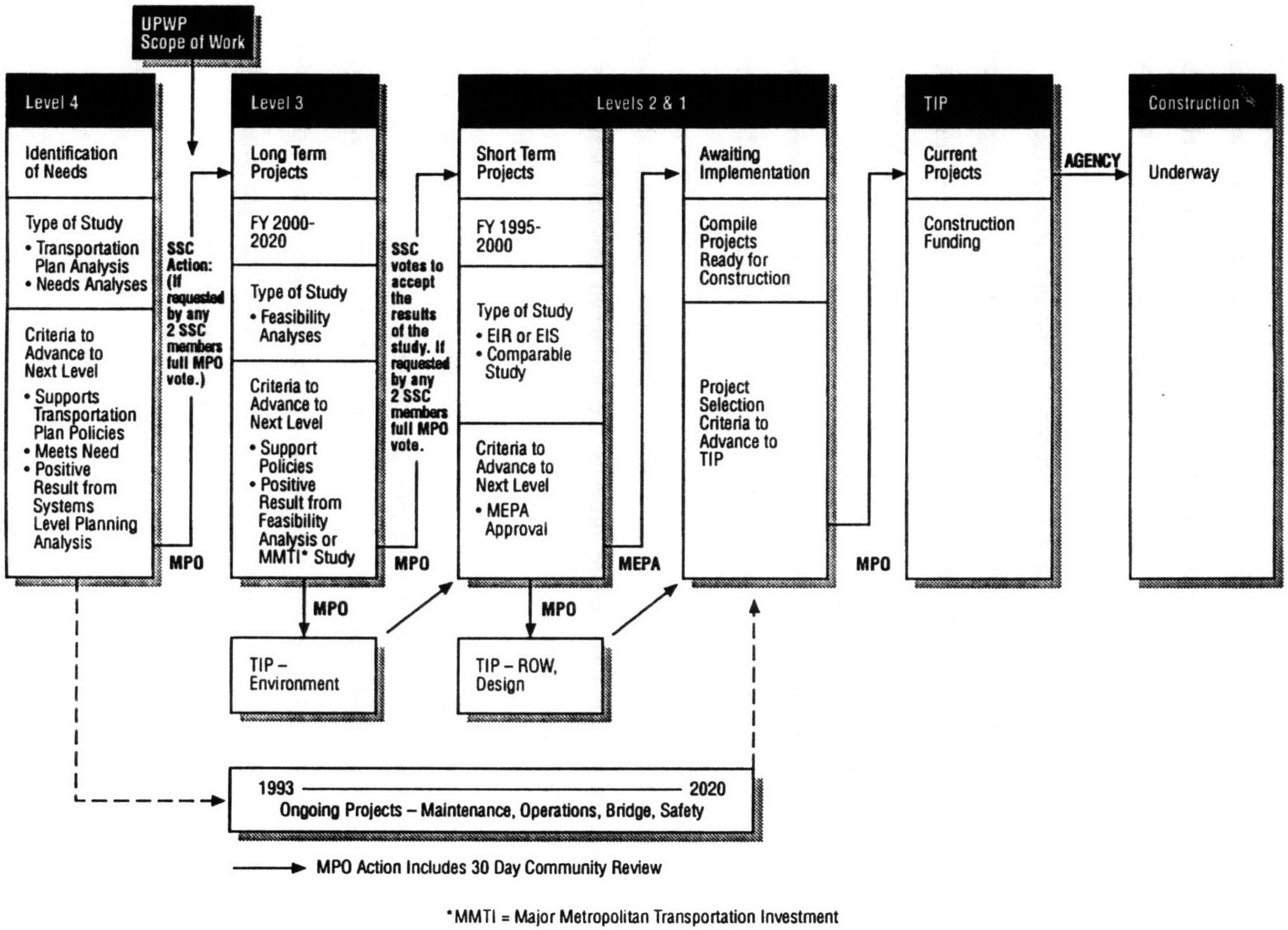
- **Ongoing:** This category spans all of the other time periods. It covers routine maintenance and infrastructure replacement and safety projects that occur on an ongoing basis.
- **Current:** This category covers non-maintenance projects that are under construction, and therefore are funded or at least partially funded (such as the Central Artery/ Third Harbor Tunnel).
- **Level 1, Awaiting Implementation:** This category covers projects that have Massachusetts Environmental Policy Act (MEPA) approval and are ready to be included in the TIP but are awaiting funding.

Highway Department (MHD), the Massachusetts Bay Transportation Authority (MBTA), the Metropolitan Area Planning Council (MAPC), the Advisory Board to the MBTA, and the Massachusetts Port Authority (Massport). The Joint Regional Transportation Committee (JRTC) is the advisory component of the MPO. Several other agencies who are involved in transportation, but are not members of the MPO, include the Massachusetts Turnpike Authority (MTA), the Massachusetts Aeronautics Commission (MAC), and the Metropolitan District Commission (MDC). The MPO's main goal is to carry out the transportation planning process first set out in the Federal Aid Highway Act of 1962, and subsequent amendments.

[68] Boston #1, p. 8-4.

Figure 5- 1 Project Selection Framework Presented in Boston's Transportation Plan

(Source: reproduction from Boston No. 1, p. 8-7, figure 8-1.)



- **Level 2, Short-term Projects (FY1996-FY2000):** This category includes projects that are undergoing detailed environmental, feasibility, and alternative analyses. Level 2 covers most SIP and ADA transportation commitments as identified by the Massachusetts Bay Transit Authority (MBTA), Massachusetts Highway Department (MHD), Massachusetts Turnpike Authority (MTA), and the Executive Office of Transportation and Construction (EOTC). It also includes the study of projects for which short-term implementation appears feasible and/ or desirable.
- **Level 3, Long-term Projects (FY2001-FY2020):** This category covers projects which appear desirable given current analyses but which need further analyses in the regional planning and modeling processes to determine if the benefits justify further expenditures in Level 2.
- **Level 4, Future Projects:** These projects are the result of transportation plan analysis or other systems level needs analysis and are nominated by local governments, MPO agencies, and other transportation agencies that serve the public. The MPO reviews projects in this list to determine if they are consistent with the goals and policies of the Transportation Plan before projects are advanced towards feasibility analysis and eventual implementation.[69]

The arrows in Figure 5-1 show how projects rise on the priority hierarchy through the various "levels" to eventually be incorporated into the TIP. In order to pass between levels, a project must satisfy certain screening criteria. These screening criteria address factual issues regarding how developed a project is, as well as more subjective issues regarding the costs and benefits of the project. In particular, the screening criteria which grant passage through the project selection hierarchy are as follows:

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[69] Boston #1, p. 8-3 to 8-4.

- *Screen between Level 4 and Level 3:*
  - Addresses identified need in the regional transportation network
  - General compliance with the goals and policies of the Transportation Plan and Sub-Signatory Committee of the MPO (SSC)[70] / MPO approval of the work scope /Unified Planning Work Program for feasibility study.
  - Positive result from system level planning analysis.

- *Screen Between Level 3 and Level 2:*
  - Contributes to an integrated transportation system consistent with financial feasibility.
  - Supports compact development.
  - Compatible with state energy and economic development plans.
  - Demonstrates compliance with Clean Air Act.
  - Complies with American with Disabilities Act.

- *Screen Between Level 2 and Level 1:*[71]
  - Completed environmental study and Massachusetts Environmental Policy Act (MEPA) approval.
  - Complete alternatives analysis.
  - Modeled as part of the regional transportation system and found in compliance with goals and policies of the Transportation Plan.
  - Consistent with state and regional development plan.
  - Financially feasible and cost effective.
  - Public support.
  - Notification to all communities.
  - Best project based on studies above to meet an identified deficiency.

- *Screen Between Level 1 and TIP:*[72]
  - Reasonable notification to all communities for public comment.
  - MPO approval to move to TIP.
  - Availability of funds for the defined three year period of the TIP.

Within these screening criteria lie the prioritization mechanisms of the project selection process. These mechanisms will be refined as the MPO continues to improve the TP.[73] In

[70] SSC - Designees of MPO members. They review and approve distribution of reports and other documents related to the Transportation Plan, Transportation Improvements Program (TIP), and Unified Planning Work Program.
[71] Boston #1, p. 8-5 and 8-16.
[72] Boston #1, p. 8-14.

their current form, these prioritization mechanisms are very vague. For example, a criterion in the screen between levels 4 and 3 requires that a project produce "positive results from the system-level planning analysis". The criterion does not make clear what would qualify as a "positive" result. Section 5.4 of this chapter defines a methodology for more clearly specifying these prioritization mechanisms.

5.2 BOSTON'S TCM PRIORITIZATION PROCESS

Section 5.1 discussed Boston's conceptual framework for prioritizing transportation investments. TCM prioritization is a subset of this framework. This section will briefly describe Boston's *TCM* prioritization process and how it interacts with the overall transportation prioritization framework.

TCM Prioritization is a continuous process which can be broken down into 3 "sieves" (The "3-sieve structure was suggested by the case studies and is pictured in Figure 4-1, explained in Section 4.7.1 and reprinted as Figure 5-2.) These three sieves are:

- Sieve #1: Analysis of TCMs for inclusion in the SIP
- Sieve #2: Project development process
- Sieve #3: TIP programming process

Sieve #1 is unique to TCMs. In other words, non-TCM projects do not pass through this sieve. This is because the SIP is the state's plan for attaining and maintaining regional air quality. It deals specifically with air quality and is only interested in transportation projects if they are/ or could be part of the state's plan for attaining and maintaining air quality.

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[73] Boston #1, p. 8-5.

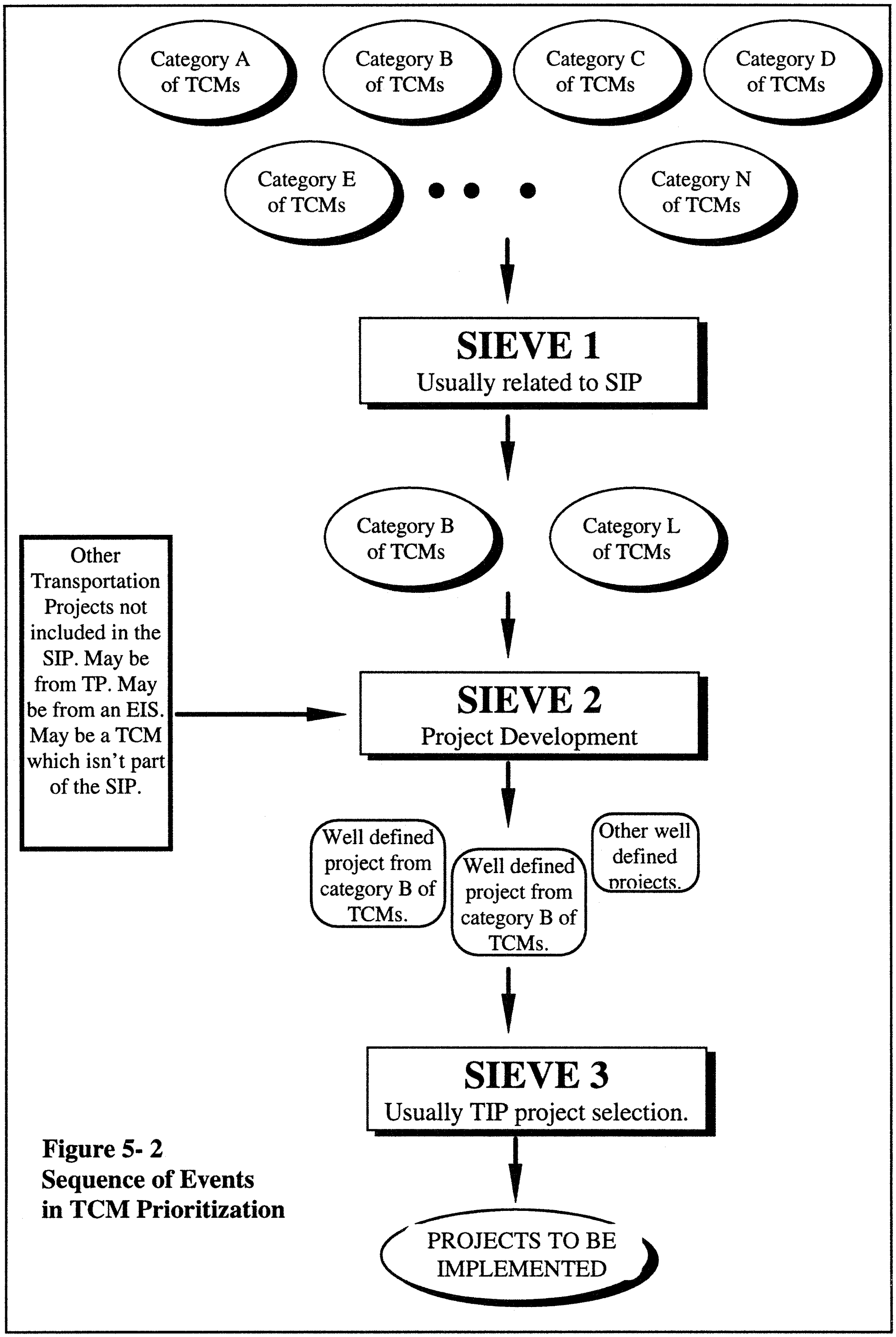

Figure 5- 2
Sequence of Events
in TCM Prioritization

Sieve #2 is synonymous to a portion of the transportation prioritization process pictured in Figure 5-1. In particular, Sieve #2 is equivalent to Levels 1, 2, 3, and 4 of Figure 5-1. However, TCMs do receive unique treatment within these four Levels. Namely, if a TCM is committed to in the SIP, it automatically receives Level 1 or Level 2 status.

Sieve #3 is also synonymous to a portion of the prioritization process pictured in Figure 5-1. Namely , Sieve #3 is equivalent to the screening process which links "Level 1" and the "TIP" level of Figure 5-1. TCMs do receive unique treatment within this screening process. In particular, if a TCM is a SIP commitment it receives funding priority; the availability of funding is a major screening criterion in Boston's existing Level 1 - TIP screening process.

5.3 POSITIVE CHARACTERISTICS OF BOSTON'S EXISTING TECHNICAL ANALYSIS PROCEEDINGS

The case studies and literature revealed many of the issues involved in effectively addressing TCM analysis. It was found that many of the issues and insights brought forth by the case studies and literature were accounted for in Boston's existing technical analysis activities. A list of these positive characteristics is presented by the next few subsections; the title of each subsection indicates what insight brought forth by the case studies is being discussed in the subsection. The body of the subsection discusses how the region addressed the insight.

5.3.1 The interaction of transportation and land-use is a major determinant of travel behavior, and therefore emission impacts

The region recognizes that "there is clearly a close relationship between transportation and land-use" and that it is not a simple one.[74] In an effort to address this issue, a land-use allocation model has been integrated with the region's transportation models. Now, not

[74] Boston No. 1, p. ES-3.

only can the impacts of population and employment on transportation be forecasted, but also the impacts of transportation on employment and population.[75]

5.3.2 *Air quality analysis is more accurate when conducted on a regional (or broader than regional) level as opposed to a local level*

The case studies and literature review revealed that it is preferred to conduct air quality planning on a regional, rather than local level. This is because pollutants, as well as the mobile sources of pollutants, usually traverse local boundaries. The Clean Air Task Force (which was appointed to develop a strategy to reduce the growth of vehicle trips and emissions in the Commonwealth in order to attain, and maintain, clean air) agreed that its task should be performed on a regional and statewide basis due to the nature of the air quality issue.[76] The Task Force includes representatives from several regional and state-level agencies. Also, the technical analysis conducted by the Task Force was regional in scale.

5.3.3 *Analyzing TCM packages enables the analysis to better identify synergies and induced impacts amongst projects*

The Task Force agreed that it is important to analyze packages of various measures, in addition to analyzing the effectiveness of individual measures.[77] This was an issue brought up by the San Francisco case study, the Washington DC case study, as well as by several TCM emission impact models which were reviewed in Chapter 3. Unfortunately, the case studies and literature review do not offer any conclusions regarding the most suitable way to analyze TCM packages.

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[75] Boston No. 1.
[76] Air Quality #1, p. 1.
[77] Air Quality #1, p. 1.

Although the Task Force identified the need to analyze TCM packages, it is not clear how exactly they went about performing the analysis. Nevertheless, the issue is reflected in its recommendations. For example:

- Recommendations are broken down into seven categories which could be considered to be "packages". The case studies broke measures down into similar categories and called each category a "package". The seven categories Boston used were:
    1. Cleaner vehicles and fuels;
    2. Improvements in the efficiency of existing highway capacity which encourage higher-occupancy vehicle use;
    3. Enhanced transit services and operations;
    4. Enhanced bicycle and pedestrian access programs;
    5. Employer ride-sharing requirements;
    6. Development strategies; and
    7. Market-based measures.

- The Task Force recommends "encouraging new development which is located near existing alternative transportation infrastructure, and which promotes the highest feasible average vehicle occupancy."[78] In other words, it is suggesting that land-use measures be coupled with transit measures, bike measures, pedestrian measures, or HOV measures.

- Also, one of the Task Force recommendations was to "incorporate performance measures... of transit service quality developed by the MBTA [Massachusetts Bay Transportation Authority] and other RTA's [Regional Transit Authorities], in the State Implementation Plan."[79] This recognizes that "if the transit goals prove consistently unattainable it could signal the need to reassess the entire package of mobile source strategies that rely on transit as the alternative model." In other words, it recognizes that if the transit element of the emission reduction program does not

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[78] Air Quality #1, p. 8.
[79] Air Quality #1, p. 6.

materialize, the effectiveness of the other strategies which were "packaged" with it will also be jeopardized.

5.3.4 Data availability limits the accuracy the analysis is able to achieve

This issue has implications on the best use of these analysis results. Professionals from Boston's Central Transportation Planning Staff and Metropolitan Area Planning Council have acknowledged the limitations of the region's data resources. Due to data limitations, the accuracy of analysis results is also limited. The region has chosen not to pursue highly quantitative scoring procedures at the TIP level in part because of this issue. This is not an atypical situation, although some MPO's have invested funds in improving data and analysis tools.

5.3.5 There is a range of methods available for quantifying the emissions and travel impacts of TCMs- certain methods can better analyze a given TCM than other methods can

The Central Transportation Planning Staff (CTPS) advised the Technical Advisory Committee to the Clean Air Task Force on the optimal use of regional modeling tools for the analysis of TCMs. The CTPS made clear that a range of methods exist and that certain methods could better analyze a given TCMs than others. Appendix N discusses these recommendations in detail; it describes the analysis possibilities for each TCM category.

Also, the CTPS enumerated several "guiding considerations" which practically parallel the conclusions drawn from the case studies and literature review. These considerations are reprinted below[80]:

- The larger or broader the anticipated TCM impact, the greater the rationale for using the regional model.

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[80] Document No. 7.

- The smaller or more localized the anticipated impact, the greater the rationale for using "back of the envelope" techniques or case study information from the literature.
- The more specifically an action can be defined, the easier it may be to analyze.
- If an action clearly affects a specific component of travel cost or travel time, use of the regional model might be appropriate.
- For many TCM's, case study information will be far more valuable than any original analysis.
- Many TCMs – transit, HOV, land-use based - are being analyzed now or will be analyzed soon in the context of other studies.
- There are several EPA (US Environmental Protection Agency), FHWA (Federal Highway Administration) and other reports – CTPS has several of them – containing suggested non-model based quantitative analysis approaches.
- The impacts of many TCM's simply cannot be credibly quantified.

Thus, Boston is clearly aware of many of the issues surrounding TCM analysis brought forth by the research. However, it should be noted that Boston's manner of dealing with these issues differs from the approaches found in the case studies. Namely, Boston's approach is less structured, or systematic. By drawing on the case studies, the next section (5.4) recommends a methodology for systematizing the use of technical analysis for prioritizing TCMs.

5.4 RECOMMENDED PRIORITIZATION METHODOLOGY

This section recommends a methodology for better structuring the interaction of technical analysis with the (TCM) decision-making process in Boston. These recommended improvements do not guarantee a better TCM program, however. They are merely tools for making more informed decisions.

According to the literature, quantification methods and prioritization methods are often best used as "learning tools", given their limited accuracy and precision. Thus, much of the benefit of conducting technical analysis lies in the insights gained while conducting the analysis, rather than in the actual results. (Though the results are not worthless, of course.) The recommended methodology thus does not focus on the results, but on the method used to produce the results. In other words, it does not provide a "plug-and-chug formula" for producing a relative ranking of TCMs. Rather it specifies a sequence of tasks which would lead to a relative ranking of projects, possible ways for performing these tasks, and the issues to consider when selecting an approach for performing these tasks.

This methodology follows directly from the conclusions of Chapters 3 and 4. These conclusions are summarized in sections 3.4 and 4.8; they are not reprinted here. However, four conclusions at the heart of the proposed methodology are summarized below:

1. Project selection processes focused on by the case studies often ranked projects in "cycles"; they begin by ranking projects roughly so as to reduce the number of potential projects. Once the potential list of projects has been reduced to a point at which more detailed analysis of all the remaining projects is a feasible endeavor (i.e. would not consume too much money and time) projects may be ranked more precisely.
2. Some regions found it beneficial to use systematic ranking schemes.
3. A systematic ranking scheme need not be highly quantitative.
4. The general components of a systematic ranking scheme were identified as follows:

Based on the examples found in the case studies, it may be concluded that developing a systematic ranking process generally involves the following components:

INPUTS:

- ***Criteria*** **-** Choose the criteria upon which project ranking will be based.
- ***Measures and Standards*** **-** Determine measures and standards which will be used to determine if a project complies to the above criteria.
- ***Calculations*** **-** Determine the value (qualitatively or quantitatively) of these measures and standards.
- ***Weight Criteria*** **-** Determine the relative importance of the above criteria.

"PROCESSOR":

- Choose a ranking process such as screening; screening and scoring; or some other method. The ranking process should specify what characteristics a project must have in order to obtain a particular rank. For example, the ranking process could specify that projects which meet all of the screening criteria are ranked as "high priority," and that all other projects are ranked as "low priority." Or, a ranking process could specify that projects with scores between 0 and 30 are ranked as "low priority," projects with scores between 30 and 70 are ranked as "medium priority," and projects with scores between 70 and 100 are ranked as "high priority."

OUTPUT:

- The output of a highly systematic ranking process not only indicates what a project's rank is, but why it was ranked that way. For example, if a project was ranked as "low priority" because its score was very low, this explanation should be available somewhere in the documentation.

The components listed above are not unique to systematic ranking schemes - any ranking scheme must contain the above inputs, outputs, and "processor." What distinguishes a systematic approach from a non-systematic one, is how explicitly and specifically the above components are defined. The proposed "Prioritization Methodology" therefore attempts to specify a sequence of tasks which, if followed and documented, would produce a ranking of TCMs in a systematic manner. This sequence of tasks is summarized below.

Proposed Prioritization Methodology

In order to structure the use of technical analysis in making a particular decision, a series of five questions could be answered. When applied to a particular decision and set of TCMs, this series of questions results in a prioritized list of TCMs. The five questions are:

1. Which criteria to consider?
2. Which measures best indicate a project's ability to meet these criteria?
3. What analysis method should be used to estimate the value of these measures?
4. What is the relative weight or importance of the criteria identified in Question #1?
5. Which method(s) could develop the "best"[81] relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

Chapter 4 describes how the case study regions chose to answer these five questions. In addition, Chapter 3 describes, in detail, the range of answers to question #3. Both Chapters 3 and 4 identify the factors which govern how to "best"[82] answer each of the five questions listed above.

The next two sections (5.5 and 5.6) apply the proposed "Prioritization Methodology" to two critical decisions of the TCM prioritization process.

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[81] Chapter 1 defined the "best" method as the method which (1) maximized the accuracy of the final prioritized list, (2) was the most inexpensive, and (3) was sufficiently precise.
[82] Same as above.

5.5 APPLYING THE PROPOSED PRIORITIZATION METHODOLOGY TO BOSTON'S SIP PROCESS

5.5.1 Background

The State Implementation Plan (SIP) documents the state's plans for attaining and maintaining air quality goals. It deals with all sources of air pollution, not just mobile transportation sources. However, because mobile transportation sources contribute significantly to the region's air quality problem, strategies for minimizing emissions from these sources are included in the SIP. The Clean Air Act Amendments encourage regions to consider the ability of TCMs to reduce emissions.[83]

Massachusetts has considered the ability of various TCMs to reduce regional emissions. The most recent[84] attempt to analyze TCM strategies, and the one which is discussed in this section, was conducted by the Clean Air Task Force for Transportation. The Secretary of Environmental Affairs and the Secretary of Transportation and Construction appointed the Task Force in January, 1993, to develop a strategy to reduce the growth of vehicle trips and emissions in the Commonwealth of Massachusetts in order to attain, and maintain clean air. This strategy was intended to contribute to the Commonwealth's overall State Implementation Plan for achieving clean air.

The Task Force considered seven categories of TCMs:

- Improved Efficiency for Existing Highway Capacity
- Improved Transit Service and Operations
- Bicycle and Pedestrian Measures
- Employer-based Actions to Increase Vehicle Occupancy
- Parking Controls and/or Fees
- Land-use Controls and/or Indirect Source Permitting
- Market Based Fees and Other Programs

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[83] Appendix P describes the requirements the Clean Air Act places on non-attainment regions.
[84] As of 1994.

Based on a set of selection criteria, the results of previous analysis efforts, and with the aid of a Technical Advisory Group, the Clean Air Task Force reduced this broad list of potential TCMs to a set of recommended strategies for achieving air quality goals in Massachusetts.[85]

The next few subsections will compare the methodology used by the Clean Air Task Force, to the "Prioritization Methodology" which was derived from the case studies and summarized in Section 5.4. The "Prioritization Methodology" consisted of five questions. Each question will be discussed in a separate subsection. Each subsection will describe

- which elements of the Task Force's methodology could be used to implement the proposed "Prioritization Methodology," and
- what additional analysis is needed in order to implement the proposed methodology.

5.5.2 *Question #1: Which criteria to consider?*

The Clean Air Task Force attempted to select TCMs which:

1. Offer the largest reductions for the air pollutants of greatest concern (volatile organic compounds and nitrogen oxides),
2. Have the lowest marginal cost of control ($/ ton of emission reduction),
3. Cost the least to Massachusetts' economy overall,
4. Cost the least to administer, to implement, and to monitor,
5. Spread the cost burden equitably,
6. Have the broadest regional applicability to prevent competitive disadvantages for Massachusetts businesses,
7. Can accommodate reasonable economic growth within the region in an environmentally sound manner,
8. Rationalize pricing and/or provide incentives to use markets wherever possible to ensure successful implementation of TDM measures. Encourage businesses to

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[85] Air Quality #1, p. 1-3.

develop least-cost methods on site for activities which support state efforts to achieve Clean Air Act requirements,

9. Avoid measures that increase or relocate emissions and congestion rather than reduce them.[86]

These were the "criteria" the Task Force based their recommendations on. As can be seen from the above list of criteria, the Task Force based their recommendations on much more than air quality; most case study regions also based their prioritization process on a broad set of criteria, although not all case studies used the same set of criteria as each other.

Also, it should be noted that the Task Force's criteria did not explicitly refer to some common benefits of transportation projects such as mobility, accessibility, maintenance, and improved safety. These are important benefits to consider because their is an opportunity cost to any transportation investment; in light of limited funding, money committed to TCMs cannot be spent on other transportation projects, so it is important to choose TCMs which have as much total benefit to the transportation system as possible, not just air quality benefit.

In conclusion, the Task Force answered the first question of the Prioritization Methodology, and documented its answer.

5.5.3 Question #2: Which measures best indicate a project's ability to meet these criteria?

It is not clear how the Clean Air Task Force measured compliance to the criteria just discussed. Sometimes criteria imply how to measure compliance with them, but the exact definition is not clear. Other criteria provide no indication of how compliance with them should be measured. The next few paragraphs describe the measures specified or implied for each of the criteria.

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[86] Air Quality #1, p. 4-5.

Criterion #1: Largest reduction of Air Pollutants

The Task Force presented some analysis on the strategies which were eventually chosen. This analysis consisted of the following measures:

- 1996 VOCs in kgs/ day,
- 1999 VOCs in kgs/ day, and
- 1999 NOx in kgs/ day.

All case study regions used this same basic measure of air quality benefit: "amount of pollutant reduced per day by a given TCM." However, there were distinctions amongst the case studies. For example, they did not all calculate the measure for the years 1996 and 1999; not all regions used the units of kilograms - some used pounds or tons. Also, some subtleties of the measures can only be uncovered by delving into how they were calculated. Chapter 3 provides an in depth discussion of the basic methodology used to estimate the "amount of pollutant reduced per day by a given TCM", and the various methods available for doing so.

Criterion #2: Lowest Marginal Cost

A measure of the second criteria was specified: "$/ ton of emission reduction". This was the measure all case study regions used to quantify "cost-effectiveness" (other regions did not call it "marginal cost.") As discussed in Chapter 4, most regions use this same measure name ("$ per ton of emissions reduced"), but the exact definition varies amongst regions. To begin with, the costs which make up the "$" part of the measure, varies amongst regions. Some regions include only capital costs, while others include operations and maintenance costs as well.

Criteria #3 and #6:

These two criteria are very broad. No measure was mentioned or implied. Also, no examples of how to measure these criteria were provided by the case studies.

Criterion #4: Cost the Least to Administer, to Implement, and to Monitor

The measure of compliance with this criteria seems obvious enough; it would most likely be the sum of a TCM's estimated administration, implementation, and monitoring costs. However, the Task Force never specifies how these costs will be calculated; a variety of approaches to calculating these costs exist, each one with its own set of implications. For example, would the administration/ implementation/ monitoring cost of an HOV lane include the cost of policing the lane.

Criterion #5: Spread the Cost Burden Equitably

This criteria seems amenable to quantification, i.e. quantitative measures of compliance could be used.. However, neither a quantitative or more qualitative measure is specified.

Criteria #7, #8, and #9:

The Task Force did not discuss how to measure compliance with these three criteria.

In conclusion, the Task Force did not fully answer the second question of the proposed "Prioritization Methodology," and its answer was not clearly documented.

5.5.4 Question #3: What analysis methods should be used to estimate the value of these measures?

The Technical Advisory Group to the Clean Air Task Force had access to a range of methods for quantifying the emission and travel impacts of TCMs. These methods are summarized in Appendix N. Appendix N contains a memo written from the Central Transportation Planning Staff[87] to the Technical Advisory Group describing the range of methods available to the Technical Advisory Group for analysis of TCMs. The memo breaks the available methods into three groups:

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[87] The Central Transportation Planning Staff provides technical and policy analysis support to the Boston MPO. CTPS provides regional modeling and forecasting studies, air quality analysis and various other technical assistance.

- regional model based,
- partial regional model based, and
- non-regional model based.

The memo made the Technical Advisory Group aware of many of the issues brought forth by Chapters 3 and 4 regarding how to choose the "best" [88] quantification method for a given application. The issues the memo identified have already been listed in Section 5.3.6. In addition to these issues, the Task Force recognized the value of analyzing TCM packages in its Final Report. However, it never documented (or perhaps it never developed) a methodology for quantifying the impacts of TCM packages.

Although the memo made the Technical Advisory Group Aware of the range of methods available and indicated the issues which determine the "best" method for a given application, it is unclear from the documentation[89] which methods the Advisory group eventually chose. Furthermore, since measures were specified only vaguely , if at all, it is hard to say what type of quantitative analysis tool would "best" estimate the value of the measures. Chapter 3 outlined the factors which govern which method is "best" for a given application. Figure 3-3 summarizes that discussion.

The main conclusions drawn from comparing the Task Force's analysis approach (to estimating TCM impacts) and the approaches found in the case studies are as follows:

- The Technical Advisory Group to the Clean Air Task Force was aware of many of the issues brought forth by the case studies and literature review of quantification methods.
- It is not clear if the Task Force analyzed TCM packages, even though they acknowledged their merit. While not all case study regions managed to develop

[88] In chapter 1 the "best" method was defined as the method which would (1) maximize the accuracy of the prioritized list, (2) be as inexpensive as possible, and (3) produce sufficiently precise results.
[89] The analysis in this section is based on the Final Report of the Clean Air Task Force. The researchers were unable to contact members of the Technical Advisory Group to the Task Force to clarify if, how, and

a methodology for analyzing TCM package, they recognized the importance of this issue.

- Because the Task Force specified measures of compliance only vaguely, it is unclear what type of quantification method would "best" estimate the values of these measures.

In conclusion, the Task Force's Final Report does not make it clear how the Task Force chose to answer the third question of the "Prioritization Methodology."

5.5.5 Question #4: What is the relative weight or relative importance of the criteria identified in Question #1?

The Task Force did not weight competing criteria in a systematic manner. This differs from the approaches found in the case studies which were, in general, more systematic than that of the Massachusetts Task Force. As defined in this thesis a "systematic" method provide some guidelines for determining how important one criteria is relative to another criteria and would document these relative weights. It is useful to systematize this process because it encourages all projects to be analyzed in a comparable manner. Analyzing projects in a comparable manner is important if the analysis is to be used for ranking projects relative to one another.

Some of the Task Force's criteria clearly conflict with each other, so the Task Force must have used some means of weighting their importance before developing their recommendations. For instance, the first and third criteria clearly conflict. They were:

- Offer the largest reductions for the air pollutants of greatest concern (volatile organic compounds and nitrogen oxides), and
- Have the lowest marginal cost of control ($/ ton of emission reduction).

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which quantification methods were used to analyze potential TCMs. The Final Report does not make this clear.

TCMs which offer the largest emission reductions, do not necessarily have the lowest marginal cost (when the only benefit considered is air quality as is typically done). For example, "area-wide ridesharing" and "signal-timing" have one of the strongest abilities to reduce hydrocarbon emissions, but they are not amongst the most cost-effective measures.[90]

5.5.6 Question #5: Which method(s) could develop the "best"[91] relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

While the final recommendations presented by the Task Force are very logical and well presented, it is unclear how or why these recommendations were better than any other possible recommendations. In other words, it is unclear how all the potential TCMs identified at the beginning of the process were ranked. Some case study regions used a relatively systematic method for ranking TCMs. In these case studies, the ranking scheme was generally based on the results of questions 1 through 4. These regions used one or both of two methods to systematize the relative ranking of TCMs: scoring and screening. Chapter 4 discusses these findings in detail.

Unfortunately, the thesis cannot suggest even a hypothetical scoring and/or screening methodology given the analysis contained in the Task Force's Final Report. Some key pieces of information which are unavailable or nonexistent include:

- more exact definitions of the meaning of certain criteria and what constitutes compliance with these criteria,
- which TCM impacts were estimated, how accurate these estimates are, and how precise, and

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[90] Document No. 8, p. i and ii. (A report by Apogee Research entitled "Costs and Effectiveness of Transportation Control Measures.") The "averages" produced by this report are discussed in section 2.6 of this thesis.

[91] Chapter 1 defined the "best" method as the method which (1) maximized the accuracy of the final prioritized list, (2) was the most inexpensive, and (3) was sufficiently precise.

- how important a given criterion is relative to each of the other criteria (i.e. criterion weights).

5.5.7 Summary of Conclusions and Recommendations Regarding Boston's SIP Process

Although prioritization did obviously occur during the process conducted by the Task Force, the basis for prioritization is not clear. The past few subsections (5.5.2 through 5.5.6) compared the process conducted by the Task Force to the "Prioritization Methodology" which was developed based on the case studies (presented in Section 5.4.) This comparison produced the following conclusions:

- QUESTION #1: The Clean Air Task Force based their recommendations on much more than air quality, just as all the other case study regions did. However, they did not consider some common benefits of transportation projects such as mobility, accessibility, maintenance, and improved safety. These are important benefits to consider because their is an opportunity cost to any transportation investment; in light of limited funding, money committed to TCMs cannot be spent on other transportation projects, so it is important to choose TCMs which have as much total benefit to the transportation system as possible, not just air quality benefit.

- QUESTION #2: It is not clear how the Clean Air Task Force measured compliance to the criteria. Sometimes criteria imply how to measure compliance with them, but the exact definition is not clear. Other criteria provide no indication of how compliance with them should be measured.

- QUESTION #3: The main conclusions drawn from comparing the Task Force's analysis approach (to estimating TCM impacts) and the approaches found in the case studies are as follows:

- The Technical Advisory Group to the Clean Air Task Force was aware of many of the issues brought forth by the case studies and review of quantification methods.
- It is not clear if the Task Force analyzed TCM packages, even though they acknowledged their merit. While not all case study regions managed to develop a methodology for analyzing TCM package, they all recognized the importance of this issue.
- Because the Task Force specified measures of compliance only vaguely, it is unclear what type of quantification method would "best" estimate the values of these measures.

- QUESTION #4: The Task Force did not weight competing criteria in a systematic manner. This contrasts the approaches found in the case studies which were, in general, more systematic than the Task Force's.

- QUESTION #5: While the final recommendations presented by the Task Force are very logical and well presented, it is unclear how or why these recommendations were better than any other possible recommendations. The Task Force did not use a systematic ranking scheme, unlike some case study regions which used scoring and/or screening to rank projects systematically. Unfortunately, the thesis cannot suggest even a hypothetical scoring and/or screening methodology given the analysis contained in the Task Force's Final Report. Some key pieces of information which are unavailable or nonexistent include:
  - more exact definitions of the meaning of certain criteria and what constitutes compliance with these criteria,
  - which TCM impacts were estimated, how accurate these estimates are, and how precise, and
  - how important a given criterion is relative to each of the other criteria (i.e. criterion weights).

Thus, there are some elements of the Task Force's existing methodology which could be used to conduct the "Prioritization Methodology" proposed in Section 5.4. However, as a whole, the Task Force did not approach its task in the manner the "Prioritization Methodology" encourages. In order to use the "Prioritization Methodology," the Task Force would have to enhance its existing methodology as was discussed in the previous paragraph. Also, it would have to approach its task in a more systematic and explicit manner.

5.6 APPLYING THE PROPOSED PRIORITIZATION METHODOLOGY TO BOSTON'S TIP PROCESS

This section will briefly describe the process Boston used to prioritize projects for their 1996-1998 TIP. It then describes Boston's past and current efforts to revise their TIP prioritization process. Five subsections (5.6.1 through 5.6.5) follow this discussion; each subsection describes how Boston *currently* addresses a step of the 5-step "Prioritization Methodology" which was presented in Section 5.4. The last subsection (5.6.6) draws some conclusions.

In order to be included in the TIP, projects follow the following general process:

- The 101 cities and towns in the region submit project proposals to Boston's Metropolitan Area Planning Council (MAPC).
- The MAPC weeds out proposals that cannot be implemented within the next three years. This usually means that many details such as right-of-way must be sorted out in order for a project to be accepted. These projects are collected into a draft TIP.
- The Metropolitan Planning Organization (MPO), with the aid of the Central Transportation Planning Staff (CTPS), financially constrains this draft TIP and sends out the revised TIP for public review. A sample of the financial constraints governing the 1996-1998 TIP are provided in Appendix L.

- Public review entails publishing the TIP in the paper and receiving/responding to comments sent in by interested parties.
- The TIP then is reexamined by the MPO until it meets their approval. A final TIP is made.
- Any amendments to this TIP must also undergo public review.[92]

No systematic scoring, ranking, or prioritization process was used to generate the 1996-1998 Boston TIP. However, the 1996-1998 TIP process did employ some prioritization mechanisms. For example, SIP projects were required to receive funding. This does not necessarily mean that they would be the first projects to be implemented, however. More detail on the sequence of events leading to a projects inclusion in the TIP and forms used in the process are provided in Appendix M.

Much thought has been given to revising the current TIP programming process. TIP prioritization studies can be summarized by three statements: (1) the available data and analysis cannot support a highly quantitative prioritization scheme; (2) a statewide prioritization process is difficult to devise because regions within the state have differing priorities; and (3) currently, a qualitative prioritization scheme is being tested by Boston's Metropolitan Area Planning Council. This newest attempt prioritizes projects based on their consistency with regional growth policy, and based on their safety, maintenance, or mobility benefits.

5.6.1 Question #1: Which criteria to consider?

In order to pass from level 1 status (of the project selection framework pictured in Figure 5-1) into the TIP, a project must meet 5 criteria:

- Reasonable notification to all communities for public comment.
- MPO approval to move to TIP.
- Availability of funds for the defined three year period of the TIP.

[92] Boston Interview No. 1.

- In order to be programmed for implementation, a project must be construction-ready.
- If a project is a SIP, EIS, some other type of legislative commitment, or a project which has been given top priority (e.g. projects part of the CA/T) - then it receives priority in the TIP programming process by being guaranteed funding.

These criteria contrast the range of criteria considered by most case study regions. Most other case study regions considered the above criteria, in addition to criteria which more directly reflect a project's benefits. For example, Dallas/ Fort Worth used the following set of criteria to select projects to receive Congestion Management/ Air Quality Funds:

1. Current Cost Effectiveness
2. Local Cost Participation
3. Air Quality/ Energy Conservation
4. Congestion Management Plan/ Transportation Control Measures
5. Intermodal/ Multimodal/ Social Mobility

San Francisco's TIP scoring scheme contains an especially broad range of criteria - too broad to list here. (See Appendix S for details.)

In conclusion, the Boston MPO (who leads the TIP programming process) answered the first question of the proposed "Prioritization Methodology," and documented its answer.

5.6.2 Question #2: Which measures best indicates a project's ability to meet these criteria?

All of Boston's TIP criteria listed above are also the measures of the criteria. Conformity to them is indicated by a "yes/no" answer. The TIP specifies under what conditions a "yes" will be granted. For example, in the case of the first criterion, what constitutes "reasonable notification" has been defined. Likewise, what constitutes "MPO approval" and "construction-ready" have also been defined. Thus, Boston answered the second question of the proposed "Prioritization Methodology."

5.6.3 Question #3: What analysis methods should be used to estimate the value of these measures?

This does not apply to the particular set of criteria Boston uses in its TIP prioritization process since none of the criteria (or criterion measures) are based directly on impact estimates. Thus, no analysis of impacts is necessary to conduct the TIP prioritization process (although much analysis was required for the processes which proceeded it.)

5.6.4 Question #4: What is the relative weight or relative importance of the criteria identified in Question #1?

The criteria in Boston's TIP prioritization process are not "competing" criteria. They are all equally important, and a project must conform to all of them in order to be programmed into the TIP. Thus, Boston answered the fourth question of the proposed "Prioritization Methodology."

5.6.5 Question #5: Which method(s) could develop the "best" relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

Projects may receive one of two rankings in Boston's current TIP process:

1. Include the project in the TIP, or
2. Do not include the project in the TIP.

A screening process consisting of all the criteria listed in "Question #1," is used to determine which ranking a project receives. The financial demands of the projects which pass the screen generally do not exceed the funding available; therefore, all of the projects which pass the screen can be assigned a funding source and included in the TIP. So long as this remains true, a more precise ranking of projects is not necessary.

However, some planners in the Boston region are worried about the financial demands being imposed by the Central Artery/ Tunnel project; namely they are worried that the project's cost will exceed its initially forecasted value. If this happens, then the financial demands of the projects passing the existing screening process, may exceed the available funding. In order to decide which projects should receive funding first and be included in the TIP a more *precise* ranking scheme would need to be used. Some planners in Boston's Metropolitan Area Planning Council (MAPC) have been experimenting with alternative TIP prioritization processes. For example, a highly quantitative scoring scheme was developed but then rejected because its data and analysis needs could not be met by existing resources. A more qualitative, policy-based scheme is currently being tested. All of the schemes being experimented with would offer a higher degree of precision than the existing one.

In conclusion, the Boston MPO answered the fifth question of the proposed "Prioritization Methodology."

5.6.6 Conclusions

Boston's existing TIP process conducts all of the five-steps outlined by the proposed "Prioritization Methodology." The main contrast between Boston' approach and those found in other case study regions, is that Boston selected projects based on a much more limited set of criteria. Most other regions included criteria related directly to a project's benefits, while Boston did not. For example, Boston did not directly consider benefits such as mobility, accessibility, safety, or maintenance when prioritizing project proposals.

It is unclear, however, if Boston should follow the lead of these other regions, and revise its process to include a broader range of criteria. It is unclear because in Boston most prioritization decisions are made pre-TIP; the projects which are proposed for inclusion in the TIP generally match the available funding which implies one of two things:

- either that some major "prioritization" occurs prior to TIP programming decisions, or

- that it is so clear which (types of) projects the TIP programming process will prioritize, that sponsoring agencies[93] do not find it worthwhile to invest time in developing alternative or additional project proposals.

Including a broader range of criteria will be of no use if project proposals continue to match the available funding.

However, some of Boston's transportation planners believe that developing a broader range of criteria, and ensuring project sponsors that projects meeting these criteria would receive a fair chance of receiving funding - might provide sufficient motivation for project sponsors to develop a broader set of project proposals. This is one issue which stimulated recent attempts to restructure Boston's TIP prioritization process. The main benefit of stimulating a more competitive TIP prioritization process is that the quality of project proposals might increase. A higher "quality" set of projects would be more cost-effective (i.e. cost-effective in the sense that the new set of projects would fulfill more of the region's transportation needs for the same cost of a lower "quality" set of projects.)

Another major stimulus for revising Boston's existing TIP structure is related to the Central Artery/ Tunnel project. As described in the previous section (5.6.5) if the CA/ T exceeds its expected budget, then a more precise ranking scheme will be needed in order to decide which projects are most worth funding.

Another major conclusion regards the treatment of SIP TCM commitments in the TIP ranking scheme. In the current TIP ranking scheme, TCMs are given priority if they are included in the SIP. However, as noted in Chapter 3, a TCM's effectiveness is dependent largely on how the transportation system, as a whole, is developed. Thus, if limited funding results in a transportation program different than the one assumed when the SIP commitments were originally made, the value and effectiveness of these SIP commitments should be re-assessed. Perhaps in the context of the new transportation program another

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[93] Every project proposed for inclusion in the TIP is proposed by a *sponsoring agency*.

set of TCMs would be more effective than the ones originally committed to. The next Section (5.7) is related to this issue.

5.7 SECONDARY CONCLUSION: TYING THE PRIORITIZATION PROCESS TOGETHER

There was one issue brought forth by both Boston and the other four case studies, which neither addressed fully: TCMs which reduce emissions greatly in the long-run must *change* travel behavior. A web of factors govern an individual's travel behavior. Considering this web of factors when prioritizing TCMs involves a high degree of coordination amongst transportation agencies, as well as other public agencies, developers, politicians, businesses, and private citizens.

For example, in addition to selecting TCMs, transportation agencies need to coordinate such factors as:

- *Which other transportation projects are also implemented.* This is important because choosing a travel mode is based on the relative level of utility offered by the available modes.
- *When the TCM is implemented relative to these other projects.* This is important because once individuals structure their lives around a certain travel pattern, the benefits of restructuring their lives and travel patterns do not only need to be greater than the benefits of their current status, but they also need to outweigh the inconvenience of "restructuring" (e.g. moving costs, stress, time consumption.) Thus, implementing a TCM sooner, rather than later, may reduce the magnitude of TCM investment needed to effect a given change in travel patterns.

In order to facilitate this high level of coordination amongst the various agencies and parties, the technical analysis framework could be used to streamline and tie the various prioritization decisions together.

Unfortunately, the case studies did not explore this issue, since it only became apparent after they were conducted. The following discussion suggests a means for addressing this issue in Boston which is based on the information which was gathered.

A Proposed Method For Tying the 3 Sieves (SIP, project development, TIP) Together

Boston's existing TCM prioritization structure has "weak links." Extensive analysis of TCMs is conducted at the SIP stage. Much of the analysis focuses on identifying TCMs with large air quality potential; a lot of thought is invested in defining an effective strategy. However, this is often the only point in the prioritization process at which the unique needs of air quality projects are considered in detail or at all. In prioritization stages following the SIP stage, SIP commitments generally receive priority simply because they are "SIP commitments".

One method for ensuring that the extensive air quality analysis conducted at the SIP level is carried through into subsequent planning processes revolves around the use of performance measures and standards to "manage" air quality concerns. The SIP could become the basis of an air quality "management system" in the following manner.

Extensive analysis of regional air quality is conducted at the SIP level. While not many TCMs are included in the SIP, many are analyzed. The SIP analysis is used to identify which TCMs have the greatest potential to improve air quality; but, the analysis could also be maneuvered to *reveal under what conditions* various TCMs have the potential to reduce air pollution. This information could be the basis for *performance measures and standards* used to guide the "Project Development" and "TIP Programming" phases of prioritization.

Massachusetts' Clean Air Task Force alluded to this concept and specified three means of achieving it in its recommendations.

1. It suggested incorporating performance measures of transit service quality in the State Implementation Plan.
2. With regard to the Commonwealth's existing employer ride-sharing program, the Task Force identified the need for a "fairer, performance-based standard for measuring success."
3. Also, "some members recommended that the Commonwealth streamline and strengthen existing air quality reviews of new development, providing clearer, more effective standards and incentives that result in better location decisions and reduced trips generated by new development."

All three recommendations regard developing performance measures and/or standards to monitor and guide the implementation of various SIP commitments.

5.8 SUMMARY OF CONCLUSIONS DRAWN IN CHAPTER 5

The objective of this chapter was to draw upon the case studies (i.e. Chapter 4) and the review of quantification methods (i.e. Chapter 3) in order to develop a technical analysis framework for the Boston region which specified the interaction of technical analysis with the TCM prioritization decision-making process. In particular, the framework was to address two issues underlying the interaction:

1. *Which prioritization decisions should the technical analysis facilitate?* (The TCM prioritization process consists of a continuous sequence of decisions regarding how to define projects and which projects to develop further.)
2. *How exactly should analysis results be used to facilitate decision making?*

The next two subsections (5.8.1 and 5.8.2) describe the conclusions drawn in regard to these two issues. Subsection 5.8.3 summarizes some general conclusions regarding Boston's TCM analysis methods.

5.8.1 *"How exactly should analysis results be used to facilitate decision making?"*

The thesis focuses on the second issue discussed above partly because the research mainly addressed the second issue. As a result, this was the focus of the proposed technical analysis framework and the conclusions. The main component of the proposed technical analysis framework was the "Prioritization Methodology" developed in Section 5.4 of this chapter. This prioritization methodology specifies "how exactly analysis results should be used to facilitate decision-making."

One underlying theory of the proposed "Prioritization Methodology" is that the insights gained by applying the methodology are just as valuable to the decision-making process than the actual results of the methodology. The results are relevant to the decision-making process, but only when considered within the context of the methodology used to produce them.

A second underlying theory of the proposed "Prioritization Methodology" is that systematizing the interaction of technical analysis and decision-making is beneficial. A systematic approach is desirable because it helps ensure that all projects are analyzed and considered for priority in an equitable manner (equitable in the sense that all projects are treated in the same manner and have the same opportunity to receive priority status.)

This "Prioritization Methodology" was based on the examples found in the case studies, which focused on TIP and SIP related processes. However, the proposed prioritization methodology is very general and could easily be applied to processes not related to the TIP and SIP. In order to demonstrate the implications of this "Prioritization Methodology" on Boston's current TCM prioritization process, it was applied to 2 critical decisions in Boston's current TCM prioritization process:

1. Which TCMs to consider for inclusion in the SIP. The methods used by the Clean Air Task Force was discussed in Section 5.5.

2. Which TCMs to include in the TIP. The 1996-1998 TIP prioritization process was discussed in Section 5.6.

The conclusions drawn from these 2 comparisons were summarized in Table 5-1 and by Sections 5.8.1.1 and 5.8.1.2.

5.8.1.1 Conclusions Regarding Boston's SIP Process

Although prioritization did obviously occur during the process conducted by the Task Force, the basis for prioritization is not always consistent with what is proposed by this thesis as an idealized method for setting priorities. Sections 5.5.1 through 5.5.5 compared the process conducted by the Task Force to the Prioritization Methodology which was developed based on the case studies (presented in Section 5.4). This comparison produced the following conclusions:

- QUESTION #1: The Clean Air Task Force based their recommendations on much more than air quality, just as all the other case study regions did. However, they did not explicitly consider some common benefits of transportation projects such as mobility, accessibility, maintenance, and improved safety (in the sense that they were not one of the stated selection criteria.) These are important benefits to consider because their is an opportunity cost to any transportation investment; in light of limited funding, money committed to TCMs cannot be spent on other transportation projects, so it is important to choose TCMs which have as much total benefit to the transportation system as possible, not just air quality benefit.

- QUESTION #2: It is not clear how the Clean Air Task Force measured compliance to the criteria. Sometimes criteria imply how to measure compliance with them, but the exact definition is not clear. Other criteria provide no indication of how compliance with them should be measured.

Summary of Proposed Prioritization Methodology

In order to structure the use of technical analysis in making a particular decision, a series of five questions could be answered. When applied to a particular decision and set of TCMs, this series of questions results in a prioritized list of TCMs. The sequence of question is as follows:

1. Which criteria to consider?
2. Which measures best indicate a project's ability to meet these criteria?
3. What analysis method should be used to estimate the value of these measures?
4. What is the relative weight or importance of the criteria identified in Question #1?
5. Which method(s) could develop the "best"[94] relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

Chapter 4 describes how the case study regions chose to answer these five questions. In addition, Chapter 3 describes, in detail, the range of answers to question #3. Both Chapters 3 and 4 identify the factors which govern how to "best" answer each of the five questions listed above.

- QUESTION #3: The main conclusions drawn from comparing the Task Force's analysis approach (to estimating TCM impacts) and the approaches found in the case studies are as follows:
    - The Technical Advisory Group to the Clean Air Task Force was aware of many of the issues brought forth by the case studies and literature review of quantification methods.
    - It is not clear if the Task Force analyzed TCM packages, even though they acknowledged their merit. While not all case study regions managed to develop a methodology for analyzing TCM package, they all recognized the importance of this issue.

[94] Chapter 1 defined the "best" method as the method which (1) maximized the accuracy of the final prioritized list, (2) was the most inexpensive, and (3) was sufficiently precise.

- Because the Task Force specified measures of compliance only vaguely, it is unclear what type of quantification method would "best" estimate the values of these measures.

- QUESTION #4: The Task Force did not weight competing criteria in a systematic manner. This contrasts the approaches found in the case studies which were, in general, more systematic than the Task Force's.

- QUESTION #5: While the final recommendations presented by the Task Force are very logical and well presented, it is unclear how or why these recommendations were better than any other possible recommendations. The Task Force did not use a systematic ranking scheme, unlike some case study regions which used scoring and/ or screening to rank projects systematically. Unfortunately, the thesis cannot suggest even a hypothetical scoring/ screening methodology given the analysis contained in the Task Force's Final Report. Some key pieces of information which are unavailable or nonexistent include:
    - more exact definitions of the meaning of certain criteria and what constitutes compliance with these criteria,
    - which TCM impacts were estimated, how accurate these estimates are, and how precise, and
    - how important a given criterion is relative to each of the other criteria (i.e. criterion weights).

Thus, there are some elements of the Task Force's existing methodology which could be used to conduct the "Prioritization Methodology" proposed in Section 5.4. However, as a whole, the Task Force did not approach its task in the manner the "Prioritization Methodology" encourages. In order to use the "Prioritization Methodology," the Task Force would have to enhance its existing methodology as was discussed in the previous paragraph. Also, it would have to approach its task in a more systematic and explicit manner.

Table 5- 1 Summary of Conclusions (Each cell states whether the Boston's current process addresses the given question and specifies key details on how it was answered.)

	SIP	*TIP*
Question 1: Criteria	YES. Based recommendations on much more than air quality, but did not consider benefits such as mobility, accessibility, safety, and maintenance.	YES. The main contrast between Boston' approach and those found in other case study regions, is that Boston selected projects based on a much more limited set of criteria.
Question 2: Measures	NO. Not clear how compliance with certain criteria was measured	YES. The criteria specified conditions under which a project could be in compliance.
Question 3: Computing the Measures	NO. Aware of many of the issues. Not clear if they analyzed TCM packages. Because measures were specified only vaguely, it is unclear what type of analysis is necessary.	NOT APPLICABLE. Impact estimates were not needed to determine if a project met the specified criteria. However, extensive analysis proceeded the TIP process.
Question 4: Weighting Criteria	NO. Did not systematically weight competing criteria. This contrasts the methods found in the case studies which were, in general, more systematic.	YES. All criteria were equally important.
Question 5: Ranking Projects	NO. Unclear how or why recommended TCMs were better than other TCMs. Did not use a systematic method like scoring or screening like some regions did	YES. Used a screening process to rank projects. The ranking produced was not very precise, but was sufficiently precise.

5.8.1.2 Conclusions Regarding Boston's TIP Process

Boston's existing TIP process conducts all of the five-steps outlined by the proposed "Prioritization Methodology." The main contrast between Boston' approach and those found in other case study regions, is that Boston selected projects based on a much more limited set of criteria. Most other regions included criteria related directly to a project's benefits, while Boston did not. For example, Boston did not explicitly consider benefits such as mobility, accessibility, safety, or maintenance when prioritizing project proposals.

It is unclear, however, if Boston should follow the lead of these other regions, and revise its process to include a broader range of criteria. It is unclear because in Boston most prioritization decisions are made pre-TIP; the projects which are proposed for inclusion in the TIP generally match the available funding which implies one of two things:

- either that some major "prioritization" occurs prior to TIP programming decisions, or
- that it is so clear which (types of) projects the TIP programming process will prioritize, that sponsoring agencies[95] do not find it worthwhile to invest time in developing alternative or additional project proposals.

Including a broader range of criteria would be of no use if project proposals continue to match the available funding.

However, some of Boston's transportation planners believe that developing a broader range of criteria, and ensuring project sponsors that projects meeting these criteria would receive a fair chance of receiving funding - might provide sufficient motivation for project sponsors to develop a broader set of project proposals. This is one issue which stimulated recent attempts to restructure Boston's TIP prioritization process. The main benefit of stimulating a more competitive TIP prioritization process is that the quality of project proposals might increase. A higher "quality" set of projects would be more cost-effective (i.e. cost-effective in the sense that it would fulfill more of the region's transportation needs for the same cost of a lower "quality" set of projects.)

Another major stimulus for revising Boston's existing TIP structure is related to the Central Artery/ Tunnel (CA/T) project. As was described in Section 5.6.5, if the CA/T exceeds its expected budget, then a more precise ranking scheme will be needed in order to decide which projects are most worth funding.

Another major conclusion regards the treatment of SIP TCM commitments in the TIP ranking scheme. In the current TIP ranking scheme, TCMs are given priority if they are included in the SIP. However, as noted in Chapter 3, a TCM's effectiveness is dependent largely on how the transportation system, as a whole, is developed. Thus, if limited funding results in a transportation program different than the one assumed when the SIP commitments were originally made, the value and effectiveness of these SIP commitments should be re-assessed. Perhaps in the context of the new transportation program another set of TCMs would be more effective than the ones originally committed to.

5.8.2 "Which Decisions the Technical Analysis Should Facilitate"

At the beginning of this section (Section 5.8) it was stated that the proposed technical analysis framework aimed to address two issues:

1. *Which prioritization decisions should the technical analysis facilitate?* (The TCM prioritization process consists of a continuous sequence of decisions regarding how to develop projects and which projects to develop further.)
2. *How exactly should analysis results be used to facilitate decision making?*

Although the thesis focused on the second of the two issues listed above, some conclusions related to the first issue were formed as well. These conclusions are listed below:

- The TIP and SIP processes are two very critical decisions of the TCM prioritization process. They are critical because including projects in these documents commits a region to implementing them. For example, if a region does not fulfill its SIP commitments, sanctions may be imposed on the region by the federal government. Many regions have focused attention on prioritizing projects systematically before deciding which projects to include in these two documents, the SIP and TIP. Boston might consider systematizing their TIP and SIP processes further, and a methodology for doing so was developed in sections 5.4 through 5.6.

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[95] Every project proposed for inclusion in the TIP is proposed by a *sponsoring agency*.

- Although TIP and SIP related decisions are very critical, the decisions which come in between the programming of the TIP and the development of the SIP, are also important. This is especially true in Boston since most prioritization decisions are made pre-TIP. Here are two examples of decisions which occur between TIP programming and SIP development:
    1. the project selection processes of sponsoring agencies (for example the project selection process of the Massachusetts Bay Transportation Authority), and
    2. decisions about what to include or what to advance through the Transportation Plan (TP), the region's long-range plan for developing its transportation system.

- There was one issue brought forth by both Boston and the other four case studies, which neither addressed fully: TCMs which reduce emissions greatly in the long-run must *change* travel behavior. A web of factors govern an individual's travel behavior. Considering this web of factors when prioritizing TCMs involves a high degree of coordination amongst transportation agencies, as well as other public agencies, developers, politicians, businesses, and private citizens. In order to facilitate this high level of coordination, the technical analysis could be used to streamline and tie the various prioritization decisions together. A method for doing this was formulated in Section 5.7.

5.8.3 Recurring Issues Brought Forth by Research-- Positive Characteristics of Boston's Existing TCM Analysis Methodology

The case studies, as well as the review of methods available for quantifying emission and travel impacts of TCMs - brought forth some recurring issues regarding TCM analysis.

The research suggests that transportation agencies in Boston are aware of many of these issues. These issues were discussed in detail by Section 5.3 of this chapter. In addition, they are summarized below:

1. The interaction of transportation and land-use is a major determinant of travel behavior, and therefore emission impacts.
2. Air quality analysis is more accurate when conducted on a regional (or broader than regional) level - as opposed to a local level.
3. Analyzing TCM packages enables the analysis to better identify synergies amongst project impacts.
4. If TCMs are chosen due to their synergistic nature - then the failure to implement a portion of a TCM program can compromise the effectiveness of the portion of the program which is implemented.
5. Data availability limits the accuracy quantitative methods are able to achieve - which in turn has implications on the best use of their analysis results.
6. There is a range of methods available for quantifying the emissions and travel impacts of TCMs - certain methods can better analyze a given TCM than other methods can.

Thus, this chapter has discussed the various similarities and differences between the approaches Boston and the other four case study regions have adopted to prioritize TCM investments using technical analysis. As was discussed above, Boston is aware of many of the issues brought forth by the research. However, its manner of dealing with them differs from the approaches adopted by other case study regions. Namely, it is less structured and systematic. Thus, based on the case studies, this chapter developed an idealized approach for using technical analysis to develop priorities systematically; Section 5.4 presents this "Prioritization Methodology." The next chapter tests this methodology by applying it to a hypothetical situation in the Boston region.

Chapter 6

Trial Run: Applying the Proposed "Prioritization Methodology" to a Hypothetical Situation

This chapter applies the proposed "Prioritization Methodology" to a very simple hypothetical situation; it uses the "Prioritization Methodology" to prioritize a set of 3 projects which are competing for funding in the Boston region. There are a few motivations for conducting this trial run:

1. Two underlying theories of the proposed methodology are that (1) approaching the process in a systematic manner is beneficial, and (2) the insights gained by applying the methodology are at least as valuable to the decision-making process as the actual results of the methodology. This sample application should clarify what is meant by "systematically approaching the process," in case previous discussions have failed to explain this concept sufficiently. Also, the sample application should provide some examples of valuable insights which might be gained from applying the methodology.
2. This trial run is also being conducted to identify any shortfalls of the proposed methodology, or elements of the methodology which require further definition.
3. The proposed methodology was based on the case studies. The case studies focused on TIP and SIP processes. However, the proposed "Prioritization Methodology" is not limited to TIP and SIP related applications. The trial run

illustrates this point by applying the methodology to a situation not related to the TIP or SIP.

The chapter begins with a description of the simple hypothetical situation in Section 6.1. The next five sections (6.2 through 6.6) apply the five steps of the "Prioritization Methodology" to the hypothetical situation. Briefly, the five steps being referred to are:

1. Which criteria to consider?
2. Which measures best indicate a project's ability to meet these criteria?
3. What analysis method should be used to estimate the value of these measures?
4. What is the relative weight or importance of the criteria identified in Question #1?
5. Which method(s) could develop the "best"[96] relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

Section 6.7 concludes the chapter by summarizing its findings.

6.1 DEFINITION OF THE HYPOTHETICAL SITUATION

The 1994 Program for Mass Transportation (PMT) outlines Boston's plan for developing its mass transit system. Boston plans to develop and implement a range of projects which fall into one of two categories:

- SIP and CA/T Mitigation Expansion Projects, and
- Additional Expansion.

Each of these two categories consists of projects to be implemented in the short-term (through the year 2000), as well as the long-term (after 2000).

In the hypothetical scenario being defined, Boston is considering the possibility that when the year 2000 arrives, not all of the long-term projects contained in the PMT could be implemented due to funding shortages. Amongst these long-term commitments are three extensions of the "T" (the subway/ light rail system which serves the Boston area):

1. Green Line Extension to Medford Hillside (near Tufts),
2. Blue Line Extension to Lynn, and

[96] Chapter 1 defined the "best" method as the method which (1) maximized the accuracy of the final prioritized list, (2) was the most inexpensive, and (3) was sufficiently precise.

3. Red Line Extension to Mattapan.

A brief description of each of these three projects is provided in subsections 6.1.1 through 6.1.3. The first of these three projects is committed to in the State Implementation Plan (SIP) and is a mitigation commitment for the Central Artery/ Tunnel (CA/T) project. Because of this, either the Green Line project, or a substitute project, must be implemented and would therefore receive funding priority. The planning staff would like to answer the following question:

> *In the event that not enough funds are available to even implement SIP and CA/T mitigation commitments such as the Green Line project, could less expensive projects be substituted for the existing commitments. In the case of the hypothetical scenario described in this chapter, could either the Blue Line project or the Red Line project be substituted for the Green Line commitment?*

In sections 6.2 through 6.6 the proposed "Prioritization Methodology" is used to develop an answer to this question.

6.1.1 Green Line Extension to Medford Hillside (near Tufts)[97]

A Green Line extension to Medford Hillside would provide rapid transit service through Somerville to Medford Hillside in the vicinity of Tufts University. The extension would run from Lechmere Station 3.9 miles along railroad rights-of-way to Medford Hillside. There would be stations at Washington, School, and Lowell Streets in Somerville, at Ball Square (Broadway) on the Somerville/Medford border and at Medford Hillside (see Figure 6-1.) The School Street and Lowell Street Stations would each include 50 parking spaces. The Medford Hillside Station would have 200 spaces.

6.1.2 Blue Line Extension to Lynn

The Blue Line currently runs from Wonderland Station in Revere to Bowdoin Station in the Government Center area of downtown Boston. At six miles, it is the shortest of the MBTA's three high-platform rapid transit lines. The Blue Line has direct connections with the Orange and Green Lines, but not with the Red Line.

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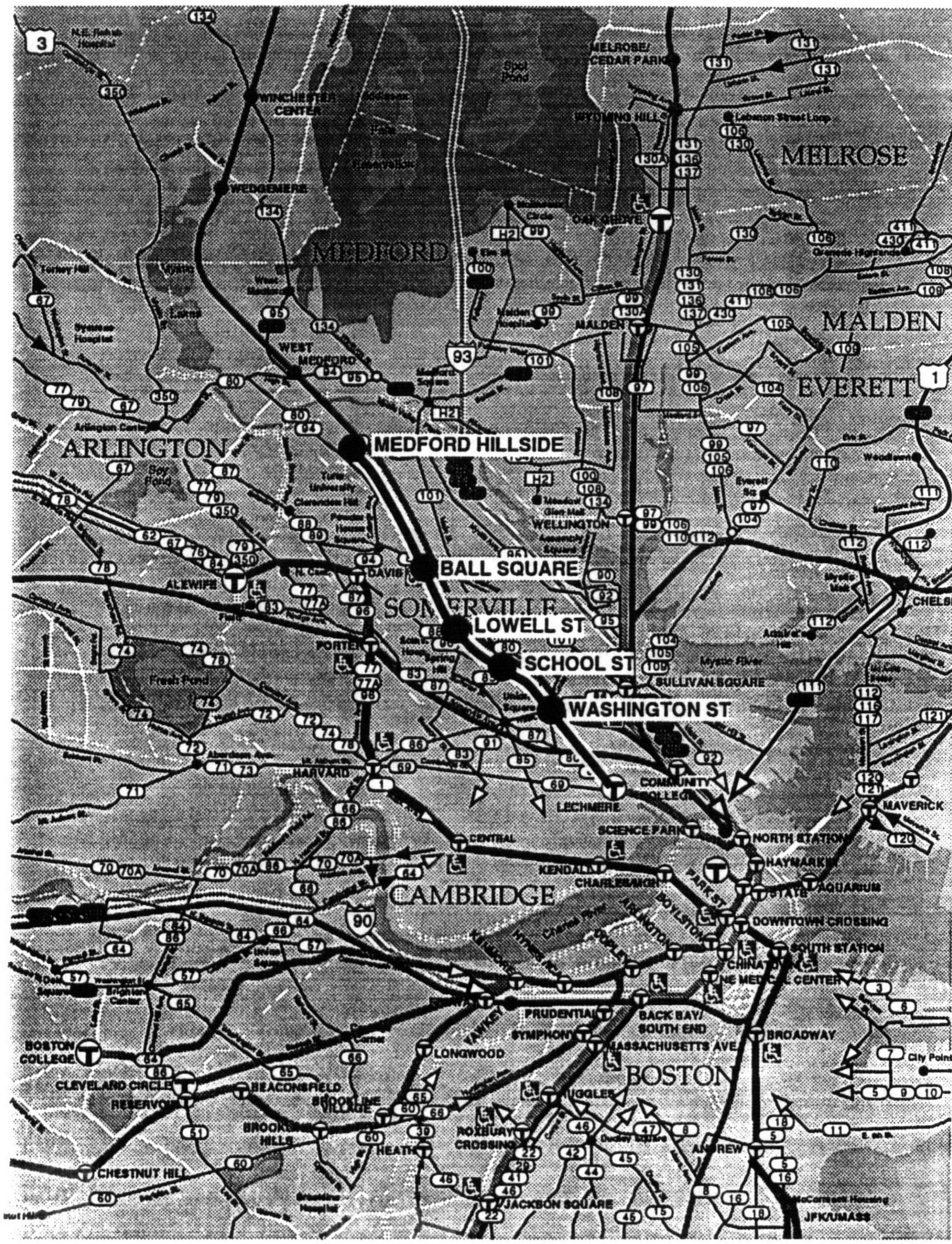
[97] The following description is taken from page 8-20 of the 1994 PMT (Boston No. 8.)

Figure 6- 1 Green Line Extension to Medford Hillside is shown in dark print ("T" is the symbol for the rest of the subway system)

(Reprinted from Boston No.8, page 8-21, figure 8-6.)



An extension of this line to Lynn would consist of a four-mile extension from Wonderland to Central Square in Lynn, via the Narrow Gauge right-of-way (see Figure 6-2). Intermediate stations would be located at Point of Pines, serving a residential community in northern Revere, and at West Lynn, serving the General Electric Plant and other employment.[98]

6.1.3 Red Line Extension to Mattapan[99]

A Red Line extension to Mattapan would replace the current Mattapan High Speed Line, which runs approximately 2.6 miles from Ashmont station at the end of one branch of the Red Line to Mattapan Square at Blue Hill Avenue. There are six station stops between Ashmont and Mattapan serving residential neighborhoods in South Dorchester and Milton.

At present, a trolley car runs every 4 minutes during peak periods, every 8 minutes during the day, and every 12 minutes at night. The fleet for the High Speed Trolley is made up of President's Conference Committee (PCC) cars built in the 1940's. These are used because maintenance of the electronic systems of modern Light Rail Vehicles would require an on-line carhouse. It will not be possible to operate the High Speed Line indefinitely with the present cars, and a decision on their replacement will be needed in the near future. Present peak schedules require six cars, all operated as single units.

The Red Line extension would operate along the same right-of-way as the Mattapan line, but with fewer stations. New rapid transit stations would be located only at Mattapan, Central Avenue, and Butler Street (see Figure 6-3). Present stations at Capen Street, Valley Road, Milton, and Cedar Grove would be discontinued. Frequency would decrease on the Mattapan Line from 4 minute headways to 8 minute headways during the peak.

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[98] The following description is taken from page 9-48 of the 1994 PMT (Boston No. 8.)
[99] This description was taken from page 9-50 of the 1994 PMT (Boston No. 8).

Figure 6- 2 Blue Line Extension to Lynn is shown in dark print ("T" is the symbol for the rest of the subway system)

(Reprinted from Boston No. 8, page 9-49, figure 9-18.)

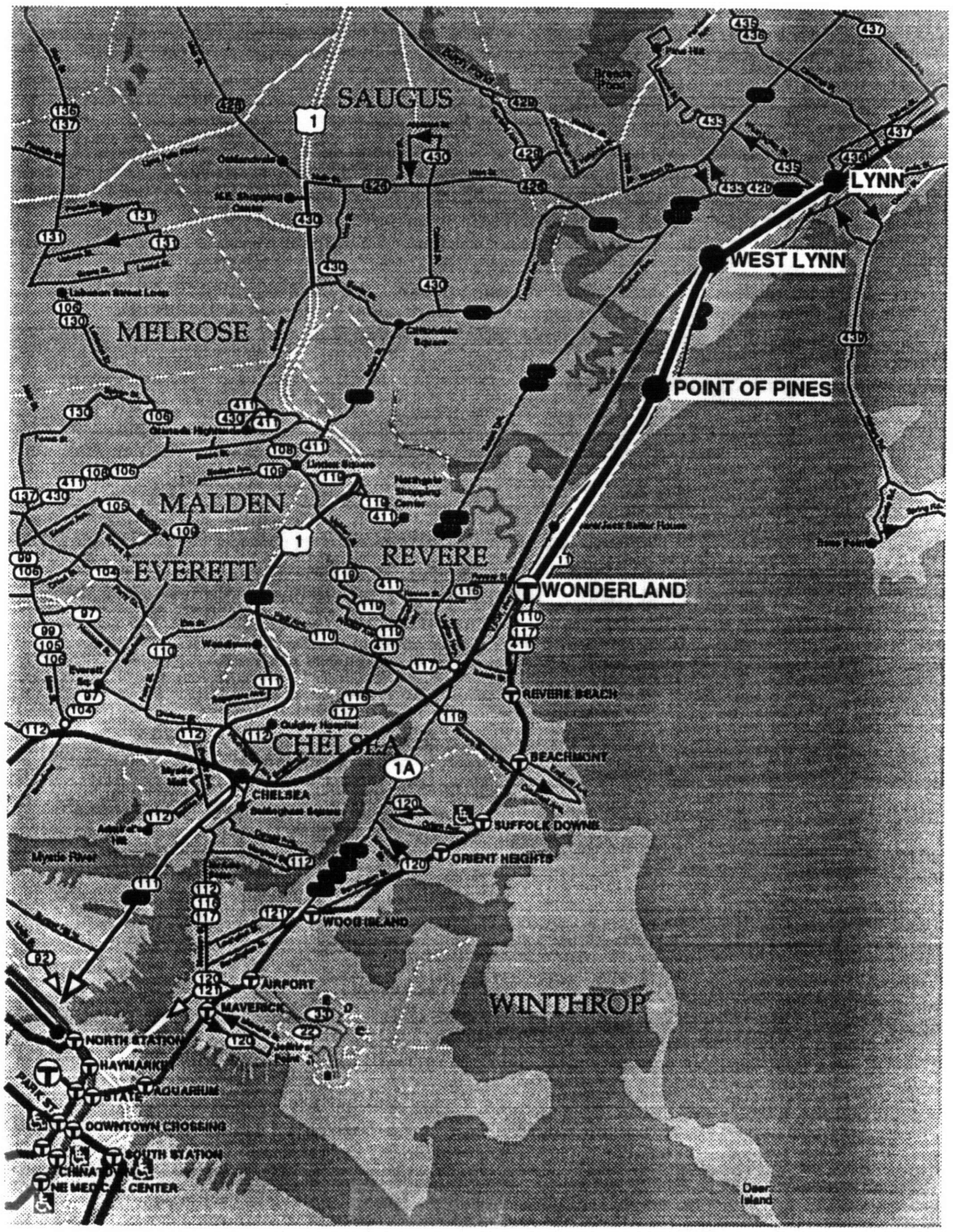
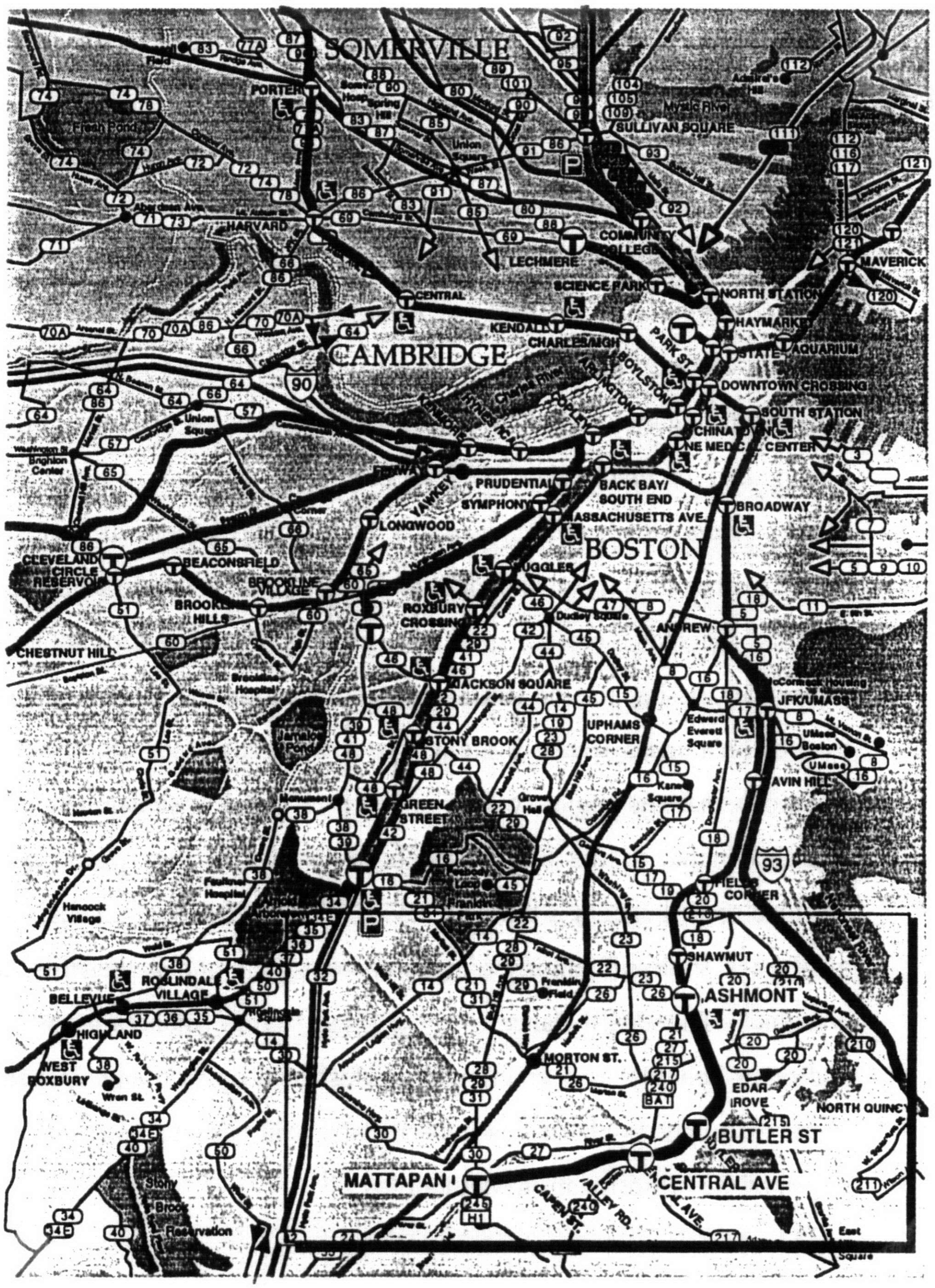


Figure 6- 3 Red Line Extension to Mattapan is shown in dark print ("T" is the symbol for the rest of the subway system)

(Reprinted from Boston No. 8, page 9-52, figure 9-19.)



6.2 QUESTION #1: WHICH CRITERIA TO CONSIDER?

If either the Blue Line Extension to Lynn or the Red Line Extension to Mattapan is to be substituted for the Green Line Extension to Medford Hillside then they should meet the following three criteria (according to the hypothetical scenario being defined in this chapter):

1. *Their air quality benefit should be at least as great as the air quality benefit of the Green Line project.* This is a criterion because this must be true in order for a project to qualify as a substitute for a SIP commitment.
2. *Their cost should be less than or equal to the cost of the Green Line project.* This is a criterion because a presumed funding shortage is the main motivation for substituting the original Green Line commitment with another project.
3. *The quality of their other benefits should be sufficiently comparable to the quality of the Green Line project's benefits.* "Other benefits" refers to project benefits other than those included in Criteria 1 and 2; some examples of "other benefits" includes a project's ridership impacts, the amount of additional service it provides, its impacts on traffic, and its impact on the service quality provided by Boston's mass transit system. It is being assumed (in this hypothetical situation) that the region would not like to select a substitute project whose overall benefits to the transit system were inferior, but would be willing to sacrifice some benefits if the cost savings were substantial. Thus, this criterion involves a trade-off amongst monetary cost, air quality benefits, and "other benefits." The ideal balance of these three factors (monetary cost, air quality, and other benefits) is a function of professional opinion and financial realities. Some assumptions about this ideal balance will need to be made in upcoming stages of the "Prioritization Methodology."

6.3 QUESTION #2: WHICH MEASURES BEST INDICATE A PROJECT'S ABILITY TO MEET THESE CRITERIA?

This section discusses how a project's compliance with the above criteria is measured. The suggested measures are based on the system level analysis conducted for the 1994 PMT and presented within it.[100] In other words, the analysis conducted in the PMT limits the range of measures available for determining compliance with the three criteria listed in the previous section, according to the hypothetical scenario being defined by this chapter. Possible measures of these three criteria are discussed in sections 6.3.1 through 6.3.3.

6.3.1 Criterion #1: The air quality benefit of a substitute project should be at least as great as that of the Green Line project

The PMT analysis calculates two measures which are directly related to Criterion #1:

1. *"VOC Reduction in kilograms per weekday"* The estimated number of kilograms of volatile organic compounds the project will eliminate. These estimates were derived by multiplying the reduction in vehicle miles traveled by an emission factor from Mobile 5A.[101] [102]
2. *"Percent Emission Reduction"* This measure represents the percent reduction of regional volatile organic compound emissions resulting from the project and the ridership it attracts.[103]

Both of these two measures are useful in measuring a project's compliance to Criterion #1. Thus, a project may be said to comply with Criterion #1 if both of the following is true:

- Its "VOC reduction" is greater than or equal to the "VOC reduction" of the Green Line Project. According to the PMT, the Green Line project reduces 47.3 kilograms of VOC per weekday.[104]

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[100] A detailed description of the PMT analysis process is available in the Boston Case Study which is presented in Appendix A of this Thesis.
[101] Boston No. 9, page F-4.
[102] More information on emission factors and Mobile5A are provided in Chapter 3 of this thesis.
[103] Boston No. 9, page F-14.

- Its "Percent Emission Reduction" is at least as great as the "Percent Emission Reduction" of the Green Line project. According to the PMT, the Green Line project should reduce regional emissions by 0.06 %.[105]

These two measures are described very briefly here. They are both highly quantitative measures; they are based on the results of quantitative models. Thus, their complete definition involves explaining the methodology used to calculate them. This is described more fully in Section 6.4. However, it should be noted that the 1994 PMT did define these measures very specifically, and that the measures were calculated in a uniform (i.e. systematic) manner for all projects. This is pointed out because one of the underlying theories of the "Prioritization Methodology" proposed by this thesis is that it is beneficial to systematize the analysis and decision-making process.

6.3.2 Criterion #2: The cost of a substitute project should be less than or equal to the cost of the Green Line project

This criterion is included because the main motivation for substituting the original Green Line commitment with another project is a presumed funding shortage. Thus, the appropriate measure for this criterion depends on the nature of the funding shortage. Namely, will there not be enough funds to pay for capital costs; enough funds to pay for maintenance and operation costs; or enough funds to pay for either? The PMT provides four types of cost estimates which may be used to measure compliance with Criterion #2:

1. *Total Capital Cost.* The cost to construct the new facility or service, including vehicle costs. The cost estimates are in 1993 dollars. The sources for the capital costs are based on estimates from MBTA consultant studies, estimates from the MBTA, or generated by CTPS using standard transit construction cost figures.

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[104] Boston No. 9, page F-6.
[105] Boston No. 9, page F-10.

2. *Annual Capital Cost.* The cost to maintain the facility on an ongoing basis. These costs, also in 1993 dollars, were calculated using life-cycle costing method.
3. *Annual Operating Cost.* The cost to operate the service. These figures were calculated by multiplying the number of vehicle service hours by the average hourly operating cost for that mode of transit vehicle. The average costs were provided by the MBTA.
4. *Annual Fare Revenue.* The amount of fare revenue expected to be generated by the new service. These figures were derived either through the regional model, or by applying average fares to the new ridership generated.[106]

As in the case of Criterion #1, the measures of Criterion #2 are highly quantitative. They are described briefly in this section, and the complete definition of the above measures involves explaining the methodology used to calculate them. This is described more fully in Section 6.4.

If there is only a shortage of funds available for initial capital costs then compliance with Criterion #2 could be measured as follows:

- Are the project's "total capital costs" less than or equal to the "total capital costs" of the Green Line project. According to the 1994 PMT, the "total capital costs" of the Green Line project are 88 million dollars.

If there is only a shortage of funds for operations and maintenance costs then compliance with Criterion #2 could be measured as follows:

- Are the project's {"annual capital costs" plus "annual operating costs" minus "annual fare revenue"} less than the {"annual capital costs" plus "annual operating costs" minus "annual fare revenue"} of the Green Line Project. According to the PMT, these costs are equal to {2,875,000 + 2,111,000 - 1,072,000 = 3,914,000} dollars for the Green Line project.

However, if there is a shortage of funds for both initial capital costs and operation/maintenance costs, then compliance with Criterion #2 is dependent on both of the above measures. For the purposes of this example, assume that the funding shortage would apply to initial capital costs only. Thus, savings related to operation/maintenance costs would be considered one of a project's "other benefits" that are considered in Criterion #3.

6.3.3 Criterion #3: A substitute project's other benefits should be sufficiently comparable to those of the Green Line project

This criterion is very broad. The meaning of "other benefits" is clarified by observing the range of evaluation criteria which the MBTA used to develop the PMT. These criteria could be grouped into the following categories:

- utilization
- cost-effectiveness
- air quality impacts
- service quality and coverage
- impact on existing system
- economic impacts
- land use impacts.

The PMT identifies several measures for each of the above evaluation criteria:

- *Utilization*
  - Total New Trips, New Transit Trips, Riders/Vehicle Service Hour, Riders/Vehicle Service Mile
- *Cost-Effectiveness*
  - Farebox Ratio, Investment/New Daily Transit User, Annualized Cost/ New Daily Transit User, Annualized Cost/Hour of Travel Time Savings, Annual Operating Subsidy
- *Air Quality Impacts*
  - Percent Emission Reduction, Capital Cost/ kg VOC Eliminated
- *Service Quality & Coverage*
  - Improved Connections, System Accessibility, Distribution of Service, Unmet Needs, Travel Time Savings, Safety/ Security, Comfort/ Convenience, Crowding

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[106] Boston No. 9, page F-4.

- *Impact on System*
    - Preservation of Existing System, Preservation of Future Options, Efficiency/Effectiveness
- *Economic Impacts*
    - Economic Development Potential, Potential for Private-Sector Participation
- *Land Use Impacts*
    - Supports Urban Core, Supports Suburban Compact Development

The detailed definitions of these measures, and the project characteristics upon which they are based, are available in Appendix J. They are not discussed here further because of the nature of the ranking process which will be developed in sections 6.5 and 6.6. As will be mentioned in sections 6.5 and 6.6, both Criteria #1 and #2 must be met in order for a project to be an eligible substitute for the Green Line SIP commitment. Therefore there is no need to consider a project's "other benefits" in detail, unless it has been shown to meet both Criterion #1 and Criterion #2. Not only is there no need to consider the "other benefits," but it may also be more economical not to consider them at this point in the process. This is because "other benefits" is such a broad term which would be very time consuming to define and estimate.

6.4 QUESTION #3: WHAT ANALYSIS METHOD SHOULD BE USED TO ESTIMATE THE VALUE OF THESE MEASURES?

Both quantitative and qualitative analysis are needed to define the measures discussed in the previous section (6.3). It is assumed, for the purposes of this hypothetical scenario, that the qualitative analysis upon which the PMT was based could support the needs of the hypothetical situation presented in this chapter. The qualitative analysis upon which the PMT was based is summarized in the PMT. Appendix V contains the summaries of the qualitative analysis conducted for the Green Line, Red Line, and Blue Line projects being considered in this chapter. Notice that some quantitative analysis facilitates the qualitative analysis contained in Appendix V. Also, the qualitative analysis is conducted in a relatively systematic manner, in the sense that all projects appear to be analyzed in a uniform way.

Chapter 3 discussed the factors to consider when selecting a quantification method. The main point of Chapter 3 is as follows. In essence, the "best" method for a given application should:

- be as accurate as possible,
- minimize the cost of the planning process, and
- produce sufficiently precise results.

Chapter 3 concluded that the "best" method is dependent on a two-way matching process between the characteristics of the quantification method and the characteristics of the given application. It is assumed, for the purposes of the hypothetical scenario discussed in this chapter, that the quantification methods used to develop the PMT are the "best". Appendix W discusses the quantification methods used to develop the PMT.

In conclusion, the analysis conducted for the PMT was the "best" option because it is assumed that:

- *It is accurate.* For example, in the case when cost estimates for competing projects were based on a variety of sources (e.g. the capital cost estimates were derived from three sources: MBTA consultant studies, estimates from the MBTA, or generated by CTPS using standard transit construction cost figures,) assume that analysis techniques are consistent across sources. If they were not consistent it might compromise the accuracy of the relative ranking which they will be used to produce.
- *It is the most inexpensive option.* Because the analysis has already been conducted (its cost is "sunk") it costs nothing to use it in this scenario.
- *It is sufficiently precise.* It is assumed that the hypothetical scenario being discussed in this chapter only aims to derive a rough ranking of projects. The results of this rough ranking will indicate whether a more precise ranking process needs to be conducted. It is assumed that the analysis contained in the PMT is precise enough to produce a rough, but accurate, relative ranking of projects.

Thus, the answer to question 3 of the "Prioritization Methodology" is to use the analysis conducted for, and summarized in, the PMT. This is assumed to be the most suitable choice of analysis technique for the hypothetical situation being discussed in this chapter. Appendix V and Appendix W document and summarize the analysis methods used to develop the PMT.

6.5 QUESTION #4: WHAT IS THE RELATIVE WEIGHT OF THE CRITERIA IDENTIFIED IN QUESTION #1?

Criterion #1 and Criterion #2 are equally important. This is because the hypothetical situation discussed in this chapter assumes that both criteria must be met in order for a project to be an eligible substitute for a SIP and CA/T mitigation commitment.

The relative "weight" of Criterion #3 is a two tiered issue. On one level, one must consider the importance of Criterion #3 relative to Criteria #1 and #2. On another level, one must consider the relative importance of the various "other benefits" referred to in Criterion #3. Below is a brief discussion of these two issues. However, this discussion does not go so far as to determine the actual relative weights. This is because, the ranking scheme which will be developed in Section 6.6 requires the relative weights of Criterion #3 to be known only if a project has already been shown to meet Criteria #1 and #2. Defining the relative weights of Criterion #3 would be very time consuming since it is a complex issue which has not been previously addressed (according to the hypothetical situation being defined in this chapter.) If any of the projects being analyzed (i.e. the Red Line or the Blue Line project) are shown to meet both Criteria #1 and #2, then defining the relative weights of Criterion #3 would become necessary and would be addressed.

The importance of the third criterion relative to the first two, is a matter of judgment. If it became necessary to define the relative importance it would be done as follows. Namely a standard or limit would be set in the ranking scheme (developed in Section 6.6) in regard to the third criterion. If a project failed to meet this standard then it would not be in compliance with the third criterion. The relative weight of Criterion #3 vs. Criterion #1 or Criterion #2, is a function of this standard; setting a standard which is hard to obtain indicates that Criterion #3 is very important relative to the other two criteria. Conversely, setting a standard which is very easily met indicates that Criterion #3 is less important.

Another issue in regard to the third criterion is as follows. Criterion #3 is related to a project's "other benefits". The term "other benefits" encompasses a broad range of project impacts such as utilization, cost-effectiveness, service quality and coverage, impact on existing system, economic impacts, land use impacts. The relative importance of these impacts influences a project's ability to meet Criterion #3. For example, the relative importance of service quality and economic impacts determines whether a project with positive service quality impacts but negative economic impacts is better than a project with negative service quality impacts and positive economic impacts.

In the ranking scheme proposed in Section 6.6, it will be proposed that a scoring scheme be used to measure compliance to Criterion #3. The relative weights of each of the "other impacts" could be reflected in the scoring scheme by adjusting the number of points assigned to each impact. This technique is illustrated by the following example. Two measures of "utilization" included in the PMT are "new transit trips per weekday" and "riders per vehicle service hour." If both of these measures were used in the scoring scheme their relative importance would be indicated by the conversion factors used to convert each of them into the unitless point scale of the scoring scheme. Consider two possible scenarios:

1. A project receives 1 point for every 100 new weekday transit trips it produces, and 1 point for every 50 riders per vehicle service hour.
2. A project receives 1 point for every 150 new weekday transit trips it produces, and 1 point for every 50 riders per vehicle service hour.

The first scenario attaches less weight to "new weekday transit trips" relative to "riders/ vehicle service hour", than the second scenario does.

6.6 QUESTION #5: HOW TO DEVELOP THE "BEST" RELATIVE RANKING OF PROJECTS

Given the characteristics of the hypothetical situation being analyzed the "best" method for ranking the three projects being considered is as follows. The ranking process will be divided into two parts: Ranking Cycle #1 and Ranking Cycle #2.

6.6.1 Ranking Cycle #1

The first part of the ranking process involves screening the projects as follows:

1. The project passes the screen if its "VOC reduction" is greater than or equal to 47.3 kilograms of VOC per weekday.[107]
2. The project passes if its "Percent Emission Reduction" is at least as great as 0.06%.[108]
3. The project passes if its "total capital costs" are less than or equal to 88 million dollars.

The following table applies this screening process to the three projects being considered in this chapter. A positive number in a table cell indicates that a project passes the given screening criterion; in order to accentuate this, cells with positive answers are shaded. In order for a project to pass the entire screening process, and to qualify as a potential substitute project, it must obtain a positive result (i.e. squares must be shaded) in regard to all three measures. It is obvious that the Green Line project could qualify as a substitute for itself, yet it is included in the table for the sake of completeness.

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[107] Boston No. 9, page F-6.
[108] Boston No. 9, page F-10.

	Blue Line Extension to Lynn	***Red Line Extension to Mattapan***	***Green Line Extension to Medford Hillside***
"VOC reduction" minus 47.3	60.3 - 47.3 = 13.0	10.7 - 47.3 = -36.6	47.3 - 47.3 = 0
"% emission reduction" minus 0.06%	0.07 - 0.06 = 0.01	0.01 - 0.06 = -0.05	0.06-0.06 = 0
$88,000,000 minus "total capital cost"	88,000,000 - 275,000,000 = -187,000,000	88,000,000 - 54,000,000 = 34,000,000.	88,000,000 - 88,000,000 = 0
DOES THE PROJECT PASS THE SCREEN?	NO	NO	YES

As can be scene from the above table, neither the Blue Line project, nor the Red Line project qualifies as a substitute for the original Green Line commitment. The Blue Line project is too expensive (it costs $187 million more than the Green Line project), but has sufficient air quality benefit (about 13 kg per weekday more than the Green Line project.) The Red Line project does not cost too much (costs $34 million less than the Green Line project), but has much less air quality benefit (about one sixth the air quality benefit of the Green Line project.)

Because compliance with Criterion #1 and Criterion #2 can be measured quickly and therefore inexpensively, they were both included in the first ranking cycle which is described above. Compliance with Criterion #3 is more difficult to determine because it is such a broad and vaguely defined criterion. Thus, it would be wise to invest time in measuring compliance to Criterion #3 only if some projects have been shown to comply with Criteria 1 and 2 (which are easier to measure). As the above table shows, neither the Red Line project nor the Blue Line project meet both Criteria 1 and 2, i.e. pass the first ranking cycle.

6.6.2 *Ranking Cycle #2*

If some projects had passed the first ranking cycle, then a secondary ranking scheme would be developed to determine conformity to Criterion #3. Conformity to this criterion could best be determined through the use of a rough scoring scheme. The scoring scheme would consider a project's "other benefits," as well as its air quality benefits and financial advantages. A rough scoring scheme has several advantages compared to other approaches:

- Developing a scoring scheme encourages the analyst or decision-maker to explicitly and systematically consider the relative weights of the range of impacts comprising Criterion #3. The use of other methods such as "raw evaluation measures" or "screening" (which were described in Chapter 4) does not impose as stringent requirements on the thought process as "scoring" does.
- Because all of the impacts comprising Criterion #3 have been quantified or could easily be quantified based on the PMT analysis, the highly numerical nature of scoring is not a hindrance in this example.
- The scoring scheme would be rough (e.g. would use a high- medium- low scale) because it is assumed that the impact estimates available are not highly precise. This assumption is made because analysts involved in the PMT development indicated that the PMT analysis results probably could not support highly quantitative scoring. Also, a rough scoring scheme should be used because it is assumed that the relative weights of the competing impacts could only be estimated to a certain degree of precision.

A project's score would indicate how much better than the Green Line project that project was; a positive score would indicate that a project was better than the Green Line project and a negative score would indicate the opposite. A large positive number would indicate that a project was largely better than the Green Line project, while a smaller positive number would indicate that the project's impacts are similar to the Green Line project's. A scoring scheme in which a positive score indicates a project was better than the Green Line project, and a negative score indicates the opposite, could be produced by taking differences between the impacts of the Green Line project and the proposed substitute project.

The last few paragraphs provide a general image of how to score Criterion #3. However, a few details of the scoring scheme require further definition before the scoring scheme could be applied to a simple example such as this one.

Once the scoring scheme is fully defined, and the competing projects have been scored, this information could be used to determine if a project complies to Criterion #3. This could be done as follows (keeping in mind that the Green Line project's score is "0" by definition):

- Projects with scores above a certain positive number, A, receive top priority
- Projects with scores between another positive number, B (where B is less than A), and A, receive medium priority.
- Projects with scores between B and -B, receive low priority. Thus, because this range encompasses "0", the Green Line project will always receive low priority in this ranking scheme.
- Projects with scores less than -B are considered to be not acceptable substitutes for the Green Line project.

Ranking is performed in tiers (i.e. high-medium-low) in order to reflect the precision of project scores, as well as the precision of impact estimates and relative weights upon which the scores were based.

The value of the set standards (i.e. A and B) discussed above, is a matter of judgment. If a project received either high, medium, or low priority through this ranking scheme, then it would have to be analyzed more carefully so that the results of the rough ranking processes (Ranking Cycle #1 and Ranking Cycle #2) could be confirmed.

6.6.3 Results of the Ranking Process

The ranking process described in sections 6.2 through 6.6 was conducted to determine whether the Blue Line project or the Red Line project should be considered as substitute projects for the original Green Line commitment. The ranking produced by the two ranking cycles which comprise the ranking process is as follows (keeping in mind that the Green Line project always receives "low rank" by definition):

- Green Line project = low rank
- Red Line project = unacceptable
- Blue Line project = unacceptable.

As an example, consider if some other set of projects had been analyzed using this ranking process. Assume that some of these projects had passed the first screening cycle, and continued onto the second screening cycle. The ranking which resulted might have been:

- Project B = high rank
- Project E = high rank
- Project A = medium rank
- Green Line project = low rank
- Project D = low rank
- Project C = unacceptable

This example was provided to point out the breadth of this ranking scheme which was not captured by the hypothetical scenario involving the Red Line and Blue Line projects, since both projects did not even pass the first screening cycle.

6.7 CONCLUSIONS

This chapter applies the proposed "Prioritization Methodology" to a very simple hypothetical situation; it uses the "Prioritization Methodology" to rank a set of 3 projects which included the:

1. Green Line Extension to Medford Hillside (near Tufts),
2. Blue Line Extension to Lynn, and
3. Red Line Extension to Mattapan.

The first of these three projects, the Green Line extension, is committed to in Massachusetts' State Implementation Plan (SIP) and is a mitigation commitment for the Central Artery Tunnel (CA/T) Project. Because of this, either the Green Line project, or a substitute project, must be implemented and should therefore receive funding priority. The Boston planning staff would like to answer the question:

> *In the event that not enough funds are available to even implement SIP and CA/T mitigation commitments such as the Green Line project, could less expensive projects be substituted for the existing commitments. In the case of the hypothetical scenario described in this chapter, could either the Blue Line project or the Red Line project be substituted for the Green Line commitment?*

In sections 6.2 through 6.6 the proposed "Prioritization Methodology" was used to develop an answer to this question. Each of the five steps of the "Prioritization Methodology" was addressed in these sections, and they are summarized by Table 6-1.

The results of the "Prioritization Methodology" are as follows (keeping in mind that the Green Line project always receives "low rank" by definition):

- Green Line project = low rank
- Red Line project = unacceptable
- Blue Line project = unacceptable.

The answer to the question "could either the Blue Line project or the Red Line project be substituted for the Green Line commitment?" is "NO." Neither project is an acceptable substitute for the Green Line project according to the guidelines assumed in this hypothetical situation. These guidelines (which are described by Section 6.2 in more detail) required that in order for a project to be an acceptable substitute for the Green Line commitment:

1. their air quality benefit should be at least as great as the air quality benefit of the Green Line project,
2. their cost should be less than or equal to the cost of the Green Line project, and
3. the quality of their other benefits should be sufficiently comparable to the quality of the Green Line project's benefits.

Table 6- 1 Application of the "Prioritization Methodology" (Summary of Sections 6.2 through 6.6)

Question No. & Short Description	Summary of How Each Stage of the Prioritization Methodology was Answered in Sections 6.2 through 6.6
1.Criteria Chosen as a Basis for Ranking.	• A project's air quality benefit should be at least as great as the air quality benefit of the Green Line project, • A project's cost should be less than or equal to the cost of the Green Line project, and • The quality of a project's other benefits should be sufficiently comparable to the quality of the Green Line project's benefits.
2.Measures & Standards Used to Estimate Compliance with Criteria	A project is in compliance with: • Criterion 1 if its "VOC reduction in kilograms per weekday" is greater than 47.3; and if its "percent emission reduction" is greater than 0.06%. • Criterion 2 if its "total capital costs" are less than 88 million dollars. • Criterion 3 was not dealt with because it is only necessary to deal with criterion 3 if a project has been shown to comply with Criteria 1 and 2 already.
3.Methods Used to Estimate Impacts	Both qualitative and quantitative analysis are needed to estimate the impacts discussed in question #2 (above.) It was assumed that the qualitative and quantitative analysis upon which the PMT was based could support the needs of the hypothetical situation presented within this chapter. It was assumed that these analysis results were accurate and sufficiently precise. Also, they would be the most inexpensive option since the cost of producing them was "sunk" (i.e. it had already been spent and was irretrievable.)
4.Determining the Relative Importance or Weights of Ranking Criteria	All three criteria are equally important, in the sense that a project is not an acceptable substitute unless it meets all three. However, two weighting issues related to the third criterion were not dealt with. First, the chapter never defined what "sufficiently comparable" meant; this was a phrase used to define the third criterion. Second, the chapter never defined the relative importance of the various "other impacts" referred to in the third criterion. These two issues were not dealt with because they are difficult to deal with and would only become relevant if a project was shown to comply with the first two criteria already.
5.Defining the Ranking Scheme	A two part ranking scheme was developed. The first ranking cycle results in two groups of projects: (1) projects which are not acceptable substitutes for the Green Line project because they do not comply with one or both of the first two criteria, and (2) projects which are acceptable substitutes. "Unacceptable" projects do not proceed to the second ranking cycle. The components of the first ranking cycle were all defined and the ranking scheme was implemented. The second ranking cycle determines if projects comply with the third criterion through the use of project scores, and standard scores. The second ranking cycle assigns projects one of four possible ranks: high, medium, low, or unacceptable. This ranking cycle was not fully defined and was not implemented because none of the projects passed the first ranking cycle (i.e. they were all found to be "unacceptable").

As stated at the beginning of this chapter, there were a few motivations for the trial run conducted in this chapter:

1. Two underlying theories of the proposed methodology are that (1) approaching the process in a systematic manner is beneficial, and (2) the insights gained by applying the methodology are at least as valuable to the decision-making process as the actual results of the methodology. *This sample application should clarify what is meant by "systematically approaching the process,"* in case previous discussions have failed to explain this concept sufficiently. Also, the sample application should provide *some examples of valuable insights which might be gained from applying the methodology.*
2. This trial run is also being conducted *to identify any shortfalls of the proposed methodology, or elements of the methodology which require further definition.*
3. The proposed methodology was based on the case studies. The case studies focused on TIP and SIP processes. However, the proposed "Prioritization Methodology" is not limited to TIP and SIP related applications. *The trial run illustrates this point by applying the methodology to a situation not directly related to the TIP or SIP.*

Hopefully, this sample application has managed to do these things: clarify what is meant by "systematically approaching the process," provide some examples of the insights gained by applying the methodology, demonstrate that the methodology is broadly applicable, and identify some of the methodology's shortfalls. In terms of "identifying the methodology's shortfalls", this chapter brought forth one major shortfall.

Namely, it became apparent from this trial run that all five steps of the methodology are interdependent, and therefore they should all be answered at least vaguely before investing extensive time in analysis. Although the trial run did do this (i.e. run through all 5 steps of the "Prioritization Methodology" before investing extensive time in analysis), the "Prioritization Methodology" does not clearly specify the need to do this or how to do this. Thus, an amendment to the proposed methodology is suggested by this chapter. In particular, a sixth and a seventh step could be included in the proposed methodology so that the entire methodology would now have the following form:

1. ***Choose* which criteria to consider.**
2. ***Consider* which measures best indicate a project's ability to meet these criteria.**
3. ***Consider* which analysis method should be used to estimate the value of these measures.**
4. ***Consider* the relative weight or importance of the criteria identified in Question #1.**
5. ***Consider* which method(s) could develop the "best" relative ranking of projects or options based on the above analysis (i.e. the analysis discussed in Steps 1 through 4.) Conduct ranking in cycles if appropriate.**
6. **Answer questions 1 through 5 *in detail* for the first ranking cycle. Perform all analysis and computations for the first ranking cycle.**
7. **Repeat Step 6 for each subsequent ranking cycle, if the ranking cycle is still relevant given the results of the previous ranking cycle.**

The five steps of the old methodology were interdependent in the sense that the answers to some steps influenced the answers to other steps. Table 6-2 tabulates the various interdependencies affecting the final answer produced by the "Prioritization Methodology." By proceeding through all five steps of the old methodology before investing extensive time in analysis, and by considering the interdependencies amongst the five steps, three main benefits were gained:

- *The value of the numerous "other benefits" did not need to be estimated.* In this hypothetical situation, having to estimate the value of these "other benefits" would not have increased the analysis costs drastically, since existing analysis which had originally been developed for the PMT was being used. However, if this were not the case, then having to estimate the value of the numerous "other benefits would have significantly increased analysis time and costs.

- *The relative weights of these "other benefits" did not need to be estimated.* It was assumed in the hypothetical scenario, that these weights were not previously known. Indeed, there is no reference to them in the PMT, Boston TIP, or Boston TP. Thus, estimating these relative weights would have been fairly time consuming and may have significantly increased the analysis costs.
- *A scoring scheme for determining compliance to Criterion #3 did not have to be developed in detail.* This chapter sketched a potential scoring scheme. Defining this or another scoring scheme in detail would have consumed additional time and incurred additional costs.

Applying the methodology to the hypothetical situation described in this chapter did not identify any shortfalls in the proposed methodology other than the one discussed above. But, perhaps no shortfalls were identified because the hypothetical situation was very simple. The situation did not deal with some of the more complex issues which arise and which were emphasized by the thesis such as:

- packaging projects;
- tying into and capitalizing on the SIP analysis; and
- long-term vs. short-term impacts.

The case studies offered no conclusions on how to best deal with these issues, they merely brought forth these issues and acknowledged their relevance to developing an effective TCM program. Applying the methodology to a more complex situation might reveal its ability to deal with these issues.

Table 6- 2 Interdependencies Amongst the Five Steps of the "Prioritization Methodology" Applied in this Chapter

	Question 1 (Q 1)	Question 2 (Q 2)	Question 3 (Q 3)	Question 4 (Q 4)
Q 2	The type of measure chosen in Q2 is a function of the criteria specified in Q1, but not vice versa in this hypothetical situation.			
Q 3	The precision required in the impact estimates is a function of the criteria which must be measured. However, the criteria were not chosen based on the type of analysis which was to be used. Thus Q3 is a function of Q1, but not vice versa, in this application.	Q2 is dependent on Q3 in the sense that measures which could be estimated based on the selected analysis method were chosen. In this application, Q3 was not dependent on Q2, but in many other applications it might be.		
Q 4	The type of weighting which needed to be performed was a function of what criteria needed to be considered; however the criteria considered were not chosen based on the relative weights of these criteria or the ability to estimate these weights. Thus, Q4 was dependent on Q1, but not vice versa.	Q4 was a function of Q2, but not vice versa in this application. Weights in Q4 were chosen based on the measures which were defined in Q2. However, the measures chosen in Q2 were not selected based on their ability to be compared to each other.	Q4 and Q3 were not dependent on one another. Generally the choice of impact analysis method and the definition of relative weights do not influence one another.	
Q 5	Q1 influenced the selection of ranking method (i.e. screening and scoring). Screening was used in the first ranking cycle because Criteria 1 and 2 involved "yes/no" answers. Because conformity to criterion 3 was not such a black and white issue, scoring was a more suitable method than screening for performing ranking cycle 2.	A detailed definition of how to measure compliance to Criterion 3 was not included in Q2, but a detailed definition of Criteria 1 and 2 were included due to the nature of the ranking scheme developed in Q5. Because Criterion 3 was difficult to define, but Criteria 1 and 2 were easy, ranking was conducted in two cycles (first Criteria 1 and 2 were considered, second criterion 3 was considered.	The ranking scheme developed in Q5 reflected the limited precision of the analysis methods chosen in Q3. The large gaps between the projects being ranked made it unnecessary to produce more precise analysis than was available through the PMT.	Q4 only partially addressed the weighting of criterion 3 and fully addressed the weighting of the first two criteria due to the nature of the ranking scheme developed in Q5. Because the weighting of Criteria 1 and 2 was straight forward, and because these were the two dominant criteria, they were included in the first ranking cycle, and criterion 3 (whose weighting was more complicated) was considered in the second ranking cycle.

Chapter 7

Summary & Conclusions

The objective of this thesis was to develop a technical analysis framework for prioritizing TCM investments in the Boston region. The proposed technical analysis framework attempts to *structure* the interaction of technical analysis and prioritization decision-making. Namely the technical analysis framework addresses two issues underlying this interaction:

1. Which prioritization decisions to facilitate, and
2. How technical analysis should be used to facilitate them.

However, the second of these two issues is the primary focus of this thesis. Because the research focused on two prioritization decisions (TIP related and SIP related), only very general conclusions could be drawn in regard to the first issue.

In order to achieve the thesis objective, two major research efforts were made. First, the available methods for quantifying the emission and travel impacts of TCMs were surveyed. Second, case studies of five regions with extensive TCM experience were collected. The major conclusions from these two efforts are summarized in sections 7.1 and 7.2, respectively.

After surveying the available methods for quantifying the impacts of TCMs, the prioritization methods used by other regions, in addition to Boston's own planning activities, the research suggests that *transportation agencies in the Boston region are aware of many of the issues brought forth* regarding TCM prioritization and analysis.

While the other four case study regions, like Boston, are aware of these and other issues, the "best" framework for addressing them is not obvious; any framework must balance the conflicting goals of accuracy, precision, and cost minimization.

Although the "best" framework for addressing the many issues surrounding TCM prioritization is not obvious, it should be noted that *Boston's manner of dealing with these issues contrasts the approaches adopted by the other four case study regions.* Namely, Boston's approach tends to be less structured. By drawing on the approaches found in the case studies, Chapter 5 recommends a framework for better structuring the interaction of technical analysis with the (TCM) decision-making process in Boston. These recommended improvements do not guarantee a better TCM program, however. They are merely tools for making more informed decisions. The technical analysis framework proposed in Chapter 5 is summarized by Section 7.3 of this chapter.

The main component of the proposed technical analysis framework is the "Prioritization Methodology" developed in Section 5.4. This "Prioritization Methodology" specifies "how exactly analysis results should be used to facilitate decision-making" (which was the second major issue the technical analysis framework was supposed to address as was mentioned at the start of this chapter). The proposed methodology was based on the case studies which focused on TIP and SIP processes. However, the proposed methodology is not limited to TIP and SIP related applications.

To illustrate this as well as other points, the methodology was given a trial run in Chapter 6. Also, this trial run was conducted in order to identify any shortfalls of the proposed "Prioritization Methodology." The findings from the trial run conducted in Chapter 6 are summarized in Section 7.4.

7.1 CONCLUSIONS FROM CHAPTER 3 - QUANTIFYING THE TRAVEL AND EMISSION IMPACTS OF TCMS

One of the main conclusions of Chapter 3 is that TCM analysis has been continuously evolving in recent years. Some of this "evolution" has resulted in improved methods and estimates of TCM impacts. However, this "evolution" has also resulted in a *range* of methods, none of which is universally "better" than the others. Rather, some methods better suit a given set of analysis needs than other methods do.

There are a few reasons why none of the available quantification methods is universally "best"[109]:

- Even the results of the "most accurate" methods are regarded with skepticism, according to the literature.
- Any technical analysis framework must balance its accuracy, cost, and precision. This is because increasing accuracy often increases cost or decreases precision. Similarly, increasing precision may also increase cost. So the most accurate method is not always the cheapest or the most precise.
- The ideal balance of accuracy, precision, and cost depends on the requirements of the specific application.

Thus, while there is no universally "best" method, there might be a method (or methods) which "best" suit the needs of a given application. The needs of a given application can be grouped into two categories:

- Characteristics of a specific region, and
- Legislative requirements.

The "best" tool for a given application will have characteristics which match these needs. It is a two-way matching process which determines the best method for a given application in the sense that not only must the method suit the application, but also the application

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[109] Chapter 1 defined the ***"best" method*** as the method which would: ***maximize accuracy*** of the final prioritized list, have a ***minimal cost,*** and produce ***sufficiently precise*** results.

must suit the method. Not only does a range of quantification methods exist, but there are also a range of application approaches. In particular, it should be noted that many region-specifics may be altered in the long run. Regions can choose to

- acquire new data, hardware, or software
- develop a new quantification method for themselves
- reorganize their planning structure, or
- alter the role of impact estimates in the decision-making process

in order to improve the quality of their overall decision-making process. Figure 3-3 illustrated the two-way matching process which determines the best match of method and application.

The previous discussion leads to the second main conclusion of this chapter: *The literature points out that because of their uncertainty, current quantification methods may best serve as 'learning tools'* through which the analyst familiarizes herself with the relative effects of TCMs. This limits the potential applications of analysis results; in other words, because of their limited accuracy, impact estimates can only contribute so much to the decision-making process.

Just as there is little evidence to prove that impact estimates are accurate, there is also little evidence which proves they are inaccurate. This is the third main conclusion of this chapter. The lack of before and after monitoring, and the tendency of projects not to be implemented as they were modeled, makes it difficult to determine how accurate predictions are.

Although there are no conclusions regarding the ability of existing quantification methods to accurately predict reality, some conclusions may be drawn regarding the theoretical accuracy of the available methods. From a theoretical perspective, some methods might produce more accurate estimates because they make a better attempt to capture the complexities of travel behavior, and the details of travel behavior which are relevant to air quality. Professionals experienced in the field of impact analysis, and familiar with the range of theoretical issues involved, suggest that, *of all the available methods, regional models have the most potential to produce accurate predictions.*

Accuracy is not the only consideration when choosing a quantification method. Sometimes other methods are more appropriate. The most appropriate method for a given application is determined by the two-way matching process previously described and illustrated by Figure 3-3.

The fourth and final major conclusion drawn by this chapter is that analyzing the methods used to quantify emission and travel impacts of TCMs revealed a few basic insights regarding the type of methods most likely to accurately estimate a TCM's impacts on emissions. These insights were discussed fully in section 3.2. But, in summary, the travel impacts relevant to estimating emission changes are

- change in vehicle miles traveled (VMT)
- change in speed, and
- change in trips.

Moreover it is important which portion of the vehicle fleet is affected (i.e. high-emission vehicles or low-emission vehicles), whether the changes in trips affect "hot-started" or "cold-started"[110] trips, as well as other such details.

The relationships between travel and emission categories are illustrated by Figure 7-1 (which was originally included as Figure 3-1 and discussed in Section 3.2.2). A report prepared by Sierra Research, Inc. and JHK & Associates states that a change in the number of vehicle trips effects changes in speed and VMT.[111] *Thus, changes in the number of vehicle trips has the most potential to reduce emissions* because it affects all emission categories. Changes in trips are also a very effective means of reducing emissions because they are the one type of travel impact which may reduce cold starts.

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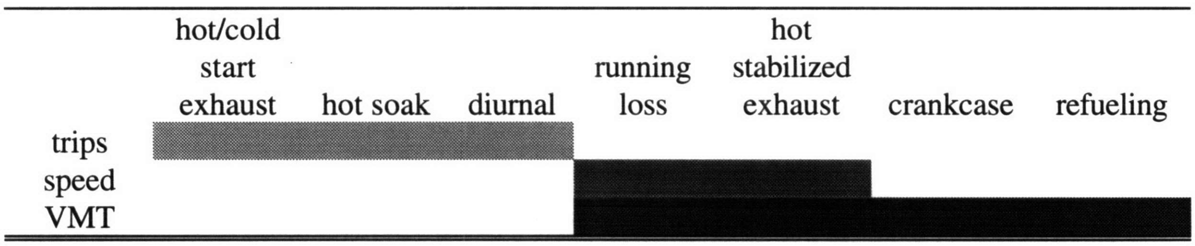
[110] Starting an engine when it is cold produces more emissions than starting an engine when it is "warm".
[111] Document No. 2, p.12.

Starting an engine cold produces a considerable amount of emissions, compared to the other 7 emission categories listed in Figure 7-1.

Figure 7- 1 How Travel Impacts Translate Into Emission Changes (shaded squares indicate the presence of a relationship) [112]



In addition to the above considerations, the literature emphasized some other issues that a more accurate method should address such as:

1. Consistency within and amongst methods
2. TCM packages vs. individual TCMs
3. Regional vs. local
4. Long-term vs. short-term
5. Transportation system vs. urban system

The discussion in Chapter 3 summarized some of the issues which were highlighted in the literature; however, estimating travel and emission impacts is a very complicated subject consisting of many more issues than were highlighted by this thesis. The issues highlighted by Chapter 3 are not only relevant to the choice of quantification method, but also to the choice of prioritization method, and the organizational structure within which analysis is conducted. Thus, the insights developed in Chapter 3 were carried into subsequent chapters.

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[112] Document No. 5, p3-6.

7.2 CONCLUSIONS FROM CHAPTER 4 - FINDINGS FROM THE CASE STUDIES

This thesis aimed to develop a framework which *structured* the interaction of technical analysis and TCM prioritization decision-making. Namely the technical analysis framework should have addressed two issues underlying this interaction:

1. Which prioritization decisions to facilitate, and
2. How technical analysis should be used to facilitate them.

The case studies intended to explore the second issue listed above: how to use technical analysis to facilitate TCM prioritization. They drew several conclusions in regard to this issue. These conclusions are summarized by sections 7.2.1 through 7.2.4 of this chapter.

In the course of exploring the second issue, the case studies brought fourth the first issue: which prioritization decisions should technical analysis be used to facilitate. Namely, from examining the case studies it became apparent that TCM prioritization was not an isolated event; it was a continual process which spanned many agencies, many planning documents, and many years. It consisted of numerous "decisions." However, because this only became apparent after the case studies were collected the case studies did not explore the issue explicitly; the conclusions they draw in regard to the first issue are very simple, perhaps even obvious. These are summarized in the upcoming sections (7.2.1 through 7.2.4).

Sections 7.2.1 through 7.2.4 summarize the findings from the case studies which relate to the main objective of this thesis: developing a technical analysis framework. These findings could be grouped into five categories:

1. Methods used to estimate the impacts of TCMs
2. Methods used to prioritize and select projects
3. Structure of project selection processes
4. Legislative requirements
5. Institutional & organizational issues

These categories were discussed in detail by sections 4.3 through 4.7 of Chapter 4.

7.2.1 *Methods Used to Estimate the Impacts of TCMs (Conclusions from Section 4.3)*

The factors which determine which quantification method is best for a given application were discussed by Chapter 3 in detail. The discussion is summarized by Figure 3-3. However, the case studies added some depth to this discussion. First, they expanded the range of available methods for estimating a TCM's impacts to include qualitative methods, not just quantitative ones. Second, they provided some "real-world" examples of the issues raised in Chapter 3. Some of these "real-world" examples are discussed in section 4.3.2. Third, the case studies clarified the types of legislative requirements which affect the choice of method for estimating TCM impacts.

A few issues on the subject of impact analysis arise repeatedly in the case studies: (1) how to package TCMs in order to capture synergistic effects, (2) when to start analyzing TCM packages, (3) analyzing measures using methods which produce comparable results, (4) the appropriate use of detailed travel models vs. sketch planning techniques, (5) when to invest time in conducting technical analysis, (6) the usefulness of quantified impact estimates, (7) the importance of considering land-use impacts, and (8) sometimes qualitative analysis is more accurate than a quantitative approach. Many of these issues were initially brought up by Chapter 3, but the examples found in the case studies add a new depth to the discussion as Section 4.3.2 shows.

7.2.2 *Methods Used to Prioritize and Select Projects (Conclusions from Section 4.4)*

In the case studies, project rankings were derived from a mixing and matching of three types of methods:

1. screening,
2. scoring, and

3. raw evaluation measures.

Tables 4-4 through 4-6 summarize the examples of these methods found in the case studies. Table 4-7 listed the examples presented in those tables, and is reprinted here as Table 7-1.

Table 7- 1 Examples of Screening, Scoring, and Raw Evaluation Measures Found in the Case Studies and Discussed in Section 4.4 ("X" indicates that the case study provided an example of a given method)

	Washington, DC	*San Francisco Bay Area*		*Dallas-Fort Worth*	*Seattle*	*Boston*	
	(SIP)	*(SIP)*	*(TIP)*	*(TIP)*	*(TIP)*	*(PMT)*	*(TIP)*
Screening	X	X		X	X		X
Scoring	X		X	X	X		
Raw Evaluation Measures	X					X	

These three methods were combined in a variety of ways to produce ranking schemes. Namely, the case studies based project ranking on: (1) screening; (2) screening and scoring; or (3) qualitative analysis supported by raw evaluation measure. *In the processes focused on by the case studies, project scores were never the sole criteria upon which projects were ranked.*

The case study regions used both systematic and non-systematic methods for ranking projects. Screening and scoring schemes catered to systematic ranking processes, whereas "raw evaluation measures" catered to non-systematic ranking processes. While screening and scoring were more systematic than "raw evaluation measures," not all screening and scoring schemes were equally systematic. Some screening schemes, such as Seattle's (the one described in Table 4-4) were very vaguely specified. On the other hand, the scoring scheme used by the San Francisco Bay Area in its TIP process (described in Table 4-5 and Appendix S) was much more systematic.

Thus, Section 4.4 lead to one of the major conclusions of this thesis: *that some regions have found it beneficial to use systematic ranking schemes.* A second major conclusion, related to the first major conclusion, is that *a systematic ranking scheme need not be highly quantitative or numerical.* For example, at the onset of Washington, DC's project selection process a highly systematic ranking scheme which combined screening and scoring was used. However, this ranking scheme was based largely on qualitative analysis. This ranking scheme is summarized in Table 4-4 and 4-5.

The third, and final, major conclusion brought forth in Section 4.4 regards the general composition of a systematic ranking scheme. Based on the examples found in the case studies, it may be concluded that developing a systematic ranking process generally involves the following components:

INPUTS:

- ***Criteria*** - Choosing the criteria upon which project ranking will be based.
- ***Measures and Standards*** - Determining measures and standards which will be used to determine if a project complies to the above criteria.
- ***Calculations*** - Determining the value (qualitatively or quantitatively) of these measures and standards.
- ***Weight Criteria*** - Determining the relative importance of the above criteria.

"PROCESSOR":

- Choosing a ranking process such as screening; screening and scoring; or some other method which was not found in the case studies. The ranking process should specify what characteristics a project must have in order to obtain a particular rank. For example, the ranking process could specify that projects which meet all of the screening criteria are ranked as "high priority," and that all other projects are ranked as "low priority." Or, a ranking process could specify that projects with scores between 0 and 30 are ranked as "low priority," projects with scores between 30 and 70 are ranked as "medium priority," and projects with scores between 70 and 100 are ranked as "high priority."

<u>OUTPUT:</u>

- The output of a highly systematic ranking process not only indicates what a project's rank is, but why it was ranked that way. For example, if a project was ranked as "low priority" because its score was very low, this explanation should be available somewhere in the documentation.

The components listed above are not unique to systematic ranking schemes - any ranking scheme must contain the above inputs, outputs, and "processor." *What distinguishes a systematic approach from a non-systematic one*, is how explicitly and specifically the above components are defined. Since not all examples found in the case studies were equally systematic, they did not all define and document the above components to the same level of detail.

Also, it should be noted that the components listed above are not discrete, they are interdependent. For example, it is best to choose measures whose values can be calculated by existing methods (whether they be qualitative or quantitative methods.) Similarly, if one criterion is much more important than any of the other criteria, the ranking process could be defined to reflect this.

7.2.3 Structure of Project Selection Processes (Conclusions from Section 4.5)

The major conclusion brought forth by this section is that *the project selection processes focused on by the case studies often rank projects in "cycles."* In other words, they prioritize projects in stages. They begin by ranking projects roughly so as to reduce the number of potential projects. Once the potential list of projects has been reduced to a point at which more detailed analysis of all the remaining projects is a feasible endeavor (i.e. would not consume too much money and time) projects may be ranked more precisely.

Thus, a given project selection process often makes use of several types of ranking schemes (these were described in section 4.4) and analysis methods (these were described in section 4.3); different ones are used at different stages of a given project selection process. Table 4-8 provides a general description of the types of methods employed at various stages of the processes focused on by the case studies. The table has several implications in regard to:

1. When regions chose to use various types of ranking schemes.
2. When regions chose to perform detailed analysis.
3. When regions attempted to package TCMs.
4. How the initial set of TCMs was derived

Section 4.5 expands on these topics.

7.2.4 Legislative Requirements, Institutional Issues & Organizational Issues (Conclusions from Sections 4.6 and 4.7)

Conclusion #1

Some distinctions between TIP and SIP processes are noted in Section 4.5. Sections 4.6 and 4.7 explain a source of these distinctions. On one level, these differences occur because TIP and SIP processes generally occur at different stages of the TCM prioritization process (as picture in Figure 4-1). Namely, SIP processes usually occur prior to the "Project Development" sieve and TIP processes occur after it. Thus, the projects being ranked at the SIP level have not yet been defined in great detail, which limits the level of detail at which their impacts may be estimated. Also, the range and number of TCMs being ranked at the SIP level usually far exceeds the number being ranked at the TIP level. Although numerous projects are ranked at the TIP level, most of these projects are not TCMs.

Also, SIP and TIP processes must meet different requirements as regards the level and type of detail of projects contained within them, the air quality benefits of the projects contained within them, and the type of financial commitment imposed on the projects contained within them. Section 4.6.2 discussed these three distinctions and their repercussions on the structure of a project selection process, and the methods used within the selection process.

Conclusion #2:

The decisions made at the SIP and TIP level are very critical portions of the TCM prioritization process. The SIP process is critical because, a region is required to implement projects included in the SIP or projects with equally great air quality benefits. The TIP process is critical because, if projects are included in the TIP, they have been assigned a funding source.

The SIP and TIP begin and end, respectively, the TCM prioritization process as can be scene in Figure 4-1. All transportation projects, including TCMs, must pass through the TIP. However, not all TCMs which pass through the TIP and are eventually implemented, originate in the SIP. Some TCMs are committed to in Environmental Impact Statements, and some originate in the project development process simply because they are good transportation projects. (In addition to their air quality benefits, the other transportation benefits of many TCMs are substantial.)

Conclusion #3:

The case studies brought forth some recurring institutional and organization themes which were:

- Who has control over funds
- The role of elected officials, interest groups, general public, & local agencies
- Timing

- Deadlines
- The MPO as an umbrella agency or as a central planner

These were expanded on in Section 4.7 of Chapter 4.

7.3 CONCLUSIONS FROM CHAPTER 5 - A TECHNICAL ANALYSIS FRAMEWORK FOR THE BOSTON REGION

The objective of Chapter 5 was to draw upon the case studies (i.e. Chapter 4) and the review of quantification methods (i.e. Chapter 3) in order to develop a technical analysis framework for the Boston region which specified the interaction of technical analysis with the TCM prioritization decision-making process. In particular, the framework was to address two issues underlying the interaction:

1. Which prioritization decisions should the technical analysis facilitate?
2. How exactly should analysis results be used to facilitate decision making?

The next two subsections (5.8.1 and 5.8.2) describe the conclusions drawn in regard to these two issues.

7.3.1 "How exactly should analysis results be used to facilitate decision making?"

The research mainly addressed the second issue. As a result, this was the focus of the proposed technical analysis framework and the conclusions. The main component of the proposed technical analysis framework was the "Prioritization Methodology" developed in Section 5.4 of Chapter 5. This prioritization methodology specifies "how exactly analysis results should be used to facilitate decision-making."

One underlying theory of the proposed "Prioritization Methodology" is that *the insights gained by applying the methodology are just as valuable to the decision-making process as the actual results of the methodology.* The results are relevant to the decision-making process, but only when considered within the context of the methodology used to produce them.

A second underlying theory of the proposed "Prioritization Methodology" is that *systematizing the interaction of technical analysis and decision-making is beneficial.* A systematic approach is desirable because it helps ensure that all projects are analyzed and considered for priority in an equitable manner (equitable in the sense that all projects are treated in the same manner and have the same opportunity to receive priority status.)

This "Prioritization Methodology" was based on the examples found in the case studies, which focused on TIP and SIP related processes. However, the proposed prioritization methodology is very general and could easily be applied to processes not related to the TIP and SIP. In order to demonstrate the implications of this "Prioritization Methodology" on Boston's current TCM prioritization process, it was applied to 2 critical decisions in Boston's current TCM prioritization process:

1. Which TCMs to consider for inclusion in the SIP. The methods used by the Clean Air Task Force were critiqued in Section 5.5.
2. Which TCMs to include in the TIP. The 1996-1998 TIP prioritization process was critiqued in Section 5.6.

The conclusions drawn from these 2 comparisons are summarized in Table 7-2 (originally included as Table 5-1) and by Sections 7.3.1.1 and 7.3.1.2.

Summary of Proposed Prioritization Methodology

In order to structure the use of technical analysis in making a particular decision, a series of five questions could be answered. When applied to a particular decision and set of TCMs, this series of questions results in a prioritized list of TCMs. The sequence of question is as follows:

1. Which criteria to consider?
2. Which measures best indicate a project's ability to meet these criteria?
3. What analysis method should be used to estimate the value of these measures?
4. What is the relative weight or importance of the criteria identified in Question #1?
5. Which method(s) could develop the "best"[113] relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4)?

Chapter 4 describes how the case study regions chose to answer these five questions. In addition, Chapter 3 describes, in detail, the range of answers to question #3. Both Chapters 3 and 4 identify the factors which govern how to "best" answer each of the five questions listed above.

7.3.1.1 Conclusions Regarding Boston's SIP Process

Although prioritization did obviously occur during the process conducted by the Task Force, the basis for prioritization is not always consistent with what is proposed by this thesis as an idealized method for setting priorities. Sections 5.5.1 through 5.5.5 compared the process conducted by the Task Force to the Prioritization Methodology which was developed based on the case studies (presented in Section 5.4).

[113] Chapter 1 defined the "best" method as the method which (1) maximized the accuracy of the final prioritized list, (2) was the most inexpensive, and (3) was sufficiently precise.

Table 7- 2 Summary of Conclusions (Each cell states whether the Boston's current process addresses the given question and specifies key details on how it was answered.)

	SIP	*TIP*
Question 1: Criteria	YES. Based recommendations on much more than air quality, but did not consider benefits such as mobility, accessibility, safety, and maintenance.	YES. The main contrast between Boston' approach and those found in other case study regions, is that Boston selected projects based on a much more limited set of criteria.
Question 2: Measures	NO. Not clear how compliance with certain criteria was measured	YES. The criteria specified conditions under which a project could be in compliance.
Question 3: Computing the Measures	NO. Aware of many of the issues. Not clear if they analyzed TCM packages. Because measures were specified only vaguely, it is unclear what type of analysis is necessary.	NOT APPLICABLE. Impact estimates were not needed to determine if a project met the specified criteria. However, extensive analysis proceeded the TIP process.
Question 4: Weighting Criteria	NO. Did not systematically weight competing criteria. This contrasts the methods found in the case studies which were, in general, more systematic.	YES. All criteria were equally important.
Question 5: Ranking Projects	NO. Unclear how or why recommended TCMs were better than other TCMs. Did not use a systematic method like scoring or screening like some regions did	YES. Used a screening process to rank projects. The ranking produced was not very precise, but was sufficiently precise.

There are some elements of the Task Force's existing methodology which could be used to conduct the "Prioritization Methodology" proposed in Section 5.4. However, as a whole, the Task Force did not approach its task in the manner the "Prioritization Methodology" encourages. In order to use the "Prioritization Methodology," the Task Force would have to enhance its existing methodology as was discussed. Also, it would have to approach its task in a more systematic and explicit manner.

7.3.1.2 Conclusions Regarding Boston's TIP Process

Boston's existing TIP process conducts all of the five-steps outlined by the proposed "Prioritization Methodology." The main contrast between Boston's approach and those found in other case study regions, is that Boston selected projects based on a much more limited set of criteria. Most other regions included criteria related directly to a project's benefits, while Boston did not. For example, Boston did not explicitly consider benefits such as mobility, accessibility, safety, or maintenance when prioritizing project proposals.

It is unclear, however, if Boston should follow the lead of these other regions, and revise its process to include a broader range of criteria. It is unclear because in Boston most prioritization decisions are made pre-TIP; the project's which are proposed for inclusion in the TIP generally match the available funding which implies one of two things:

- either that some major "prioritization" occurs prior to TIP programming decisions, or
- that it is so clear which (types of) projects the TIP programming process will prioritize, that sponsoring agencies[114] do not find it worthwhile to invest time in developing alternative/additional project proposals.

Including a broader range of criteria would be of no use if project proposals continue to match the available funding.

However, some of Boston's transportation planners believe that developing a broader range of criteria, and ensuring project sponsors that projects meeting these criteria would receive a fair chance of receiving funding - might provide sufficient motivation for project sponsors to develop a broader set of project proposals. This is one issue which stimulated recent attempts to restructure Boston's TIP prioritization process. The main benefit of stimulating a more competitive TIP prioritization process is that the quality of project proposals might increase. A higher "quality" set of projects would be more cost-effective (i.e. cost-effective in the sense that it would fulfill more of the region's transportation needs for the same cost of a lower "quality" set of projects.)

Another major stimulus for revising Boston's existing TIP structure is related to the Central Artery/ Tunnel (CA/T) project. As was described in Section 5.6.5, if the CA/T exceeds its expected budget, then a more precise ranking scheme will be needed in order to decide which projects are most worth funding.

[114] Every project proposed for inclusion in the TIP is proposed by a *sponsoring agency*.

Another major conclusion regards the treatment of SIP TCM commitments in the TIP ranking scheme. In the current TIP ranking scheme, TCMs are given priority if they are included in the SIP. However, as noted in Chapter 3, a TCM's effectiveness is dependent largely on how the transportation system, as a whole, is developed. Thus, if limited funding results in a transportation program different than the one assumed when the SIP commitments were originally made, the value and effectiveness of these SIP commitments should be re-assessed. Perhaps in the context of the new transportation program another set of TCMs would be more effective than the ones originally committed to.

7.3.2 "Which Decisions the Technical Analysis Should Facilitate"

At the beginning of this section (Section 7.3) it was stated that the proposed technical analysis framework aimed to address two issues:

1. Which prioritization decisions should the technical analysis facilitate.
2. How exactly should analysis results be used to facilitate decision making?

Although the thesis focused on the second of the two issues listed above, some conclusions related to the first issue were formed as well. These conclusions are listed below:

- The TIP and SIP processes are two very critical decisions of the TCM prioritization process. They are critical because including projects in these documents commits a region to implementing them. For example, if a region does not fulfill its SIP commitments, sanctions may be imposed on the region by the federal government. Many regions have focused attention on prioritizing projects systematically before deciding which projects to include in these two documents, the SIP and TIP. Boston might consider systematizing their TIP and SIP processes further, and a methodology for doing so was developed in sections 5.4 through 5.6.

- Although TIP and SIP related decisions are very critical, the decisions which come in between the programming of the TIP and the development of the SIP, are also important. This is especially true in Boston since most prioritization decisions are made pre-TIP; the project's which are proposed for inclusion in the TIP generally match the available funding.

- There was one issue brought forth by both Boston and the other four case studies, which neither addressed fully: TCMs which reduce emissions greatly in the long-run must *change* travel behavior (e.g. change the number of trips, the number of vehicel miles traveled, or the speed of travel.) A web of factors govern an individual's travel behavior. Considering this web of factors when prioritizing TCMs involves a high degree of coordination amongst transportation agencies, as well as other public agencies, developers, politicians, businesses, and private citizens. In order to facilitate this high level of coordination, the technical analysis could be used to streamline and tie the various prioritization decisions together. A method for doing this was formulated in Section 5.7.

7.4 CONCLUSIONS FROM CHAPTER 6 - TRIAL RUN OF THE PROPOSED PRIORITIZATION METHODOLOGY

Chapter 6 brought forth one major shortfall of the "Prioritization Methodology" proposed in Chapter 5. Namely, it became apparent from the trial run conducted in Chapter 6, that all five steps of the methodology are interdependent, and therefore they should all be answered at least vaguely before investing extensive time in analysis. Although the trial run did do this (i.e. run through all 5 steps of the "Prioritization Methodology" before investing extensive time in analysis), the "Prioritization Methodology" does not clearly specify the need to do this or how to do this. Thus, an amendment to the proposed methodology is suggested by Chapter 6. In particular, a sixth and a seventh step could be included in the proposed methodology so that the entire methodology would now have the following form:

Revised Prioritization Methodology

1. ***Choose*** **which criteria to consider.**
2. ***Consider*** **which measures best indicate a project's ability to meet these criteria.**
3. ***Consider*** **which analysis method should be used to estimate the value of these measures.**
4. ***Consider*** **the relative weight or importance of the criteria identified in Question #1.**
5. ***Consider*** **which method(s) could develop the "best" relative ranking of projects/options based on the above analysis (i.e. the analysis discussed in Questions 1 through 4.) Conduct ranking in cycles if appropriate.**
6. **Answer questions 1 through 5 *in detail* for the first ranking cycle. Perform all analysis and computations for the first ranking cycle.**
7. **Repeat Step 6 for each subsequent ranking cycle, if the ranking cycle is still necessary given the results of the previous ranking cycle.**

Applying the methodology to the hypothetical situation described in Chapter 6 did not identify any shortfalls in the proposed methodology other than the one discussed above. But, perhaps no shortfalls were identified because the hypothetical situation was very simple. The situation did not deal with some of the more complex issues which arise and which were emphasized by the thesis such as:

- packaging projects;
- tying into and capitalizing on the SIP analysis; and
- long-term vs. short-term impacts.

The case studies offered no conclusions on how to best deal with these issues, they merely brought forth these issues and acknowledged their relevance to developing an effective TCM program. Applying the methodology to a more complex situation might reveal its ability to deal with these issues. Thus, a potential next step to this thesis would involve further testing and refining of the "Prioritization Methodology" proposed.

APPENDIX A

Five Detailed Case Studies

Source: This Appendix is an excerpt from a companion report entitled "The Development of TCM Programs by Regional Transportation Agencies: Assessing the Current-State-of-Practice" listed as Document No. 44.

2.5 How the Case Study Regions Were Selected

Extensive search of the most current literature, together with targeted telephone surveys were used to gather information. In particular, we contacted the US Environmental Protection Agency (USEPA), the Federal Highway Administration (FHWA), consulting companies who had conducted similar research, and selected Metropolitan Planning Organizations (MPO's). Also, current research on related topics was sought. A complete list of contacts made and literature obtained is available in the bibliography.

Due to CAAA guidelines, all areas having "moderate" ozone problems, "moderate" carbon monoxide (CO) problems, or worse, should consider including TCMs in their SIP.

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[1] Document No. 24, p. 64.
[2] Document No. 24, p. 156.

Appendix P describes the specific requirements imposed on ozone, CO, or PM_{10} nonattainment areas. Appendix Q lists the regions in nonattainment for those three pollutants. The complete range of potential case studies includes all nonattainment areas. However, not all of those areas have seriously considered, or implemented TCM's. Research conducted by the Texas Transportation Institute identified cities which have had experience implementing TCMs. Table 2.2 summarizes these findings. Furthermore, a few of these areas have had particularly extensive, or unique experiences devising TCM programs according to FHWA staff and other transportation professionals involved in TCM analysis. Table 2-1 lists some of these regions, as well as the type and amount of information gathered from them to date.

TABLE 2-1: Partial list of regions with significant TCM analysis experience and the amount/type of information obtained from them.

REGIONS in/ including	PHONE INTERVIEW	DOCUMENTATION
Boston Region	yes	yes
State of Connecticut	no	no
Los Angeles, CA	yes	yes
Houston, TX	yes	no
New Jersey	no	incomplete
State of Pennsylvania	not	incomplete
Phoenix, AZ	no	no
Portland, OR	no	no
Sacramento, CA	no	no
Seattle, WA	yes	yes
San Diego, CA	incomplete	incomplete
San Francisco, CA	yes	yes
Tucson, AZ	no	no
Dallas-Fort Worth, TX	yes	yes
Washington, D.C.	no	yes

Of the 15 regions listed above, five were selected to be case studies presented in this report. Each of the selected case study regions have been classified as non-attainment areas by the USEPA. They include Boston, as well as Dallas-Fort Worth, Seattle, San Francisco, and Washington, D.C.

Table 2-2: TCM Use by Metropolitan Statistical Areas (MSA) and Non-MSA's (regions without this statistical distinction)[3]

Location	Trip Reduction Ordinances	Employer-Based Transportation Management Programs	Work Schedule Changes	Areawide Rideshare Incentives	Improved Public Transit	High Occupancy Vehicle Lanes	Traffic Flow Improvements	Parking Management	Park-and-Ride/Fringe Parking	Bicycle and Pedestrian Programs	Special Events	Vehicle Use Limitations/ Restrictions	Accelerated Retirement of Vehicles	Activity Centers	Extended Vehicle Idling	Extreme Low-Temperature Cold Starts
TRANSPORTATION CONTROL MEASURES USED IN MSAs GREATER THAN 1,000,000 POPULATION																
Phoenix, AZ	X	X	X	X		X	X									
Los Angeles - Anaheim - Riverside, CA	X	X	X	X	X	X	X	X	X		X	X	X		X	
Sacramento, CA	X			X			X	X							X	
San Diego, CA						X	X									
S. F. - Oakland - San Jose, CA	X	X	X	X		X	X	X				X				
Denver - Boulder, CO	X	X	X		X	X	X					X				
Hartford - New Britain - Middletown, CT		X		X				X	X							
Washington, DC - MD - VA	X	X	X	X			X	X				X				
Miami - Fort Lauderdale, FL						X						X				
Orlando, FL						X		X			X					
Atlanta, GA						X	X		X							
Chicago - Gary - Lake County, IL - IN - WI		X	X			X	X	X	X							
Indianapolis, IN						X										
Boston - Lawrence - Salem, MA - NH			X			X	X	X	X		X	X				
Baltimore, MD						X		X								
Detroit - Ann Arbor, MI							X									
Minneapolis - St. Paul, MN - WI		X	X			X	X	X	X			X				
Kansas City, MO - KS		X														
St. Louis, MO									X							
New York - Northern New Jersey - Long Island, NY - NJ - CT		X	X	X		X	X					X				
Cincinnati - Hamilton, OH - KY - IN							X									
Cleveland - Akron - Lorain, OH									X							
Columbus, OH							X									
Portland - Vancouver, OR - WA				X	X	X	X	X				X				
Philadelphia - Wilmington - Trenton, PA - NJ - DE - MD						X	X		X			X				
Pittsburgh - Beaver Valley, PA						X	X									
Providence - Pawtucket - Fall River, RI - MA							X					X				
Dallas - Fort Worth, TX		X				X	X									
Houston - Galveston - Brazoria, TX		X	X			X	X		X							
San Antonio, TX						X	X	X	X							
Norfolk - Virginia Beach - Newport News, VA					X		X									
Seattle - Tacoma, WA	X	X	X	X		X	X	X	X	X	X					
Milwaukee - Racine, WI							X		X							

*Continued on the Next Page

[3] Document No 16, p. 7-8, table 1.

Location	Trip Reduction Ordinances	Employer-Based Transportation Management Programs	Work Schedule Changes	Areawide Rideshare Incentives	Improved Public Transit	High Occupancy Vehicle Lanes	Traffic Flow Improvements	Parking Management	Park-and-Ride/Fringe Parking	Bicycle and Pedestrian Programs	Special Events	Vehicle Use Limitations/ Restrictions	Accelerated Retirement of Vehicles	Activity Centers	Extended Vehicle Idling	Extreme Low-Temperature Cold Starts
TRANSPORTATION CONTROL MEASURES USED IN MSAs WITH POPULATION FROM 250,000 to 999,999																
Tucson, AZ					X		X			X						
Oxnard - Ventura, CA	X	X														
Melbourne - Titusville - Palm Bay, FL					X											
Honolulu, HI			X			X	X	X				X				
Des Moines, IA							X									
Ft. Wayne, IN							X									
Louisville, KY					X	X	X					X				
Albuquerque, NM							X									
Albany - Schenectady - Troy, NY			X							X						
Syracuse, NY							X									
Toledo, OH									X							
Eugene - Springfield, OR								X								
Allentown - Bethlehem - Easton, PA - NJ												X				
Harrisburg - Lebanon - Carlisle, PA						X										
San Juan, PR						X										
Charleston, SC							X									
Knoxville, TN			X								X					
Memphis, TN - AR - MS												X				
Austin, TX							X									
Beaumont - Port Arthur, TX																
El Paso, TX																
Madison, WI			X			X	X	X		X		X				
TRANSPORTATION CONTROL MEASURES USED IN MSAs WITH POPULATION FROM 100,000 to 249,999																
Gainesville, FL							X									
Lake Charles, LA							X									
Kalamazoo, MI												X				
Sioux Falls, SD							X									
Amarillo, TX		X														
TRANSPORTATION CONTROL MEASURES USED IN NON-MSAs																
Fairbanks North Star Borough, AK																X
El Segundo, CA		X	X													
San Ramon, CA		X														
Ottawa-Carleton, Canada						X										
Golden, CO		X														
Idaho Springs, CO							X									
Danville, IL												X				
Atchison, KS												X				
Salisbury, MD												X				
Maplewood, MN		X														
Minnetonka, MN		X														
Ft. Lee, NJ						X										
Nutley, NJ		X														
Princeton Area, NJ		X														
Corning, NY		X														
Tarrytown, NY							X									
Kent, OH					X											
Lehigh, PA							X									
Brattleboro, VT		X														

3.3 WASHINGTON, D.C.

3.3.1 WHY THIS REGION WAS INCLUDED AS A CASE STUDY

The Washington, D.C. region is designated as a "serious" nonattainment area for ozone pollution and as "moderate" for carbon monoxide. Because of this the region had to develop a plan to reduce emissions of volatile organic compounds (VOCs) 15% below 1990 levels. The plan had to be completed no more than three years after the 1990 CAAA was enacted (November 15, 1993). The 15% reduction itself, had to be achieved within 6 years of the 1990 CAAA's enactment.

The Washington, D.C. region undertook an extensive TCM analysis/ prioritization/ selection process in order to identify measures worth including in the 15% reduction plan. The process, partially funded by FHWA, was clearly and concisely documented so that other MPOs might benefit from Washington's experiences.[1]

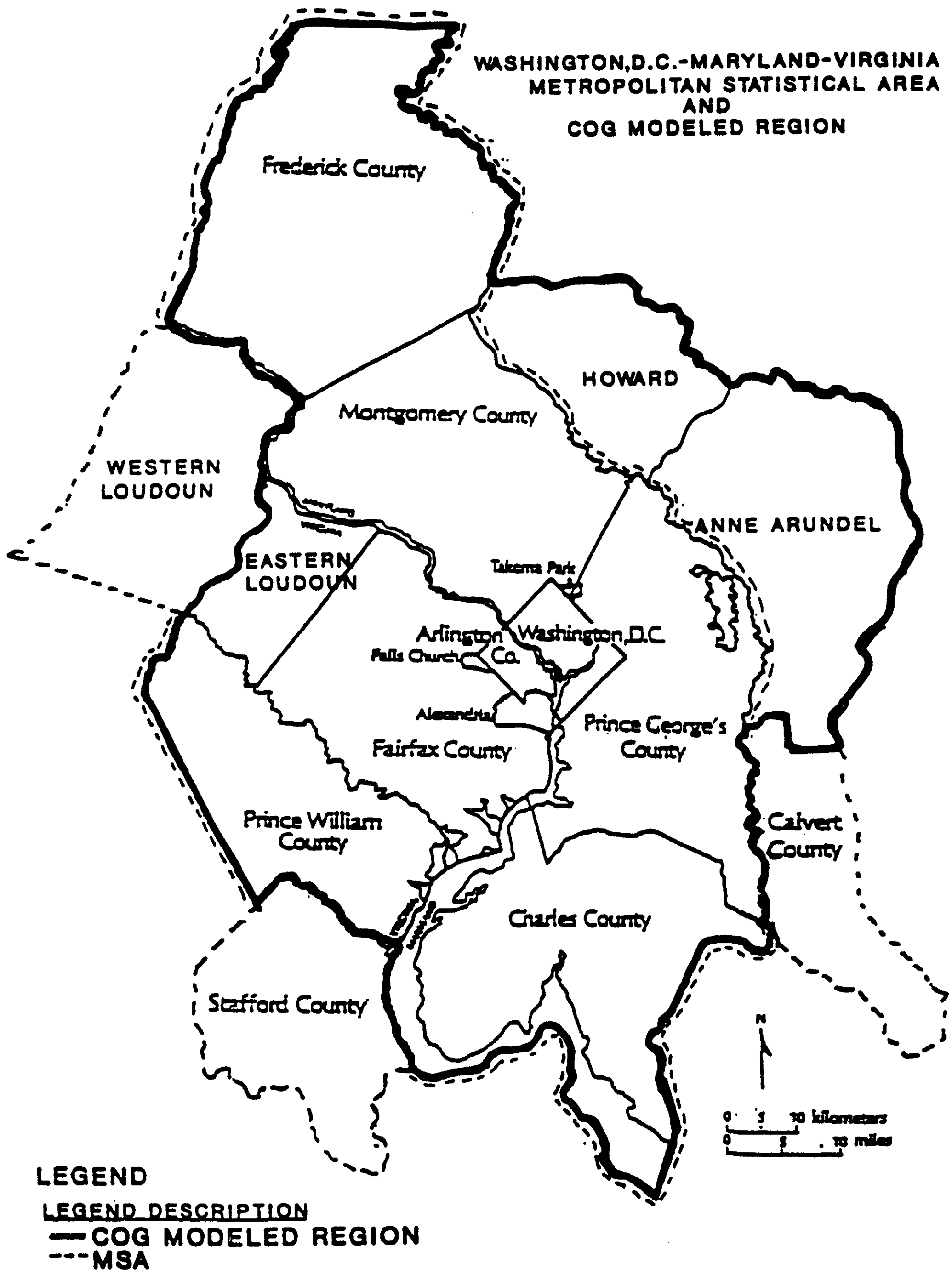
It was primarily because of the comprehensive nature of Washington, D.C.'s experiences and documentation that it is included as a case study. However, it is also included because its transportation system and location are similar to Boston's. The Washington, D.C. area has invested heavily in both its subway and roadway network. Also like Boston, Washington, D.C. is located on the east coast.

3.3.2 BRIEF REGIONAL PROFILE

The Washington, D.C. non-attainment area covers portions of Maryland, Virginia, and the District of Columbia. In particular, it includes the following jurisdictions: District of Columbia; Arlington, Fairfax, Loudoun, Prince William, Stafford, Alexandria, Falls Church, and Fairfax in Virginia; Calvert, Charles, Frederick, Montgomery, and Prince George in Maryland. Figure 3.3-1 presents a map of the nonattainment area.

[1] Washington No. 1, p. 1-5.

Figure 3.3-1: Map of Non-Attainment Area



3.3.3. DESCRIPTION AND STATUS OF CURRENT TCM RELATED PROGRAMS

The TCM analysis process described in this case study was followed to screen and select TCMs for inclusion in Washington, D.C.'s 1993 SIP revision to achieve a 15% VOC reduction. Of the nearly 200 TCMs initially identified, 159 were scored. Based on the scoring 59 were chosen for detailed analysis and 14 TCMs were finally selected and packaged into five groups. A complete list of the TCMs originally considered is available in Appendix A and the 14 measures eventually selected are listed below.[2]

- *Group 1: Public Information Campaign*
  Voluntary no drive days during episodes

- *Group 2: Traffic Engineering/Advanced Technology*
  - Cash for Clunkers
  - Speed Limit Adherence
  - Construct Missing Sidewalks and Other Pedestrian Facilities
  - Install Bicycle Racks and Lockers
  - Signals to Flashing Yellow between 12 a.m. and 5 a.m.
  - Implement Advanced Transportation Management System
  - Bicycle Element of the Long-Range Plan
  - Right Turn on Red in D.C.

- *Group 3: Employer Trip Reduction (support)*
  - Upgrade Ride Finders
  - Telecommuting Centers in Outlying Areas and the District of Columbia

- *Group 4: Transit and HOV Incentive*
  - Expand Full Park-and-Ride Lots at Rail Stations
  - New Park-and-Ride Lots in vicinity of selected major intersections

- Group 5: Employee Commute Option Program (ECO)
  - Employee Trip Reduction Program

The Transportation Planning Board deleted the fifth option form the list before forwarding it to the Metropolitan Washington Air Quality Committee (MWAQC). By December 17, 1993, the MWAQC decided to include one TCM, "Right turn on red in D.C.", in the primary group of control measures included in the SIP. The remaining measures were to be considered for the contingency portion of the plan which had to be completed by November 15, 1994.

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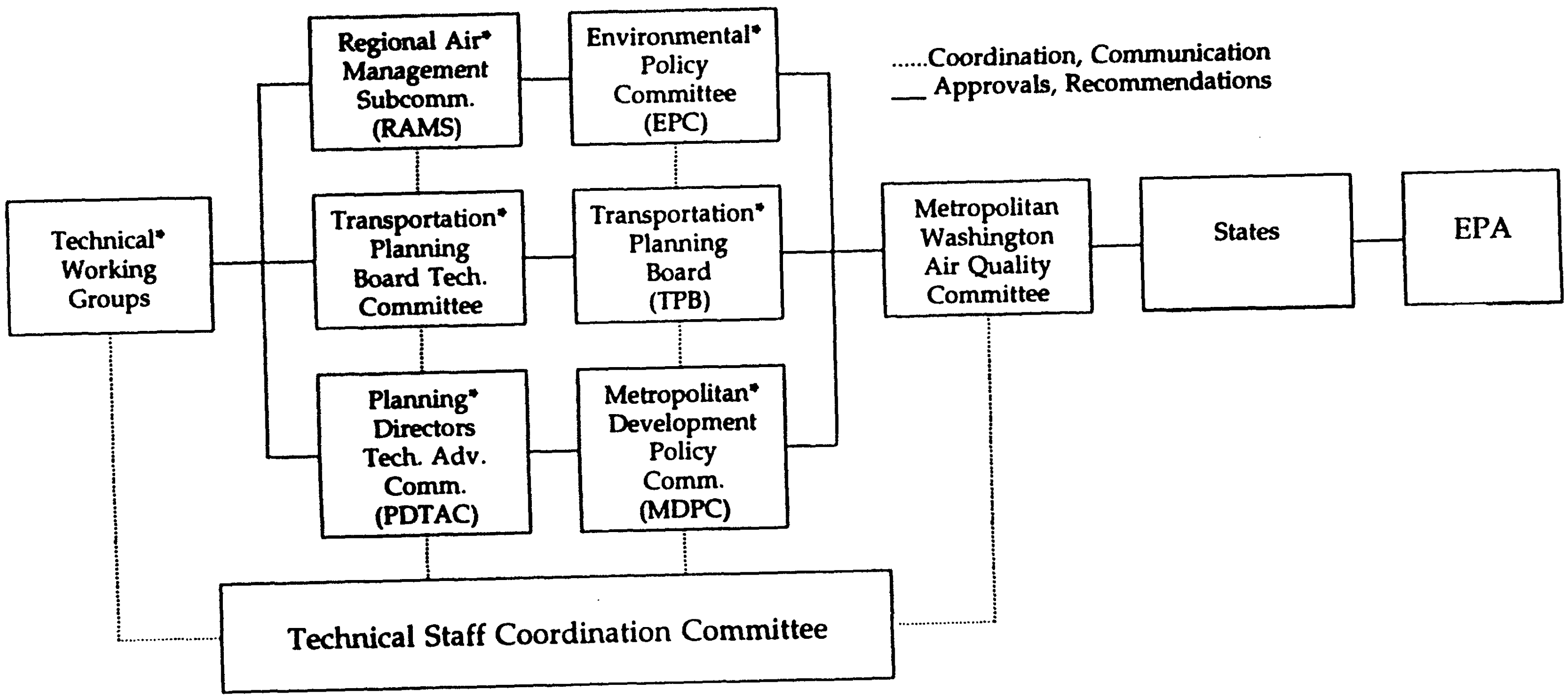
[2] Washington No. 1, p. 9.

Figure 3.3-2: Air Quality Planning Process and Organizational Structure[3]



* Stafford, Calvert and Charles Counties to be represented on all policy and technical committees for purposes of air quality plan preparation and adoption. Tri-County Council for Southern Maryland to be a voting representative of Calvert and Charles Counties at their option.

The Traffic Mitigation Subcommittee falls under the Technical working group.

[3] Washington No. 1, p. 6.

3.3.4 ORGANIZATIONAL STRUCTURE

The states of Maryland, Virginia, and the District of Columbia all participate in the air quality planning for the Washington, D.C. nonattainment area. The organizational structure may best be understood through Figure 3.3-2 and the following "job descriptions".

The Metropolitan Washington Air Quality Committee (MWAQC): One of two policy committees, this one deals with all air quality issues.

The Transportation Planning Board (TPB): The second of the two policy committees. This is the Metropolitan Planning Organization for Washington, D.C. It is responsible for the development, analysis, and financial commitment of TCMs.

Traffic Mitigation Subcommittee (TMS): A subcommittee of the Technical Committee to the TPB, this group was in charge of formulating and screening measures. The TMS was two years old when assigned this role. Previously it had focused on congestion reduction and other such topics. The subcommittee consists of about 40 transportation professionals with varied backgrounds and modal experiences, as well as representatives form environmental, citizen, and business groups. Added to the committee were representatives from the Bicycle Technical Advisory Subcommittee, the Mid-Atlantic Telecommuting Advisory Council, the Ride Finders Network, and the Transportation Management Associations Group.[4]

3.3.5 METHODS USED TO PRIORITIZE AND SELECT PROJECTS

Process

The TCM analysis process described in this case study took one and a half years to complete. A sequence of five phases comprise the overall process which culminated in the proposal of 14 TCMs to the MWAQC.

Phase I: In the first phase a list of 200 potential TCMs was compiled. The Traffic Mitigation Subcommittee attempted to gather a comprehensive list by consulting a variety of sources: the USEPA, FHWA, the Environmental Defense Fund, the American Automobile Association, other parts of the country (California, Oregon), other metropolitan areas, other parts of the immediate states involved, and local jurisdictions (Montgomery county, MD, the City of Alexandria, VA). The list of 200 TCMs was eventually reduced to a size of 164 without the use of any systematic scoring method. (See appendix A for a list of the 164 TCMs)

[4] Washington No. 1, p. 5.

Phase II: Unlike phase I, phase II involved a systematic scoring procedure. First, the 164 TCMs were grouped into five categories: mobility improvements, policy/legislative instruments, employer programs, non-work measures, and traffic operations. The TCMs were then analyzed in terms of seven evaluation criteria which had been developed during phase I:

1. Travel reduction potential (surrogate for emission reduction)
2. Cost (subdivided into public and private categories according to who would bear responsibility for a measure's implementation)
3. Speed of implementation
4. Political acceptability
5. Synergistic effect
6. Cost effectiveness (a ratio of the cost divided by the travel reduction potential)
7. And other benefits (including related non-air quality gains such as revenue generation potential, quality of life, reduction of energy demand, etc.)

Since evaluations were made before actual values for these measures were available, each criteria was scored in a very general manner. A project was scored as "low", "medium", or "high" in each category. Thus, a total of three points could be earned in each category accept in those categories which received double weighting: "Cost" and "Travel Reduction Potential".

In addition to being evaluated on this combination of qualitative and quantitative criteria, a project could receive a "must include" vote. Given this scoring system, the list of 164 measures was distributed to all members of the subcommittee and other interested participants for their evaluation. The results of the evaluations were tabulated and then used to reduce the list of 164 measures to a size of 59. The selection of these 59 measures revolved around three factors:

- a numeric score of 16 or above
- project implementable by 1996
- five or more "must include" votes

Phase III: During phase III, the 59 measures underwent quantitative testing. Eleven of the measures involved land use changes not readily modeled by available transportation methodologies. Their analysis was therefore delegated to the Planning Directors Technical Advisory Committee. The other 48 measures were analyzed using a combination of the Council of Government's mode choice model, the COMSIS TDM model, the MOBILE emissions model, and sketch planning techniques. The next section (3.3.6) describes these tools in more detail.

Phase IV: The eventual goal of the fourth phase was to identify which measures should be recommended to the Technical Committee for their review and consideration. A motley of tasks were undertaken simultaneously in order to achieve this goal. Some of the primary efforts included:

- The first attempt to group TCMs so as to capture potential synergistic effects.
- TCMs were being analyzed in more detail
- Information exchange and coordination amongst the Traffic Mitigation Subcommittee and other agencies involved in developing the 15% reduction plan (not necessarily transportation related agencies, since the transportation sector contributes only a portion of air pollution.) Some "other agencies" include the Regional Air Management Subcommittee, the Planning Directors Technical Advisory Committee, COG TPB subcommittees, the Mid-Atlantic Telecommuting Advisory Council, the Bicycle Technical Advisory Committee, the Ride Finders Network, and Transportation Management Association Group. More on these institutional experiences will be provided in a following section.

The attempt to package TCMs was not completed although some proposals were made. Some groupings suggested were:

- by mode
- by date of effect and/or benefit
- by degree of difficulty or implementation
- by economic factors such as market based, combined public-private approach, and public investment
- by underlying life style values and preferred outcomes

Since time ran short on this phase, around 40 TCMs were eventually recommended to the TPB Committee for their consideration and decision.

Phase V: During the fifth and final phase of the process, the TPB and its various committees would select the set of TCMs to be recommended to the MWAQC for inclusion in the SIP. Over a period of six months policy makers, elected officials, and the public reviewed a list of 48 control using their own criteria. The TPB Technical Committee finally selected 14 measures and packaged them into 5 groups listed previously in this report. The TPB eventually deleted the employee commute option from the list and forwarded the rest to the MWAQC.

Conclusion: On December 17, 1993, the MWAQC decided to adopt one TCM, "right turn on red in D.C.", in the primary group of control measures included in the SIP. The remaining measures would be considered for the contingency plan whose deadline had been extended to November 15, 1994.[5]

[5] Washington No. 1, p. 5-10.

3.3.6 ANALYSIS OF IMPACTS

The analysis of impacts consisted of four stages: calculation of emission reduction potential, emission reductions, cost/cost-effectiveness, and synergistic effects. The following sections describe each of these sections in more detail.

Methods Used to Estimate Emission Reduction Potential

Based on the scoring completed in phase II of the process, 59 measures were forwarded to phase III for detailed analysis. All of these measures, except for the 11 which dealt with land- use policy changes, were analyzed using a combination of four tools: the Metropolitan Washington Council of Governments' (MWCOG) mode choice model, the COMSIS TDM model, EPA's MOBILE emissions model (for measures that lead to system-speed changes) , and sketch planning techniques.[6] These four tools were used to calculate the "emission reduction potential" of each measure in the form of vehicle-trip (VT) reductions, vehicle-miles-traveled (VMT) reductions, and emission factor changes.

Results from these four tools had to be adapted to account for the following factors:

- The MWCOG modeled region is different from the non-attainment region.
- The modeling techniques used account for only home-based work trips. Survey data suggests that approximately 40-50% of all travel has some association with work, although it is not home-based. For instance, a chain of trips (home-daycare-supermarket-work) on the way to/from work are all work-related journeys, but are not "home-based" trips technically speaking.

The next few paragraphs describe the three transportation modeling techniques in more detail:

The COG Mode Choice Model: It has a multinomial logit form and uses a market segmentation strategy to better account for the variety of travel markets. The choice set is two tiered. In the first tier a traveler chooses between "drive alone", "group ride", and "transit". Having chosen the "group ride" option a traveler then chooses between a "2 person car occupancy", a "3 person", or a "4 or more person". Two models are used to represent this two tiered choice set: a primary model and a car occupancy model. Much more detail on the COG Mode Choice Model is available in the footnoted source.[7]

The TDM Evaluation Model: The model was developed by COMSIS Corporation in the late 1980's and a public-domain version was released in late 1993 by FHWA. It is a self-contained software package that operates on a microcomputer. It was developed to provide quick, quantitative analysis of the travel impacts of Travel Demand Management strategies. It enables the testing of both individual TCMs and TCM-packages (i.e. it

[6] Washington No. 1, p. 8.
[7] Washington No. 1, p. 12-18.

accounts for synergistic effects). Trip tables are the general input requirement, although surveys and other data may be needed. The model converts these inputs into impacts by a "pivot point" technique. Essentially this involves discerning the current condition from the modal split of the background travel data, and then projecting the change in modal split due to the tested policies/strategies as departures from this starting point. This technique eliminates the need to compile detailed information on starting conditions. While this is the main strength of this method, it is also its main weakness relative to the COG Mode Choice Model since it prevents the TDM model from providing the same level of detail.

In short, the TDM model was deemed to be a quick, reasonably accurate, interactive "policy" tool capable of analyzing a variety of TDM strategies, some of which could not be analyzed by the COG Mode Choice model. In particular, the model was developed to analyze a variety of employer-based TDMs, but it can also analyze some areawide measures such as transit improvements, HOV lanes, and a range of pricing actions. Some TDMs which the model can analyze include:

- Employer Support Measures:
  - Information programs
  - Employer transportation coordinators
  - Flexible work schedules
  - Rideshare matching
  - Vanpool formation and support
  - Transit pass sales
  - Preferential parking for HOVs
  - Guaranteed ride home

- Alternate Work Schedules:
  - Flexible work hours
  - Staggered work hours
  - Compressed work weeks
  - Telecommuting

- Financial Incentives and Disincentives:
  - Modal subsidies for transit, carpool or vanpool
  - parking surcharges

Of the 48 TCMs analyzed in detail during phase III, several were difficult or impossible to analyze using the regional mode choice model. The TDM model was found to be the best way to analyze the following types of measures:

- Employer Trip Reduction Programs (measures M-41 and M-45 to be listed later)
- Telecommuting (M-46)
- Compressed Work Weeks (M-45)
- Some Park-and-Ride (M-35 and M-39)
- Select Work-based Pricing Measures (M-07, M-19, M-49, M-42)
- Select Regional HOV Lane Improvements (M-52)

Sketch Planning Analysis: In the absence of pre-existing formal techniques (e.g. 4-step model or TDM model), project-specific methodologies are devised to analyze impacts. Because the method varies from project to project, presenting all such methods here would be a lengthy diversion. However, an example is available in Appendix Band all other approaches are described in document "Washington No. 1".

Methods Used to Estimate Emission Reductions

Following the calculation of the "emission reduction *potentials*" using the methods just described, three stages of the technical analysis procedure remained. During the first of the three stages, Mobile emission factors were used to convert VT, VMT, and emission factor changes into emission reductions. The emission factors used were:

Cold Start:	2.919 grams/trip
Running:	0.551 grams/mile
Hot Soak:	1.114 grams/trip

Level of detail was compromised so that a few simplifying assumptions could be made:

- Non-travel related emissions such as spillage during transport/fueling, resting loss, and diurnal emissions were not accounted for in this analysis.
- Unlike the conformity process which used different emission factors for each jurisdiction and time of day, the TCM analysis used an average for the region.

However, the analysis did attempt to improve its accuracy by considering a few specifics:

- Whether the measure related only to home-based work trips or to all trips
- Whether the impact is only during the peak periods, during the off-peak periods, or at all times
- Whether the impact was felt region-wide or only in a certain jurisdiction

How Applied to Measures

The analysis of each measure is described in detail in document "Washington No. 1". Table 3.3-1 lists the 48 measures analyzed by transportation staff and the methodology used for each project. Also, three sample analysis are included in Appendix B.

Table 3.3-1: TCMs analyzed by transportation staff and methodology used for each[8]

NO.	SHORT DESCRIPTION	MODE-CHOICE MODEL	TDM EVALUATION MODEL	SKETCH PLANNING
M-04	Cash for Clunkers			√
M-07	Mandatory Cash-Out Subsidy for Transit/HOV		√	
M-08	Single Price Public Transit Services	√		
M-09	"Pollution Fee" for Gasoline-Powered Motor Vehicles	√		
M-10	Increase Gasoline Taxes by $0.75 Per Gallon	√		
M-11	Congestion Pricing on LOVs (Max. 20¢/mile)	√		
M-12	Employee Parking Space Tax Outside Metro Core	√		
M-13	Employee Parking Space Tax in Metro Core	√		
M-14	Half price fares on feeder bus service to metrorail	√		
M-15	Graduated Tax on Vehicle Mileage	√		
M-16	Market-based Parking Charges for Federal Facilities	√		
M-17	Congestion Pricing on LOVs (Max. 10¢/mile)	√		
M-18	Free Rail Fares Between 10am and 3pm Weekdays			√
M-19	Free Parking for Carpools and Vanpools	√	√	
M-20	Congestion Price Low Occupancy Vehicles (Min./$0.10)	√		
M-23	Graduated Additional Vehicle Registration Fee	√		
M-24*	Increased Adherence to the 55 MPH Speed Limit			√
M-25	Increase the Frequency of Existing Transit Service	√		
M-26	Increase the Frequency of Commuter Rail	√		
M-27	Timed Transfer Service with Extensive Suburban Coverage	√		
M-28	Improve Pedestrian Facilities Near Rail Stations			√
M-29	Provide Bicycle Racks and Lockers at All Transit Stations			√
M-30	Flashing Yellow in Predominant Direction, Midnight-5am			√
M-31	Highway Ramp Metering	√		
M-32	Increase Bus Speeds in High Volume Bus Corridors	√		

[8] Washington No. 1, p. 24-25.

NO.	SHORT DESCRIPTION	MODE-CHOICE MODEL	TDM EVALUATION MODEL	SKETCH PLANNING
M-33	Develop Pedestrian/Bicycle Access to Commercial Centers			√
M-35	Build New P&R Lots Associated With HOV Facilities			√
M-36*	Implement Advanced Transportation Management Systems			√
M-37	Complete Bike Element of LRP within 10 years			√
M-38	Right Turn on Red throughout D.C.PAGE 107			√
M-39	P&R Lots Near Selected Major Highway Intersections			√
M-41	Mandatory Employee Commute Options		√	
M-42	Regional Voucher Program		√	
M-43	Monthly Transit Passes/Regional Fare Media	√		
M-44	On-site Employer Trip Reduction Programs		√	
M-45	Flexible Work Week/Four Day Work Week		√	
M-46	Financial Incentives for Telecommuting Programs		√	
M-47	Integrated Ridesharing Measures			√
M-38	Shorter Distances from Bus Stops to Buildings	√		
M-49	Regional Vanpool Insurance Pool		√	
M-50	Convenience Commercial Centers in Residential Areas			√
M-52	Build HOV Network in the Freeway System		√	
M-53	Control Student Parking at High Schools			√
M-54	Free Transit Passes for Students			√
M-55	Employer-Provided Bicycles			√
M-56	Control of Extended Idling			√
M-57	Restrict New Parking Construction		√	
M-58	Telecommuting Centers in Outlying Areas		√	

* requires MOBILE model run

Results

The analysis results may best be summarized by the tables 3.3-2 and 3.3-3.

Table 3.3-2: Summary Table of Transportation Impacts and Emission Reduction of TCMs[9]

NO.	SHORT DESCRIPTION (page #)	VT REDUCED	VMT REDUCED	VOC REDUCED (tons/day)
M-04	Cash for Clunkers (43)	N/A	N/A	1.00
M-07	Mandatory Cash-Out Subsidy for Transit/HOV (44)	555,300	7,166,500	6.82
M-08	Single Price Public Transit Services (50)	129,700	2,114,700	1.86
M-09	"Pollution Fee" for Gasoline-Powered Motor Vehicles (53)	56,200	1,027,700	0.87
M-10	Increase Gasoline Taxes by $0.75 Per Gallon (56)	52,500	973,400	0.83
M-11	Congestion Pricing on LOVs (Max. 20¢/mile) (60)	29,400	108,600	0.20
M-12	Employee Parking Space Tax Outside Metro Core (64)	154,500	2,063,100	1.94
M-13	Employee Parking Space Tax in Metro Core (68)	147,100	1,954,500	1.84
M-14	Half price fares on feeder bus service to metrorail (71)	41,600	453,200	0.46
M-15	Graduated Tax on Vehicle Mileage (74)	13,600	286,500	0.23
M-16	Market-based Parking Charges for Federal Facilities (77)	44,100	597,200	0.56
M-17	Congestion Pricing on LOVs (Max. 10¢/mile) (80)	18,400	(108,600)	0.02
M-18	Free Rail Fares Between 10am and 3pm Weekdays (84)	6,300	50,900	0.06
M-19	Free Parking for Carpools and Vanpools (87)	3,700	108,600	0.08
M-20	Congestion Price Low Occupancy Vehicles (Min./$0.10) (89)	3,700	(217,200)	(0.12)
M-23	Graduated Additional Vehicle Registration Fee (93)	60,600	1,054,100	0.91
M-24	Increased Adherence to the 55 MPH Speed Limit (97)	N/A	N/A	0.7
M-25	Increase the Frequency of Existing Transit Service (99)	72,100	1,153,300	1.02
M-26	Increase the Frequency of Commuter Rail (102)	8,100	221,400	0.17
M-27	Timed Transfer Service with Exten. Suburban Coverage (105)	18,900	274,500	0.25
M-28	Improve Pedestrian Facilities Near Rail Stations (108)	1,900	17,000	0.02
M-29	Provide Bike Racks and Lockers at All Transit Stations (112)	2,000	22,800	0.02

[9] Washington No. 1, p. 40-41.

NO.	SHORT DESCRIPTION (page #)	VT REDUCED	VMT REDUCED	VOC REDUCED (tons/day)
M-30	Flashing Yellow in Predominant Direction, Midnight-5am (114)	N/A	N/A	0.06
M-31	Highway Ramp Metering (117)	0	18,300	0.01
M-32	Increase Bus Speeds in High Volume Bus Corridors (119)	4,100	49,500	0.05
M-33	Develop Pedestrian/Bike Access to Commercial Centers (122)	190	570	0.001
M-35	Build New P&R Lots Associated With HOV Facilities (124)	(2,400)	41,600	0.015
M-36	Implement Advanced Trans. Management Systems (127)	N/A	N/A	0.50
M-37	Complete Bike Element of LRP within 10 years (129)	71,600	84,300	0.37
M-38	Right Turn on Red throughout D.C. (131)	N/A	N/A	0.39
M-39	P&R Lots Near Selected Major Highway Intersections (133)	(730)	63,500	0.04
M-41	Mandatory Employee Commute Options (137)	415,600	6,135,000	5.60
M-42	Regional Voucher Program (140)	172,800	2,388,800	2.20
M-43	Monthly Transit Passes/Regional Fare Media (143)	45,900	597,500	0.57
M-44	On-site Employer Trip Reduction Programs (146)	95,600	1,411,600	1.28
M-45	Flexible Work Week/Four Day Work Week (149)	66,200	977,300	0.89
M-46	Financial Incentives for Telecommuting Programs (151)	62,500	868,700	0.81
M-47	Integrated Ridesharing Measures (154)	15,500	381,800	0.30
M-48	Shorter Distances from Bus Stops to Buildings (157)	6,400	67,500	0.07
M-49	Regional Vanpool Insurance Pool (160)	N/A	N/A	*
M-50	Convenience Commercial Centers in Residential Areas (161)	4,770	14,310	0.03
M-52	Build HOV Network in the Freeway System (163)	34,900	684,100	0.57
M-53	Control Student Parking at High Schools (165)	16,000	86,000	0.12
M-54	Free Transit Passes for Students (167)	10,000	50,000	0.07
M-55	Employer-Provided Bicycles (169)	4,500	13,500	0.03
M-56	Control of Extended Idling (171)	N/A	N/A	0.39
M-57	Restrict New Parking Construction (172)	53,400	776,500	0.71
M-58	Telecommuting Centers in Outlying Areas (177)	19,000	1,083,400	0.74*

* Full emission benefits

Table 3.3-3: TCM Emission Reduction vs. Cost Effectiveness[10]

EMISSIONS REDUCTION (tons per day)*	REVENUE PRODUCING	$0 - $49K/ton	$50K - $99K/ton	$100K - $249K/ton	$250K - $499K/ton	More than $500K/ton
Less than 0.5	M-11 Cong. Price (20s) (60) M-15 Mileage Tax (74) M-17 Cong. Pricing (10s) (80) M-20 Cong. Pricing (min) (86) M-30 Flashing Yellow (114)	M-29 Bicycle Racks/Lockers (112) M-38 RTOR in D.C. (131) M-60 Conv. Ctrs @ Resident.(161) M-63 Control Student Parking(165) M-66 Control Extend Idling (171)	M-37 Bike Element in 10 yrs (129) M-39 P&R Lots at Intersect (133) M-47 Ridesharing (154)	M-14 1/2 Price Feeder Bus (71) M-27 Timed Transfer (105) M-32 Increase Bus Speeds (119) M-55 Employer provides Bikes (169)	M-26 Increase Commuter Rail (102 M-33 Ped/Bike Access to Ctrs (122) M-35 New P&R Lots (HOV) (124) M-48 Short. Dist to Bus Stop (157)	M-18 Free off-peak Rail (84) M-19 Free Pool Parking (87) M-28 Pedestrian Facilities (108) M-31 Ramp Metering (117) M-54 Free Transit for Student (167)
0.5 - 0.99	M-09 Pollution Fee (53) M-10 Gasoline Tax (56) M-16 Market Park. for Feds (77) M-23 Veh. Registration Fee (93) M-45 Flex Work Schedule (149) M-67 Restrict New Parking (172)	M-24 Speed Limit Adherence (97) M-36 A.T.M.S. (127)		M-43 Transit Passes (143) M-58 Telecommute Cntrs (177)	M-46 Incentives to Telecomm. (151)	M-62 Freeway HOV System (163)
1.0 - 1.49		M-04 Cash for Clunkers (43)		M-25 Increase Existing Transit (99)	M-44 ETR Program (146)	
1.5 - 1.99	M-12 Parking Tax (non-core) (64) M-13 Park Tax (core) (68)			M-08 Single Price Transit (50)		
2.0 - 2.49						M-42 Regional Voucher (140)
2.5 - 2.99						
3.0 - 3.49						
3.5 - 3.99						
4.0 - 4.49						
4.5 - 4.99						
5.0 - 5.49						
5.5 - 5.99				M-41 Mandatory ECO (137)		
6.0 +						M-07 Cash-Out (44)

* Emission benefits by 1996

[10] Washington No. 1, p. 42.

3.3.7 LESSONS LEARNED

Project Selection Process

The Washington, D.C. report describes some of the strengths and weaknesses of its project selection process that are summarized below.

- The Traffic Mitigation Subcommittee was able to formulate an exhaustive list of TCMs, select a limited number for evaluation ahead of other technical committees dealing with stationary and point source control measures. As staff and their consultants finished emission reduction analysis and cost estimation the subcommittee was able to review and provide comments within a short time. The main task of the TMS was technical advice on TCMs and it performed it admirably.

- Coordination with the various subcommittees and groups was achieved by including the chairs/representatives in the TMS. However, this did not work all the time and subsequent review of this policy was necessary to achieve the desired results.

- One of the strengths of the process was that it was bottom-up and an open one. Also, non-traditional ideas were evaluated as fully as available methodology and time permitted.

- Conversely, this degree of openness, and the length of the comprehensive list which ensued from it, resulted in an exhaustive review, analysis, and selection process, perhaps making it more difficult to subsequently narrow the focus, to build consensus around the measures which would be chosen for the plan, and to reach closure. The bottom-up process also takes an enormous amount of time which proved to be difficult during this process.

- One of the other weaknesses of the process was the lack of a well defined set of critical dates and outcomes which could have made clearer the interrelationship of the different committees, their products and how they all interacted to form a final plan. This, in turn, could have facilitated the building of consensus, and the lessening of conflict, since conflict is likely to be inherent in any undertaking seeking to create significantly new public policy, especially that with an attendant element of implied social change.

- Consensus does not simply happen; it must be worked at and built - even more so when a plan is being developed which may result in significant changes to prior working relationships or the way in which people live. In such an instance, leadership and vision are needed in order to bring the different plan elements and divergent public perspectives together, as well as to avoid gridlock and acrimony. That the building of consensus and the lessening of conflict did not occur early in the process constitute another of its weaknesses.

- Another element essential to the attainment of a successful plan is the immediate initiation of an extensive public education and awareness program which clearly identifies the costs and negative consequences of the continuation of the status quo, as well as how initially inconvenient changes can result in reducing the undesirable outcomes. This campaign must be aimed at the many different elements of the public at large, as well as at key decision-makers.

- Lastly, it is important that there also be a strong linkage between the planners, and the entities ultimately responsible for the implementation of the plan. Suggested measures must be reviewed early on at the appropriate field levels within the respective implementing bodies to assure that the necessary resources are available -- be they materials, personnel, funds and/or time - so that it is realistically possible to implement a given measure. This involves the scrutiny of suggested measures by individuals who have command of the necessary lead-times, critical paths, and whatever else it takes to actually provide needed support facilities and infrastructure, in order that a given measure will be operational in time to achieve the requisite benefits.[11]

Technical Analysis Methods

The Metropolitan Washington Council of Governments (MWCOG) also points out several strengths/weaknesses of the technical analysis methods they used. Although the MWCOG used the best modeling tools available, these models did have several shortcomings which the MWCOG is in the process of eliminating. In particular,

Weaknesses:

- Analysis of measures dealing with bike and pedestrian improvements were weak due to insufficient empirical data or surveys that could provide the basis for sketch planning approaches to modeling air quality impacts.

- Lack of a 1996 transit network handicapped the analysis of TCMs such as M-27 and M-32. These TCMs were analyzed using the mode-choice model which predicts the change in mode due to the implementation of the measure. However, the analysis could not forecast transit trip increases on specific routes.

[11] Washington No. 1, p. 10-11.

- For measures that impact all travel (work and non-work) the analytical methodology used for estimating the impact on non-work travel is weak. This is true for the transit measures such as M-25, M-32, etc., and pricing measures such as M-10, M-23, etc., analyzed using the mode choice or the TDM model. Using professional judgment, the increase or decrease in non-work transit trips was estimated based on the measured impact on home-based-work transit trips. Using an average vehicle occupancy of 1.5 for non-work trips the resulting vehicle trip and VMT reduction for the non-work trips was estimated. This methodology was employed due to the lack of a mode choice model capable of estimating the impacts on non-work trips. This approach produced a conservative estimate. It estimates only the impact of mode shift from cars to transit but does not account for trips which will be entirely eliminated or chained with other non-work trips which could result in additional VMT and VT reduction. MWCOG is in the process of developing models capable of handling non-work travel which will eliminate this problem.

- For congestion pricing and other market measures:

  - Distribution effects - It is likely that in the mid- and long-term, people would shift their travel patterns in response to roadway pricing. That is, they would tend to select housing, work, and non-work locations that allowed them to minimize the use of priced roads. The analysis used a fixed trip table that did not account for this, i.e. there is no land-use feed back.

  - Route Choice - The MWCOG model set does not include a motorist route choice model. The analysis of congestion pricing attempted to stimulate this choice by converting the toll value on the priced links to a time penalty that would effectively discourage some motorists from using those roads. This process also assumes a single average value of travel time for the region and the value of time for mode choice is the same as the value of time for path choice.

  - Non-work effects - The MWCOG model set directly estimates non-work vehicle trips without any sensitivity to trip cost. Thus, this tool did not permit direct estimation of the impact on non-work trips.

  - Time of day - The MWCOG model set models only daily trip-making and has no capability to handle peak travel differently from off-peak travel, or to shift travel from peak to off-peak periods in response to pricing or congestion. One of the likely motorist responses to roadway pricing is to make the same trip in the same mode on the same roadway, but at a different time of day. This was not simulated.

- In addition to the above, in the analysis of the congestion pricing TCM no regional traffic assignment was performed which would have allowed us to assign trips to the priced network, which would account for the question of what happens to vehicle trips that are diverted from the priced roads. Instead the analysis assumed that such trips would find capacity on adjacent roads.

Strengths:

- The COG Mode-Choice Model was calibrated using local data and the results of the TDM model were validated against the COG Mode-Choice Model. The models were used for analyzing a variety of TCMs that impacted travel cost or travel time. The auto operating feature of the mode-choice model was used for analyzing measures like gas tax, registration fee and congestion pricing.

- The availability of cold start, hot soak, and running emission factors enables the user to analyze the impact vehicle-trip reduction and vehicle-miles of travel have on emissions. Vehicle trip reductions play a bigger role than vehicle miles of travel in reducing VOC.

- A methodology was developed to measure impact on work related travel (linked trips to work) not accounted for in the home-based-work-trip tables used in the models.[12]

3.3.8 SUMMARY AND CONCLUSIONS

The Washington, D.C. case study provides a detailed description of a TCM selection process conducted to identify measures worth including in the 1993 SIP. The selection process began by considering a broad range of TCM options (about 200) relative to the number finally selected (about 14) and the number eventually implemented (at least 1). The case study discusses the entire process: starting from the development of an initial list of measures, the screening of these measures, their analysis, and the eventual recommendation/ and selection of certain measures. The discussion stops short of implementation and funding issues (i.e. which projects will be implemented when and how...) The strength of the case study is its extensive treatment of analysis methods, organizational issues, and lessons learned throughout the process.

There are several characteristics of DC's methodology worth noting:

- Scores aided the screening process, but decisions were not based exclusively on project scores. Two other factors were also considered: "implementable by 1996" and "five or more must include votes".

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[12] Washington No. 1, p. 38-39.

- Systematic scoring/ranking of projects was conducted only once towards the beginning of the process. Scores were used for screening purposes only, to help select projects meriting detailed analysis. Since scores were assigned prior to detailed analysis, they were based largely on qualitative studies. Also due to the lack of accurate quantitative analysis at the time of scoring, project impacts were estimated on a low-medium-high scale rather than a more specific numerical scale.

- Unlike Seattle, Washington, D.C. did not attempt to use the same analytical tool to assess the impacts of all measures. Whereas Seattle used TCM Tools (or a comparable method) to analyze all measures, Washington, D.C. used one of three highly different methodologies. The travel model, TDM model, and sketch planning methods used by D.C. offer different levels of detail. Also, not all measures were analyzed by the same technical staff: the 11 measures involving land use changes and the 48 other measures were analyzed by two different agencies. The use of several methodologies and the involvement of multiple technical staffs raises doubt about how comparable analytic results were. In particular, were they comparable enough to facilitate a selection process.

- The detailed analysis results were never employed in a systematic scoring/ranking process. The results were used primarily by transportation/planning staff to reduce a list of 59 to a size of 40, and possibly by the board and TPB to reduce a list of 40 to a size of 14.

- The project selection process incorporated the views of elected officials, interest groups, and the general public. In particular, the Traffic Mitigation Subcommittee which was in charge of formulating and screening measures, included 40 transportation professionals with varied backgrounds and modal experiences, as well as representatives from the Bicycle Advisory Subcommittee, the Mid-Atlantic Telecommuting Advisory Council, the Ride Finders Network, and the Transportation Management Associations Group.

While the DC Case Study provides much detail, it also raises some questions:

- Why did DC select those 7 criteria to use in its scoring/ranking process.
- Why did they not re-score projects once detailed analysis had been conducted, and use these scores to further trim the list.
- Were the analytical results comparable enough to facilitate a relative-ranking and selection process.
- Was the extensive analysis/selection process described in the case study worth while, considering that they eventually included only one of the measures (right turn on red) in the 1993 SIP.
- What happened to the ~13 measures considered for inclusion in the contingency plan.

3.4 DALLAS-FORT WORTH: North Central Texas Council Of Governments

3.4.1 WHY THIS REGION WAS INCLUDED AS A CASE STUDY

This case study was pursued because the Dallas-Fort Worth Metropolitan Area has an air quality problem, has addressed it in its planning process, and has documented these experiences well. The Dallas-Fort Worth (D-FW) area is in "moderate" nonattainment for ozone and in attainment for CO.[13] In order to reach attainment, they have committed to TCMs in their SIP. Their streamlined TIP project selection process prioritizes these/ other TCMs relative to other transportation projects.

Unlike the DC case study, this case study does not discuss the process through which they selected TCMs for the SIP. Rather, it deals with another stage of TCM programming: their inclusion in the TIP (the short-term, financially-constrained regional transportation plan). It is at this stage that TCMs must be specifically defined and assigned a funding source. Most TCMs are particularly eligible for CM/AQ funds, in addition to other funding options. This case study focuses on the 1993 and 1995 TIP project selection process, as well as the selection of projects for 1995 CM/AQ funding in the Dallas-Fort Worth Metropolitan Area. It should be noted that this is only a sub-area of the North Central Texas Region; it is "the Metropolitan Area" described in 3.4.2. Projects outside the Metropolitan Area are included in the Statewide Transportation Improvement Program.[14]

3.4.2 BRIEF REGIONAL PROFILE

The North Central Texas Council of Governments (NCTCOG) serves a 16-county metropolitan region centered around two urban centers: Dallas and Fort Worth. The sixteen counties making up the region are Collin, Dallas, Denton, Ellis, Erath, Hood, Hunt, Johnson, Kaufman, Navarro, Palo Pinto, Parker, Rockwall, Somervell, Tarrant, and Wise. The Council has 220 members currently: 16 counties, 157 cities, 25 independent school districts, and 22 special districts. The region served by NCTCOG covers 12,800 square miles and has a population of over 4.2 million.

Within the North Central Texas Region is the Metropolitan Area. This 4,980 square mile area consists of all of Collin, Dallas, Denton, Rockwall, and Tarrant Counties; and portions of Ellis, Johnson, Kaufman, and Parker Counties. Included in the Metropolitan Area are the existing urbanized areas, as well as the contiguous area expected to be urbanized by 2020.

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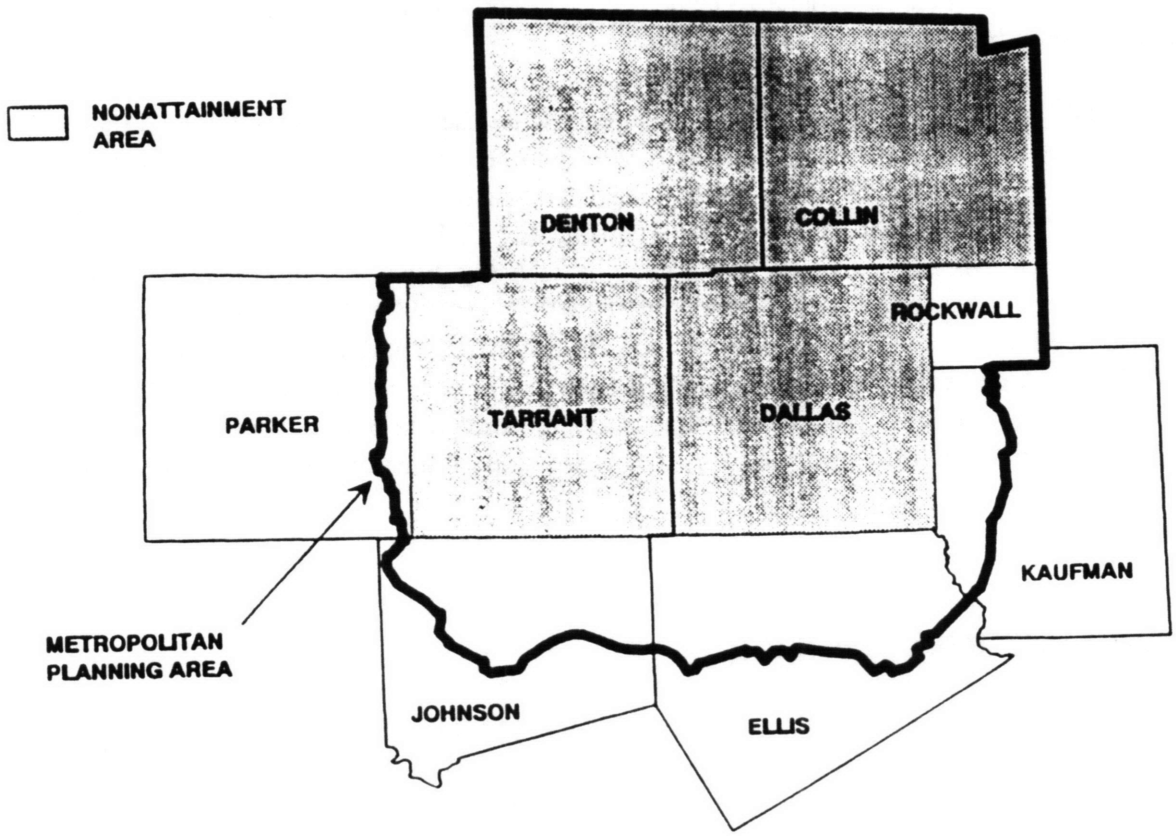
[13] Interview No. 10.

[14] Texas No. 4, p. 1.11.

Figure 3.4-1: Transportation and Air Quality Planning Areas[15]



[15] Texas No. 4, p. 1.3.

A portion of the Metropolitan Area is in "moderate" nonattainment of ozone standards and must reach attainment by 1996. The nonattainment area includes the counties of Denton, Collin, Dallas, and Tarrant. Figure 3.4-1 displays the Metropolitan Area and the nonattainment regions within it.[16]

As is the case with Los Angeles, inhabitants of the Dallas-Forth Worth area are very tied to their automobiles. Auto is the primary mode of transportation in the area and transit facilities are being developed just recently.[17]

3.4.3 ORGANIZATIONAL STRUCTURE

The North Central Texas Council of Governments is a voluntary association of cities, counties, school districts, and special districts which was established in January 1966, to assist local governments in planning for common needs, cooperating for mutual benefit, and coordinating for sounds regional development. NCTCOG's structure is relatively simple; each member government appoints a voting representative from the governing body. These voting representatives make up the General Assembly which annually elects an 11-member Executive Board (9 local elected officials and 2 regional citizens). The Executive Board is supported by policy development, technical advisory, and study committees, as well as a professional staff of approximately 100 people.[18]

3.4.4 METHODS USED TO PRIORITIZE AND SELECT PROJECTS.

TIP Project Selection Process

The NCTCOG has developed a streamlined approach to programming federally funded projects. For the 1995 TIP all federally funded projects were reviewed using this process known as the Texas Review and Comment System (TRACS) process. In general, the TRACS project review criteria are:

- Compliance with federal, State, and local laws, regulations, and ordinances
- Consistency with State, areawide, and/or local planning goals and objectives
- Addressing of a clearly defined need
- Study of effects on the environment

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[16] Texas No. 4, p. 1.11, 1.43, and cover.
[17] Interview No. 10.
[18] Texas No. 4, cover.

- Identification of goals that are specific, measurable, and achievable
- Demonstration of a feasible delivery strategy
- Contribution to a balanced delivery of services among political subdivisions covered by the application
- Analysis of costs and benefits
- Documentation of record of the applicant[19]

In order to conduct the actual project evaluation and selection, more specific criteria were developed. The evaluation of projects for inclusion in the 1993 TIP was conducted using a five-criteria/100-point rating system. The selection of these criteria was based on a series of surveys conducted on transportation professionals and local elected officials in the Dallas-Fort Worth Area. The survey presented these people with a list of 21 potential criteria which had been based on the guidelines set by ISTEA, CAAA, and ADA. A sample survey form listing these 21 criteria is presented in figure 3.4-2. Respondents scored each criteria so that the total points would not exceed 100. The initial survey reduced the list of candidate criteria to a size of 13. Further surveying produced a final list of five criteria. These criteria and the points assigned to each one are presented in table 3.4-1.

The 1995 TIP process employed a revised version of the 1993-TIP scoring-criteria. In particular, two scoring formats were used: one for CMAQ projects and one for Surface Transportation Capacity Improvements/ Metropolitan Mobility/ Transit Section 9 funds. These two scoring formats, presented in table 3.4-2 and table 3.4-3, include differing criteria and weight common criteria's differently. For example, both factor in "current cost effectiveness"; however, one allots this criteria 24 points while the other allots it only 20 points.

Table 3.4-1: Project Evaluation Criteria for the 1993 TIP Process[20]

CRITERIA	POSSIBLE POINTS
Current Cost Effectiveness (1992)	25
Future Cost Effectiveness (2010)	20
Air Quality/ Energy Conservation	20
Project Commitment/ Local Cost Participation	20
Intermodal/ Multimodal/ Social Mobility	15
TOTAL	100

[19] Texas No. 4, p. 1.18.
[20] Texas No. 4, p. 1.30.

Table 3.4-2: Project Evaluation Criteria for CMAQ Project Selection[21]

CRITERIA	POSSIBLE POINTS
Current Cost Effectiveness (1992)	20
Local Cost Participation	20
Air Quality/ Energy Conservation	20
Congestion Management Plan/ Transportation Control Measures	20
Intermodal/ Multimodal/ Social Mobility	20
TOTAL	100

Table 3.4-3: Project Evaluation Criteria for Transit Section 9 Programs and Surface Transportation Programs Metropolitan Mobility Capacity Improvements[22]

CRITERIA	POSSIBLE POINTS
Current Cost Effectiveness (1992)	24
Future Cost Effectiveness (2010)	18
Air Quality/ Energy Conservation	18
Local Cost Participation	24
Intermodal/ Multimodal/ Social Mobility	16
TOTAL	100

[21] Texas No. 4, p. 1.31.
[22] Texas No. 4, p. 1.32.

Figure 3.4-2: Transportation Criteria Survey Form[23]

(Please score criteria and sum to 100)

CRITERIA	EXPLANATION	POINTS
Safety		
1992 Cost Effectiveness	Travel Time Savings ÷ Total Project Cost	
2010 Cost Effectiveness	Future Travel Time Savings ÷ Total Project Cost	
Air Quality		
Rehabilitation/ Maintenance		
Corridor Preservation	Project includes actions which result in the preservation of rights-of-way for future transportation use	
Economic Development		
Project Commitment	Project is contained in an adopted local, regional, or State plan	
Continuity/Gap		
Intermodal Project	A project or facility which provides for the interaction of two or more transportation modes in a given area and which promotes the efficient movement and transfer of people or goods	
Multimodal Project	A project or facility in a corridor other than one supporting singe-occupant autos	
Energy Conservation		
Local Cost Participation	The percentage of the total project costs to be funded by local funds	
Social Mobility	A project which provides transportation services to individuals or groups who need some form of transportation due to an inability to utilize other forms of transportation; this can include services to the Elderly & Disabled or economically disadvantaged individuals	
Aesthetics	A transportation-related project which enhances the community appearance or urban design; the project does not necessarily have to be one which has specific mobility value	
Congestion Prevention		
Security		
Multijurisdictional/ Regional Significance		
Infrastructure Investment	A capital project with a likelihood of producing long-term economic benefits as opposed to an operational project which only provides direct benefits for a given short time period	
Future Project Flexibility	A project which permits future capacity expansion or conversion to a higher carrying capacity mode	
Implementation Schedule	A project ready for construction within 12 to 24 months	
TOTAL		100

COMMITTEE ______________________ COUNTY ______________________

[23] Texas No. 4, p. 1.28.

Once the evaluation criteria had been decided upon, methodologies for quantifying these criteria were developed for each project type. General descriptions of these methodologies are available in Appendix C.[24]

CMAQ Selection Process for the 1995 TIP

Here are some details on the CMAQ project evaluation process. Something in the range of 1000 projects proposed by various public and private agencies were analyzed, scored, and ranked. Accompanied by their ranking and professional opinions, the projects were then presented to a transportation council of elected officials which made the final selection of projects.

Each project received a score between 0 and 100 points, 100 being best. Five categories, each worth 20 points, constituted the selection criteria:

1. Current Cost Effectiveness
2. Air Quality / Energy Conservation
3. Local Cost Participation
4. Intermodal / Multimodal / Social Mobility
5. Congestion Management Plan / Transportation Control Measures

Current Cost Effectiveness was quantified as a benefit to cost ratio. The benefits considered were VMT and VHT reductions converted into annual dollars of travel time savings. The cost considered was the annual cost of the project based on the design life of the project and a capital recovery rate.

Table 3.4-4: Current Cost-Effectiveness Rating[25]

BENEFIT/COST RATIO	SCORE
0.00 - 0.49	0
0.50 - 0.99	3
1.00 - 1.49	5
1.50 - 1.99	8
2.00 - 2.99	10
3.00 - 4.99	15
>=5.00	20

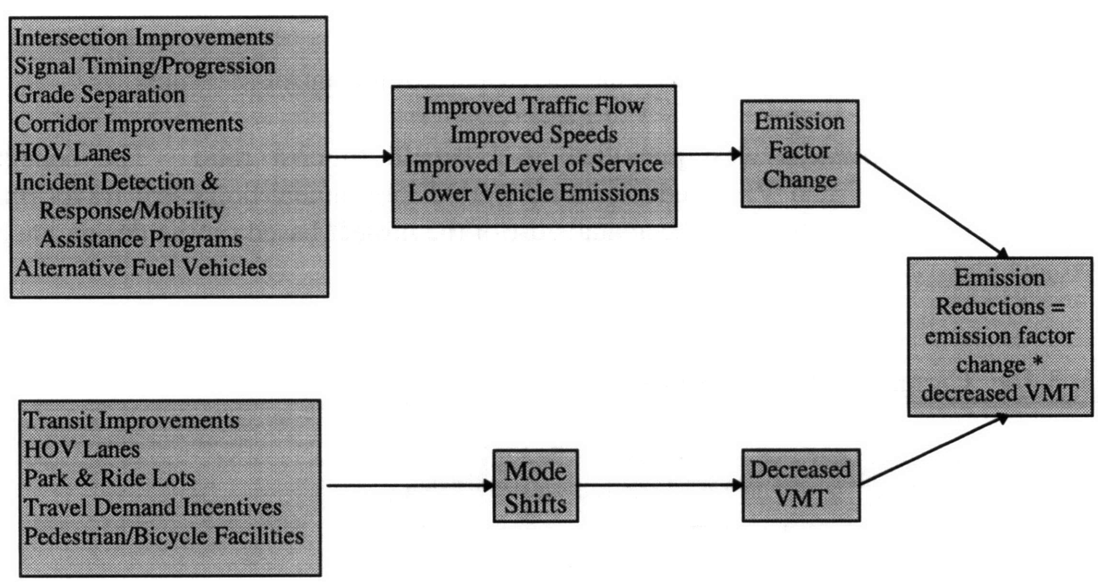
Air Quality / Energy Conservation was also measured as a benefit cost ratio, but having the units of lbs/$. The cost was the annual cost of the project. Benefits included VMT reduction from impacts such as mode shifts. Some projects which decreased VMT are

[24] Texas No. 4, p. 1.29-1.39. (available in appendices)

[25] Texas No. 2.

transit improvements, HOV lanes, park-and-ride lots, travel demand incentives, and pedestrian/bicycle facilities. Another quantified benefit was emission factor changes resulting from impacts such as improved traffic flow, improved speeds, improved level of service, and lower vehicle emissions. Projects such as intersection improvements, signal/timing progression, grade separations, corridor improvements, HOV lanes, incident detection assistance programs, response/mobility assistance programs, and alternative fuel vehicles might cause these sorts of changes. Emission reductions were calculated by multiplying VMT reductions by emission factors. This produced a benefit measure in units of pounds of volatile organic compounds (VOC) reduced.[26] The translation of projects into benefits can be seen more simply through the following diagram:

Figure 3.4-3: Conversion of Project Impacts into Emission Reductions



[26] Texas No. 1.

Table 3.4-5: Air Quality/Energy Conservation Rating[27]

$/LB OF VOLATILE ORGANIC COMPOUND EMISSION REDUCTIONS	SCORE
>=100.0	0
50.0 - 99.99	5
10.0 - 49.99	10
5.0 - 9.99	15
<=4.99	20

Projects could also earn up to 20 points from *Local Cost Participation.* In order receive CMAQ funds, the agency proposing the project must contribute at least 20 % of the total project cost. Any contribution above the required 20 % earns the project additional points.

Table 3.4-6: Project Commitment/Local Cost Participation[28]

PERCENT OF FUNDS PROVIDED BY NON-CMAQ (e.g. Local or private) FUNDS	SCORE
0-20	0
21-25	3
`26-30	7
31-35	10
36-40	13
41-45	17
>=46	20

Projects earn either 0 or 20 points in the *Intermodal / Multimodal / Social Mobility* category. Twenty points are given to projects which help goods movement or encourage/improve non-SOV travel options, generally speaking.

[27] Texas No. 2.

[28] Texas No. 2.

Table 3.4-7: Intermodal/Multimodal/Social Mobility Rating[29]

MODE OCCUPANCY	SCORE
Automobile [Occupancy = 1]	0
Goods Movement Pedestrian Bicycle TDM Bus Transit Light Rail Commuter Rail HOV Elderly & Disabled Intermodal	20

The final category allows *transportation control measures* and projects contributing to a *congestion management plan* receives additional points. For instance, projects included in the SIP would receive additional points from this category.[30]

Table 3.4-8: Congestion Management Strategies (CMS) / Transportation Control Measures (TCMs) Rating[31]

CRITERIA		SCORE
Is proposed project in the CMS or is it a State Implementation Plan TCM?	NO	0
	YES	20

Results of the CMAQ Selection Process

Some of the analysis results may be summarized in table 3.4-9. Using such results and professional advice, the transportation council allocated CMAQ funds as is shown in table 3.4-8. Almost 60% of funds went to projects which had both "high" congestion mitigation and "high" air quality benefits.[32] In terms of number alone, about 70 % of the

[29] Texas No. 2.
[30] Interview No. 10.
[31] Texas No. 2..
[32] Texas No. 2.

projects finally selected were intersection and signal improvements.[33] A detailed list of CMAQ projects selected and the scores they received is available in Appendix D.

Table 3.4-8: Projects selected for CMAQ funds in the Dallas-Fort Worth[34]

PROJECT TYPE	COMMITMENTS MADE IN THE TIP USING CMAQ FUNDS (millions of $)	PERCENT OF CMAQ FUNDS RECEIVED BY PROJECT TYPE (%)
Intersection Improvements	76	23
Signal Improvements	37	11
Grade Separation	14	4
HOV Lanes	55	17
Alternative Fuel Vehicles	53	16
Mobility Assistance	26	8
TDM Initiatives	6	2
Ozone Alert Discount Transit Fare	2	1
Pedestrian/Bicycle Facilities	6	2
Transit/Park-and-Ride/Rail	31	10
Corridor Improvements	18	6
TOTAL	$ 324	100 %

[33] Interview No. 10.

[34] Texas No. 1.

Table 3.4-9: Summary of project rankings in terms of congestion mitigation and air quality benefit/cost ratios[35]

CONGESTION MITIGATION (B/C)	AIR QUALITY ($/LB)	PROJECTS RECEIVING THESE RANKINGS
High (>10)	High (<20)	Signal/Intersection Improvements HOV Lanes Incident Detection & Response / Mobility Assistance
Moderate (2-10)	Moderate (>=20)	Transit Improvements Park & Ride Lots Pedestrian/Bicycle Facilities Travel Demand Management Ozone Alert Discount Transit Fare
High	Moderate	Grade Separation
Low	High	Alternative Fuel Vehicles
Low	Low	Do not fund

SIP Selection Process:

Because specific projects were not committed to in the SIP, the project selection process was not as detailed as the CMAQ selection process. EPA and the Texas Natural Resource Conservation Center (TNRCC) have stated that SIP commitments are not required to be project-specific. Rather, the region must commit to an overall emission reduction target and specific levels of implementation/activity in each TCM category. In addition, the total emission reduction target for all categories combined must be met.[36]

Potential projects fell into one of several categories such as "HOV lanes", or "light rail extension". An inventory was taken of potential projects in each category. For instance, the total number of HOV lanes or the miles of light-rail that might be built were measured. Then, in order to provide some room for error, only a portion (for example 75%) of these totals were committed to in the SIP.[37]

[35] Texas No. 1.
[36] Texas No.4, p. 1.46.
[37] Interview No. 10.

3.4.5 DESCRIPTION AND STATUS OF CURRENT TCM-RELATED PROGRAMS

Progress from 1994 TIP

TCM implementation has not occurred at an optimum pace in the Dallas-Fort Worth area, the NCTCOG believes it has identified and overcome many obstacles to implementation.[38] One proof of this is the extra points allotted to TCMs in the CMAQ project selection process. Also, an effort was made to identify, list, and explain significant delays in major projects scheduled in the 1994 TIP. Most projects were delayed due to funding constraints and requirements related to a specific projects (e.g. right-of-way availability). Some CMAQ projects did not proceed due to administrative delays (e.g. contract concurrence between Texas DOT and local governments.) In order to ensure the timely implementation of CMAQ and Surface Transportation Program-Metropolitan Mobility projects in the future, a detailed monitoring system is being put in place.[39]

Figure 3.4-4 summarizes those major projects implemented in the Dallas and Fort Worth sub-regions during the 1994 TIP duration, and those projects delayed.

Commitments Made in the SIP

Figures 3.4-5, 3.4-6, and 3.4-7 list TCMs committed to in the SIP and recommended congestion management strategies.[40]

Commitments Made in the 1995 TIP

Numerous projects were committed to in the TIP. (The TIP lists all of these commitments.) Appendix D provides a detailed list of all projects in the 1995 TIP funded by CMAQ moneys and the scores they received.

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[38] Texas No. 4, p. 1.48.
[39] Texas No. 4, p. 1.40-1.42.
[40] Texas No. 4.

Figure 3.4-4: Summary of Major Projects Implemented or Delayed During the 1994 TIP Duration[41]

Dallas Subregion:

- Section 9 Transit funding
- Discount Transit Fare Program
- Ozone Alert Program
- Countywide Freeway Incident and Detection Response Program
- Alternative Fuel Vehicle Program for public sector vehicles
- U.S. 67 in Southwest Dallas County: construct four-lane freeway main lanes
- U.S. 75 from Southwestern Blvd. to Walnut Hill Lane: reconstruct and expand Central Expressway, including both main lanes and frontage roads
- I.H. 35E at Frankfurt: construct interchange
- F.M. 2181 near I.H. 35E: widen from two to four lanes
- I.H. 35E in Denton County: two projects include reconstruction of the four-lane freeway and resurfacing of the existing freeway
- MacArthur Blvd. in Irving: widen thoroughfare from two to six lanes
- Shady Grove at Loop 12: reconstruct existing bridge to six lanes
- U.S. 380 near S.H. 289: construct four-lane rural section
- U.S. 380 near U.S. 75: construct four- and six-lane urban section
- S.H. 5/Avenue K near Parker Rd.: widen to six-lane urban section
- S.H. 121 near S.H. 289: widen to four lanes
- Parker Road near Los Rios: widen to six-lane urban section
- F.M. 544 at F.M. 2551: intersection improvement
- F.M. 407: signal improvements
- F.M. 1171: various signal improvements near I.H. 35E
- Barrier purchased for the East R.L. Thornton HOV extension
- Electronic freeway surveillance on U.S. 75
- Signal improvements in the Fair Park, Oak Cliff, and Oak Lawn subareas
- Assorted other Congestion Mitigation and Air Quality Improvement Program projects as shown in Appendix I

[41] Texas No. 4, p. 1.40-1.42.

Fort Worth Subregion:

- Section 9 Transit funding
- Alternative Fuel Vehicle Program for transit vehicles
- Freeway Incident and Detection Response Program on I.H. 20
- Regional Rideshare Program
- Discount Transit Fare Program
- Ozone Alert Program
- Phase 2 extension of S.H. 360 in South Arlington
- Widening of S.H. 360 in the southbound direction near U.S. 180
- Widening of F.M. 1709 from U.S. 377 to Keller
- U.S. 377 improvements north of I.H. 820
- Assorted other Congestion Mitigation and Air Quality Improvement Program projects as shown in Appendix I

The following summarizes those major projects delayed in the Dallas and Fort Worth Subregions during the 1994 Transportation Improvement Program duration:

Dallas Subregion:

- Construct noise walls on S.H. 161 north and south of Belt Line Road. This project is anticipated to go to contract in 1995.
- Replace S.H. 342 bridges at Five Mile Creek. This project is anticipated to go to contract in 1995.
- Modify existing bridge and channel of Five Mile Creek at Loop 12. This project is anticipated to go to contract in 1995.
- Install guide signs and lane-use signs on U.S. 75 south of I.H. 635. This project is anticipated to go to contract in 1995.
- I.H. 45: reconstruction of existing freeway. This project was delayed due to a cost overrun on Central Expressway and a constraint due to the District funding cap. This project is anticipated to go to contract in 1995.
- Assorted other Congestion Mitigation and Air Quality Improvement Program projects as shown in Appendix I

Fort Worth Subregion:

- I.H. 30/I.H. 35W Interchange: delayed due to right-of-way acquisition and a necessary ruling from the Interstate Commerce Commission on the Fort Worth Western Railroad.
- Assorted other Congestion Mitigation and Air Quality Improvement Program projects as shown in Appendix I

Figure 3.4-5: TCMs for the reasonable further progress SIP[42]

	PROJECT CATEGORY	NOVEMBER 1993		REVISED MAY 1994	
		IMPLEMENTATION LEVEL	EMISSION REDUCTION (VOC lbs/day)	IMPLEMENTATION LEVEL	EMISSION REDUCTION (VOC lbs/day)
1	Intersection Improvements	334 Locations	1,740	334 Locations	1,740
2	Signal Timing/ Progression	1,197 Locations	5,480	1,350 Locations	6,180
3	Grade Separations	2 Locations	16	2 Locations	16
4	High Occupancy Vehicle Lanes	33 Lane Miles	935	33 Lane Miles	935
5	Transit Alternative Fuel Vehicles	300 Vehicles	107	300 Vehicles	107
6	Nontransit Alternative Fuel Vehicles	3,032 Vehicles	780	3,032 Vehicles	180
7	Motorist Assistance/ Incident Detection and Response/ Freeway Surveillance	4 Corridors	394	4 Corridors	394
8	Park-and-Ride Lots	2 Locations	30	2 Locations	30
9	Travel Demand Management Program Phase I	N/A	N/A	N/A	N/A
10	Travel Demand Management Program Phase II	N/A	N/A	N/A	N/A
11	Pedestrian/ Bicycle Facilities	16 miles	8	16 miles	8
12	Commuter Rail	9 6 miles	9	9 6 miles	9
13	Light Rail	10.3 miles	240	7 9 miles	140
14	Arterial Street Roadway Widenings	763 lane miles	4,137	763 lane miles	4,137
15	Discount Transit Fare	N/A	N/A	N/A	N/A
16	Accelerated Retirement of Older Vehicles	N/A	N/A	N/A	N/A
17	Vehicle Impoundment Air Quality Program	N/A	N/A	N/A	N/A
18	Tune-up and Repair of High Emitting Vehicles/Smog Check	N/A	N/A	N/A	N/A
19	Pass on Left Legislation/ Enforcement	N/A	N/A	N/A	N/A
20	Reduce Empty Truck Backhauls	N/A	N/A	N/A	N/A
	TOTAL		13,876 lbs/day = 6 94 tons/day		13,876 lbs/day = 6 94 tons/day

[42] Texas No. 4, p.1.47, table 12.

Figure 3.4-6: Implementation Levels of TCMs included in the SIP[43]

Category	SIP Commitment	Federal & State Projects through 1996
Intersection Improvements/ Grade Separations	336 Locations	320 Locations[1]
Signal Improvements	1,350 Locations	2,188 Locations
HOV Lanes	33 Lane Miles	36.7 Lane Miles
Alternative Fuel Vehicles	3,332 Vehicles	3,354 Vehicles
Corridor Management	4 Corridors	14 Corridors
Park-n-Ride Lots	2 Locations	4 Locations
Travel Demand Management	N/A	15 Programs
Ped/Bicycle Facilities	16 Miles	25 Miles
Commuter Rail	9.6 Miles	9.6 Miles
Light Rail	7.9 Miles	7.9 Miles
Arterial Street Widenings	763 Lane Miles	1,707 Lane Miles[2]

[1] Additional projects have been constructed by local agencies resulting in no deficiency

[2] Includes locally funded projects

[43] Texas No. 4, p. 1.49, table 13.

Figure 3.4-7: VOC Emission Reductions of TCMs included in the SIP[44]

Category	SIP Commitment (lbs/day)	Federal & State Projects through 1996
Intersection Improvements/ Grade Separations	1,756	1,708[1]
Signal Improvements	6,180	7,833
HOV Lanes	935	1,210
Alternative Fuel Vehicles	287	0
Corridor Management	394	2,023
Park-n-Ride Lots	30	55
Travel Demand Management	N/A	941
Ped/Bicycle Facilities	8	27
Commuter Rail	9	9
Light Rail	140	168
Arterial Street Widenings	4,137	12,160[2]
Total	13,876 lbs	26,134 lbs
	6.94 tons	13.07 tons

[1] Additional projects have been constructed by local agencies resulting in no deficiency

[2] Includes locally funded projects

[44] Texas No. 4, p. 1-50, table 14.

3.4.6 ANALYSIS OF IMPACTS

Quantified results were very useful and necessary to carry out the scoring process used to rank and prioritize potential CMAQ projects.[45] Examples of assumptions and calculations made in the CMAQ scoring process are presented in Appendix E. In particular, the method used to score bikeways, bike storage projects, and intersection improvements are provided.[46]

3.4.7 SUMMARY AND CONCLUSIONS

The case study focuses on the 1995 CMAQ scoring/ranking process, but also discusses details of the general 1993 TIP and 1995 TIP scoring/ranking processes. D-FW employs a streamlined TIP project selection process which focuses on scoring/ranking projects. The case study presents much detail on the scoring framework, but not much detail on the analytical methods used to estimate impacts.

Some unique points of this case study:

- D-FW does not base project selection solely on scores, but also considers "early construction feasibility" and "if funding caps are violated".[47]
- This case study provides an example of a region having made TIP commitments it was not fulfilling and its attempt to identify/mitigate its failings.
- D-FW found quantitative scores to be helpful in the project selection process
- final project selection was conducted by a council of elected officials
- some criteria used to score projects are based on qualitative analysis, while others are largely based on quantitative methods.
- quantitative measures are converted into dollar values, then into benefit cost ratios, and ultimately into point scores.

This case study also raises some questions about D-FW's TIP project-selection process:

- Within the TIP project-selection process, different criteria were used for different funding programs. What were the reasons for choosing those criteria.
- How did they determine how many points to assign each criteria.
- Need more detail on the models used. In particular, what specific methods were used to quantify each criteria.
- D-FW developed a methodology for each project type. Why did they not use a pre-packaged method like TCM Tools.
- Did their methodologies offer consistent results.

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[45] Interview No. 10.

[46] Texas No. 2.

[47] Texas No. 4, p. I-39.

3.5 SEATTLE
The Puget Sound Region

3.5.1 WHY THIS REGION WAS INCLUDED AS A CASE STUDY

It was recommended by an FHWA staff member involved in TCM analysis as a region which has had significant experience with TCM analysis. This is partly because the Puget Sound Region is in nonattainment for carbon monoxide (CO), ozone (O_3), and particulate matter less than 10 microns in diameter (PM_{10}). The EPA has classified the region as "moderate plus" for CO and "marginal" for O_3. The Seattle Duwamish River industrial area, the Kent Valley industrial area, and the Tacoma Tideflats area were the only areas within the region designated as nonattainment ("moderate") for PM_{10}.

The Puget Sound Region was also selected as a case study because of its well documented approach to transportation-air quality planning. Also, it was selected because its transportation system is similar to Boston, relative to cities such as Los Angeles; Seattle has both an effective transit and a substantial roadway system.

This case study focuses on the 1995 TIP Project Review/Evaluation Process. It outlines the entire process, but only presents details of the methodology for quantifying air quality impacts and converting them into project scores. The detail provided on air quality scoring is one unique feature of this case study. In addition to the discussion of TIP project selection, the study touches on TIP conformity analysis and TCMs included in the SIP. The discussion of TIP conformity is another unique feature of this case study.

3.5.2 BRIEF REGIONAL PROFILE

The Central Puget Sound Region includes four counties: Kitsap, Snohomish, King, and Pierce. Figure 3.5-1 describes the regional size and the location of nonattainment areas. King's County which contains Seattle has the largest population of the four counties. However, the forecasted population and employment increase in King's County is the smallest of the four counties'. Table 3.5-1 lists the population and number of employed persons living in the region and forecasted to live in the region.

The region has developed several transportation modes. It has invested in 16,000 miles of road, a fleet of more than 2000 transit buses, 90 park-and-ride lots, 27 transit centers, a fleet of over 15 ferry boats, and 13 ferry terminals.[48] In terms of freight transportation, the region contains two major container handling ports in Seattle and Tacoma. Freight

[48] Seattle No. 6, p. 2.

traffic through these two ports as well as through Sea-Tac International Airport, have been and are expected to continue growing.[49]

Within the Puget Sound Region transit is considered a viable option and the bus system could be considered popular. This is apparent in public actions since transit accounts for about 40% of travel in downtown Seattle. However, transit plays a much more subdued role in suburban transportation. The regions receptiveness to transit is also expressed in its policies. Although voters recently turned down a transit project due to its high price tag, another project will soon be voted on. Also, the state of Washington has a Growth Management Act which helps regions recognize the need to focus population growth in urban centers and to preserve rural areas.[50]

Seattle's HOV system is one component of its transportation network which requires completion. The existing HOV system receives high priority and is well used. For instance, HOV lanes in the downtown core often operate at capacity during the p.m. peak. Thus, the PSRC may increase the required vehicle occupancy from 2-or-more-persons to 3-or-more so that more people (and fewer cars) can benefit from it. Only one HOV lane in the Seattle area currently requires 3-or-more persons per vehicle. The high volumes on this roadway may be attributed to large employers such as Microsoft located along that route. Another interesting point concerning HOV lanes in the region is that some commuters use them to access park-and-ride lots.[51]

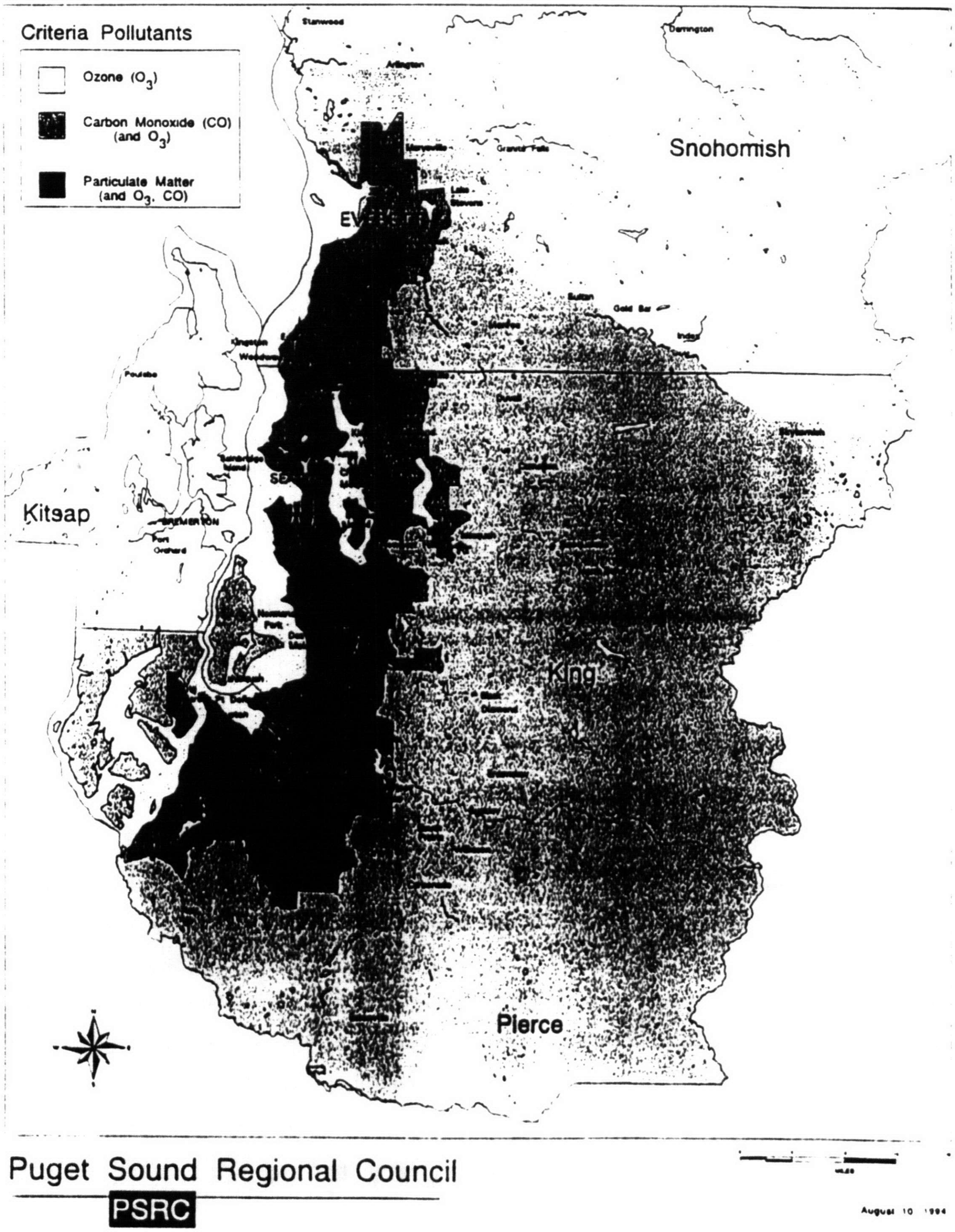
The Puget Sounds Regional Council finds several factors to be responsible for the region's traffic congestion: population/employment growth, job/housing imbalance, land use patterns, socioeconomic changes, automobile preference, declining share of trips by transit, major growth in freight/goods movement, subsidized automobile use, and funding barriers to multimodal investment. Trends in these areas will reduce the level of service provided by the already congested system unless changes are made.[52]

Table 3.5-1: Current and Forecasted Employment and Population in the Puget Sound Region[53]

COUNTY	POPULATION			EMPLOYMENT		
	1990	2020	% change	1990	2020	% change
King	1,507,319	2,071,663	37%	969,001	1,439,148	49%
Kitsap	189,731	331,369	75%	79,300	126,292	59%
Pierce	586,203	897,785	53%	227,300	350,513	54%
Snohomish	465,642	832,135	79%	162,100	289,851	79%
REGION	2,748,895	4,132,952	50%	1,437,701	2,205,804	53%

49 Seattle No. 6, p.10.
50 Interview No. 8.
51 Interview No. 9.
52 Seattle No. 6, p.6.
53 Seattle No. 6, p.7.

Figure 3.5-1: The Puget Sound Region and its Designated Nonattainment Areas[54]



[54] Seattle No. 5, p.2.

3.5.3 DESCRIPTION AND STATUS OF CURRENT TCM RELATED PROGRAMS

The Puget Sound Regional Council did not develop an extensive TCM program because it proved that an oxygenated fuel program coupled with an inspection/maintenance program would bring the region into attainment. When these two programs are combined with the new federal car performance standards, significant improvement to motor vehicle emissions are expected. Thus, only these two programs are mentioned in the 1993 SIPs for CO and O_3.[55] The SIPs also include a commitment to transportation conformity requirements. This means "that transportation plans, programs, and projects conform to the SIP's purpose of achieving and maintaining the national ambient air quality standards" and that TIPs provide for the timely implementation of TCMs contained in the SIP. Although TCMs are not needed to bring the region into attainment by the specified dates, they are expected to play a major role during the maintenance period after 1995.

In contrast to the 1993 SIP, the 1982 SIP contains 223 transportation control measures. Sixteen of these are programmed for the next phase of work needed to reach completion, but the bulk, 207, of these have been completed. The 1994-1996 TIP lists the 223 TCMs.

The Regional TIP must contain all federally funded projects which have been programmed for the next three year period. The transportation projects contained in the TIP may either increase or decrease pollution levels so long as the net effect is not to increase pollution[56]; in other words, the TIP must conform to the SIP's attainment goals. In order to achieve this goal air quality is considered when scoring, ranking, and prioritizing projects. Projects, such as TCMs, which fair well in the air quality category often find their way into the TIP, although they are not part of an explicit "TCM program". For instance, the just-completed 1996-1998 TIP contains 10 CMAQ funded projects, nine of which were amongst the highest ranked projects in terms of air quality.[57]

The Draft Metropolitan Transportation Plan (TP) identifies $60 billion in total regional transportation system program needs. However, only $36 billion is expected to be available within the region over the next 25 years unless new funding sources arise. The region is currently concerned about funding large high-cost projects with ISTEA discretionary funds because the region already funded a variety of smaller scale multimodal projects with regional ISTEA discretionary funds during the 1993 TIP process. These small scale projects typically cost between $300 and $500 thousand. In order to address these concerns, the project selection process used to construct the 1995 TIP prioritizes larger scale "regionally significant" projects[58].

[55] Interview No. 8.
[56] Seattle No. 3, p. 5-7.
[57] Interview No. 8.
[58] Seattle No. 1, p. 4.

3.5.4 ORGANIZATIONAL STRUCTURE

The processes described in section 3.5.5 are used by the PSRC to select projects for three "regionally managed" federal funding programs: the Surface Transportation Program (STP), the Congestion Management and Air Quality (CMAQ) Program, and the Federal Transit Administration (FTA) Program. While the PSRC has retained control over a portion of the funds, it has also delegated some control to countywide agencies to allow them to accommodate their unique local needs. Thus, the regions and county in each county assume responsibility for reviewing, prioritizing, and recommending for approval to the PSRC their respective area's financially balanced transportation projects for their share of ISTEA funds.

Unlike CMAQ and STP funds which may be used for variety of project types, FTA funds are less flexible; they must be used for transit-related purposes. In light of this, responsibility for FTA funded projects lies with the 5 designated transit agencies within the region:

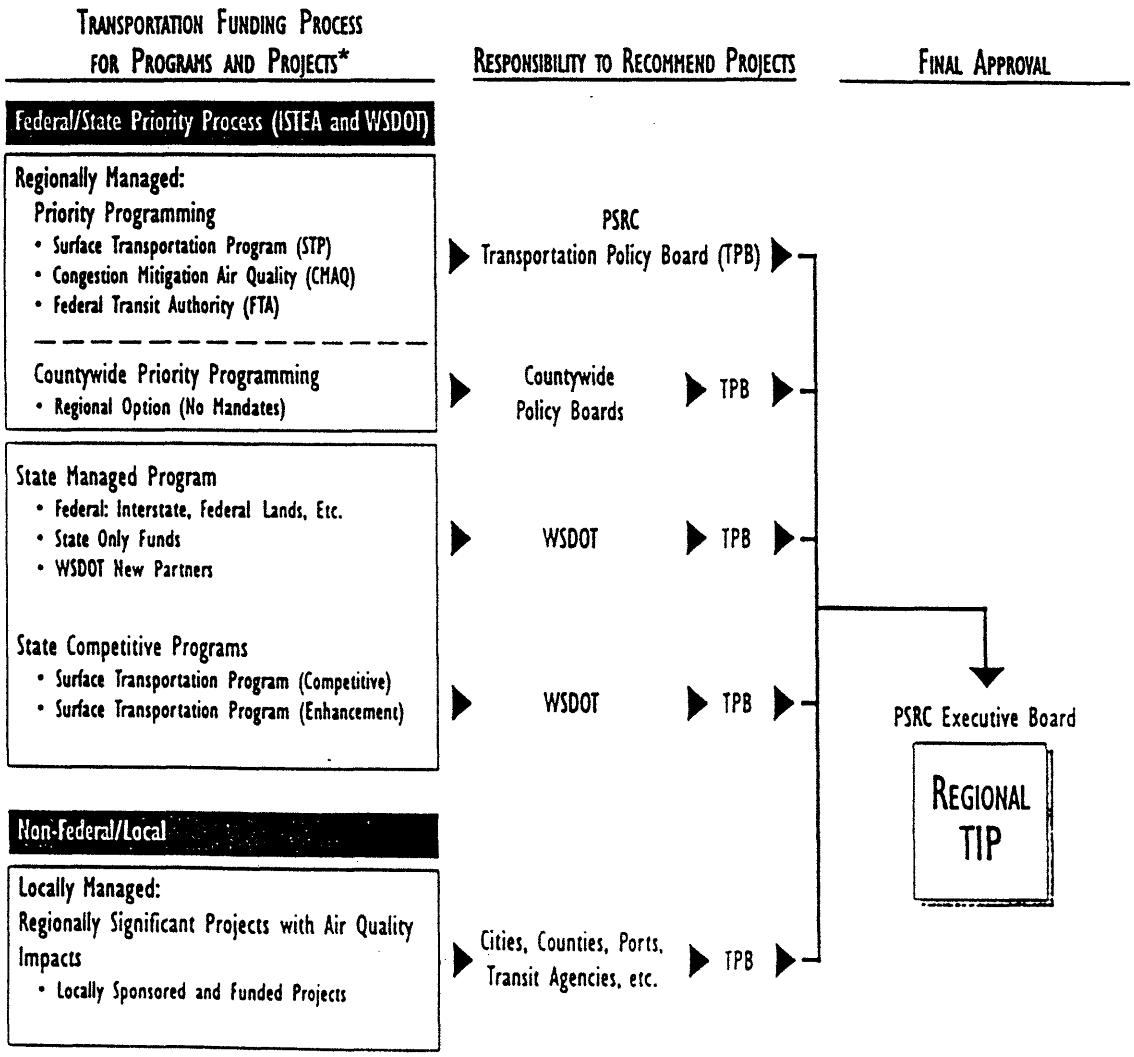
- Seattle/Everett Urbanized Area: Metropolitan King County (Metro), Community Transit, and City of Everett (for their respective portions of the urbanized area).
- Tacoma Urbanized Area: Pierce Transit
- Bremerton Urbanized Area: Kitsap Transit

These agencies are in charge of collectively prioritizing projects and then submitting them for review to the PSRC.

In summary, the criteria used and chain of events in the project selection process depends on who's in charge of the funds: the regional agency, a county agency, or the transit agencies. However, in all cases the Transportation Policy Board provides final approval of recommendations.[59] Figures 3.5-2 and 3.5-3 provide an overview of the organizational framework within which ISTEA TIP projects are selected and reviewed.

[59] Seattle No. 1, p. 1 & 12.

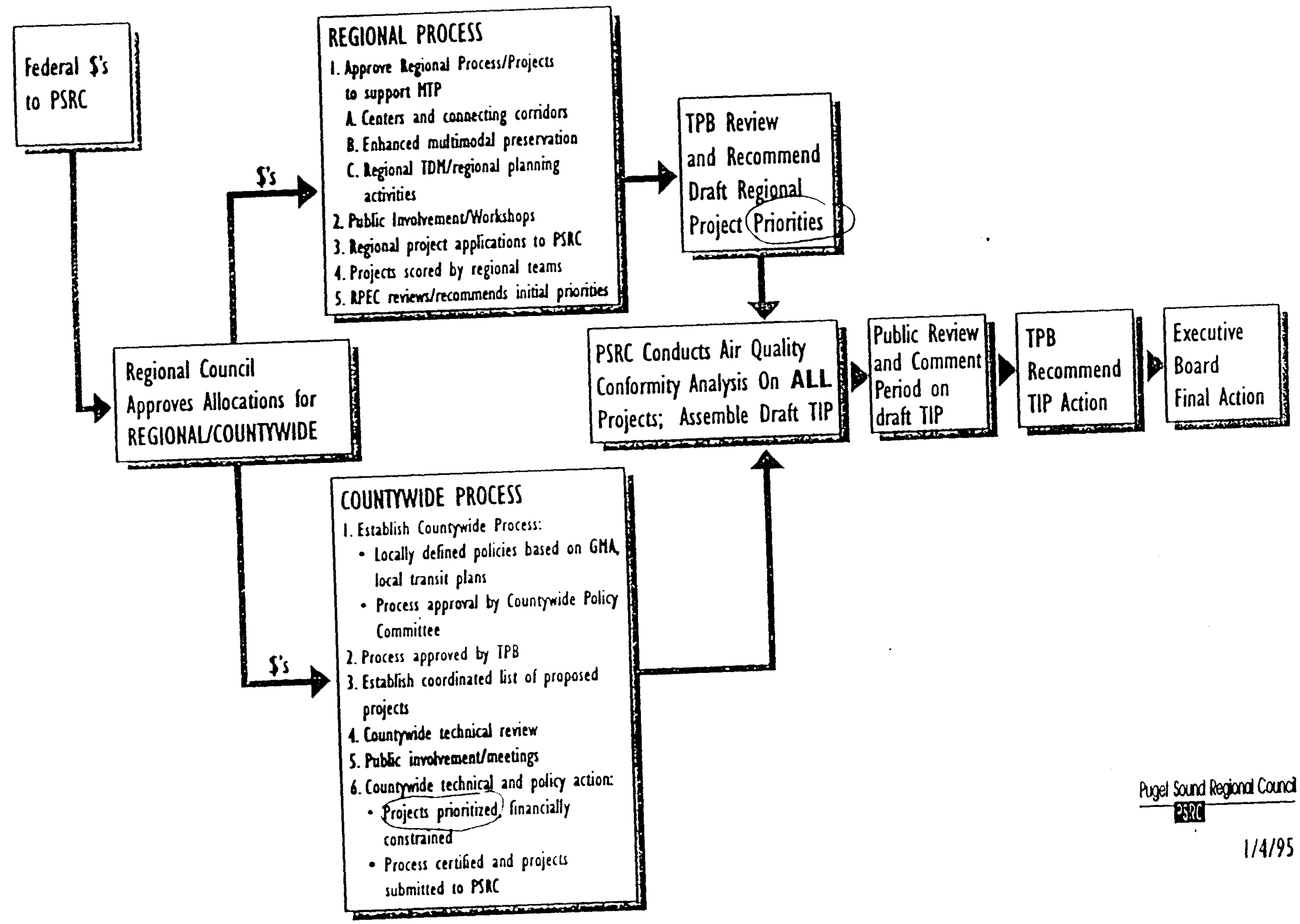
Figure 3.5-2: Overview of Transportation Programming[60]



* All programs/projects must be financially feasible, consistent with the Regional Plan (MTP) and meet air quality requirements.

[60] Seattle No. 1, attachment A.

Figure 3.5-3: 1995 ISTEA TIP Development Process for Regional and Countywide Project Applications[61]



[61] Seattle No. 1, attachment B.

3.5.5 METHODS USED TO PRIORITIZE AND SELECT PROJECTS

This section describes the PSRC's 1995 TIP Project Review/Evaluation Process. Because the Puget Sounds Region has given both regional and county agencies control over certain federal funds, they both must conduct project selection processes to allocate the funds for which they are responsible. The following text describes guidelines followed by all agencies, as well as specifics of the regional or county processes.

Qualitative Guidelines to be Followed by All Agencies (i.e. both regional & county agencies)

The PSRC's 1995 TIP policy framework describes some general qualitative guidelines for prioritizing projects. It suggests that priority be given to projects which emphasis:

- "Improved mobility within the hierarchy of designated centers (including commercial & industrial centers) or along major corridors connecting such centers.
- Projects that can demonstrate that they contribute to sustaining or encouraging continued economic vitality for the region."[62]

It also lists four broad categories of projects which should be encouraged and provides generic examples of projects which would fall under each category.

- Category 1: Critical Projects that Optimize or Manage Use of Existing Facilities/services.
- Category 2: Travel Demand Management/System Management Projects that Address Congestion and Environmental Objectives.
- Category 3: Projects that Focus Transportation on Investments that Support Transit and Pedestrian-Oriented Land Use Patterns.
- Category 4: Transportation Capacity Expansion Projects Offering Greater Mobility Options[63]

Countywide Process

Each county may develop their own evaluation criteria so long as the Transportation Policy Board approves of it.

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[62] Seattle No. 1, p. 5.
[63] Seattle No. 1, p. 5.

Regional Process

The regional project review/evaluation process is two staged. In the first stage, project sponsors submit a 2-3 page project prospectus. The Regional Project Evaluation Committee and the Transportation Policy Board of the Regional Council put these projects through a technical and qualitative screening process. Some of the screening questions considered in the first stage include (taken from the 1995 Policy Framework for PSRC's 1995 ISTEA TIP Process):

1. Does the project improve system performance? Performance can be measured in a variety of ways, such as congestion levels for highway projects, ridership per hour for transit, etc. Who benefits from the improvement should be identified.
2. Does the project reduce reliance on single-occupant vehicles?
3. Does the project help sustain and promote economic vitality through improved mobility for people or freight and goods?
4. Does the project improve or provide multimodal or intermodal access to ports, airports, or centers?
5. Does the project support air quality goals? VMT and emissions reductions are required by federal law for CMAQ funded projects.
6. How does the project support Growth Management Act/ Vision 2020 (long term regional development plan) / comprehensive plans?
7. Does the project provide greater system efficiencies or effectiveness? This may include considering improved connectivity with other elements of the transportation system or within the same system elements for improved person throughput. Examples: completion of the state HOV system; identifying missing roadway links; creating improved multimodal connections between bus, rail, ferry, and pedestrian elements.

If projects pass the screening process, they continue on to the second phase during which they are analyzed in more detail, scored and reviewed. The policy framework identifies several areas high priority projects should address:

- Maintenance and Preservation
- Traffic Congestion
- Safety
- Efficiency
- Accessibility
- Connectivity
- Reliability and Convenience
- Environmental Benefits
- Cost/Affordability

Air quality is one of the main categories considered when scoring certain projects. This is particularly the case with projects competing for CMAQ funds. During the 1993 process, air quality constituted 23% of a project's total score when dealing with CMAQ funds. It was suggested to increase this proportion to ~33% during the 1995 process. Thus, the remainder of this section will be devoted to discussing air quality scoring.

During the 1995 TIP process air quality impacts of proposed projects were estimated for the year 2005. Four measures of air quality impacts were created using the TCM Tools software package. Each of these four measures deals with "reductions". "Reductions" refers to reductions relative to expected future impacts if the proposed project were not implemented, and not to absolute reductions from presently observed impacts. These four measures are:

- *Vehicle trip reductions*: Trip reductions provide a measure of "cold-starts" and "warm-soaks" eliminated by each proposed project. Emissions resulting from these trip starts and ends often comprise a substantial portion of the emissions generated during the entire trip.

- *Vehicle miles traveled (VMT) reductions*: VMT reductions translate directly into emissions reductions, and also help reduce congestion on the region's roadway's.

- *Pollutant reductions in carbon monoxide (CO), ozone precursors -- hydrocarbons (HC) and nitrogen oxides (NOx) and particulate matter (PM_{10}):* In the past years, the region has failed to meet federal standards for carbon monoxide, ozone, and particulate matter pollution. CO, HC, and NOx reductions can be estimated using TCM Tools, which incorporates the EPA's MOBILE5a emissions factor model. The PSRC's staff are working with a consultant to investigate the use of EPA's new PART5 model, as well as other techniques, for quantifying PM_{10} impacts, and if appropriate will incorporate them in the project scoring.

- *Cost-effectiveness for CO, HC, NOx, and PM_{10} reductions*: TCM Tools provides several measures of cost-effectiveness. The current analysis is based on "gross public costs" as defined in TCM Tools. Gross public costs are comprised of the direct public expenditures associated with implementing and maintaining a project. Other measures of project costs which are not included in the analysis include avoided public costs, private costs, and individual costs. Among users of TCM Tools and similar analysis packages, there is still significant disagreement about these other cost measures based on what costs are estimated and how they are estimated. Cost-effectiveness for PM_{10} will also be addressed if a methodology for quantifying PM_{10} emissions impacts is identified.[64]

Once the analysis is completed and these four measures of impacts have been produced, project sponsors and other interested parties are allowed to review/comment on the results before final scores are produced. Revisions to the analysis results are accepted if sufficient justification is provided.

[64] Taken directly form Seattle No. 2, p I-2 and I-3.

Once all parties have agreed upon the analysis results, the above four measures are used to score each project. Each of the four measures: 1) trip reductions, 2) VMT reductions, 3) pollutant reductions, and 4) cost-effectiveness for pollutant reductions, receive equal weight in the final score. Within measures (3) and (4), reductions of each pollutant carry equal weight.

Scores within each of the four categories are tiered, since analysis results are inexact. For instance, projects eliminating either 1,500 or 1,800 daily vehicle trips receive the same score. Both projects receive lower scores than projects eliminating 5,000 trips and a higher score than projects eliminating only 500 trips. Initially, the tiers are defined by dividing the greatest observed impact by the total number of points available. These preliminary tiers are then revised if "comparable" projects have been placed on separate tiers, or if projects falling at the margins of each tier are not appropriately scored.[65]

3.5.6 ANALYSIS OF IMPACTS

Air quality and other impacts are considered during two segments of the 1995 TIP development process.

1. During the *Project Review/Evaluation Process* conducted by the PSRC, county or other agency, to select and prioritize projects.
2. During the air quality *conformity analysis* in which the PSRC analyzes the combined impact of all proposed projects.

Analysis Methods Used in the Project Review/Evaluation Process

The analysis methods used during the review/evaluation process depend on the lead agency. In particular, there is a distinction between the approach taken by regional (PSRC) agencies, countywide agencies (King, Kitsap, Pierce, and Snohomish), and transit agencies (who are responsible for certain FTA funds). Each countywide organization must develop their own technical and policy criteria. Although they are not required to use the methods adopted by the regional agency (PSRC), their methods must be approved by the Transportation Policy Board (a regional level agency associated with the PSRC).

The regional agency (PSRC) uses a combination of qualitative and quantitative methods to select/evaluate projects. The discussion here focuses on the analytical tools used to produce air quality scores.

Air quality impacts are quantified using a TCM Tools software package and other comparable methodologies. During 1993 and 1994 the regional council modified the program originally developed for the San Diego metropolitan area to produce a TCM

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[65] Seattle No. 2, p. I-2 and I-3.

Tools software applicable in the Puget Sound region. This software package was then distributed throughout the region and training sessions were provided by the PSRC. The program is through the PSRC's electronic bulletin board or the PSRC's Information Center and can be run on most IBM-compatible personal computers. It currently requires the Lotus 1-2-3- spreadsheet software.

The TCM tools software contains three modules: travel, emissions, and cost-effectiveness. It is programmed to model 23 pre-defined TCMs and has the ability to model a user-defined TCM if its travel impacts are inputted. In the case of user-defined TCMs a method comparable to TCM Tools is used to estimate travel impacts. A variety of methods for conducting such analysis exist, and the PSRC recommended that project sponsors conduct their own analysis and determine the best method for estimating travel impacts of their project. Brief summaries of some sample methodologies are available in figure 3.5-4.[66] More details on TCM Tools are available in a companion report entitled, "Documentation and Analysis of Technical Methods Currently Available for Quantifying the Emission Effects of Transportation Control Measures".

Methods Used to Conduct the Conformity Analysis

In order to prove conformity, a region must show that projects included in the TIP do not interfere with air quality goals. The details of this requirement are quite involved. In essence, it entails comparing the air quality impacts of "build" and "no build" scenarios. The "build" scenario includes regionally significant transportation projects which can be modeled. Because the analysis is based on results from a system of models, only projects which can be coded into the models are included in the analysis.

The system of models used to conduct the conformity analysis includes the PSRC's land use models, PSRC's travel demand models, and EPA's MOBILE emissions factor model.[67] A detailed diagram of the modeling system used is available in figure 3.5-5. CO, HC, and NOx emissions were calculated and compared to find that the proposed TIP did meet conformity requirements. More specifically, emissions of each pollutant were calculated for each link of the highway network and summed for the whole region and each nonattainment area.

[66] Seattle No. 2, p. I-5.

[67] Seattle No. 5, p. 5-7.

Figure 3.5-4: Brief summaries of inputs and calculations involved in modeling selected TCMs[68]

Example 1:
Targeted employer-based trip-reduction programs (TCM Tools #1)

Inputs for travel/emissions impacts:

- Number of employers targeted
- Average size of employer
- % peak SOV reduction
- Base SOV mode share

- % of participants who switch to each mode
- Average carpool vehicle occupancy

Additional inputs for cost-effectiveness:

- Hours required to review plan
- Number of plans to be prepared
- Public program administration costs

Calculations:

The number of employers and average size of employer are used to identify the target population. The % peak SOV reduction and base SOV mode share are used to estimate the total trip reduction, which is refined using the other inputs. TCM Tools also calculates changes in average speeds due to travel impacts.

[68] Seattle No. 2, p. I-5 and I-6.

Example 2:
Nonmotorized facility projects (City of Seattle methodology/user-defined TCM)

Inputs for travel/emissions impacts:

- Current bicycle/pedestrian commuting and non-commuting rate
- Average bicycle/pedestrian commute and non-commute trip length
- Average population density; length of improvement
- Estimated percent increase in nonmotorized trip due to facility

Additional inputs for cost-effectiveness:

- Number of feet of paths to be constructed and average construction cost
- Average operation and maintenance costs.

Calculations:

Average population density and length of the improvement are used to estimate the target population. The other inputs are used to calculate the estimated existing base of nonmotorized trips, and estimated travel impacts of the project.

Example 3:
Transit service expansion projects (TCM Tools #6)

Inputs for travel/emissions impact:

- Increase in revenue vehicle miles
- Average percent fare decrease
- Percent of transit ridership increase that equals trip reduction

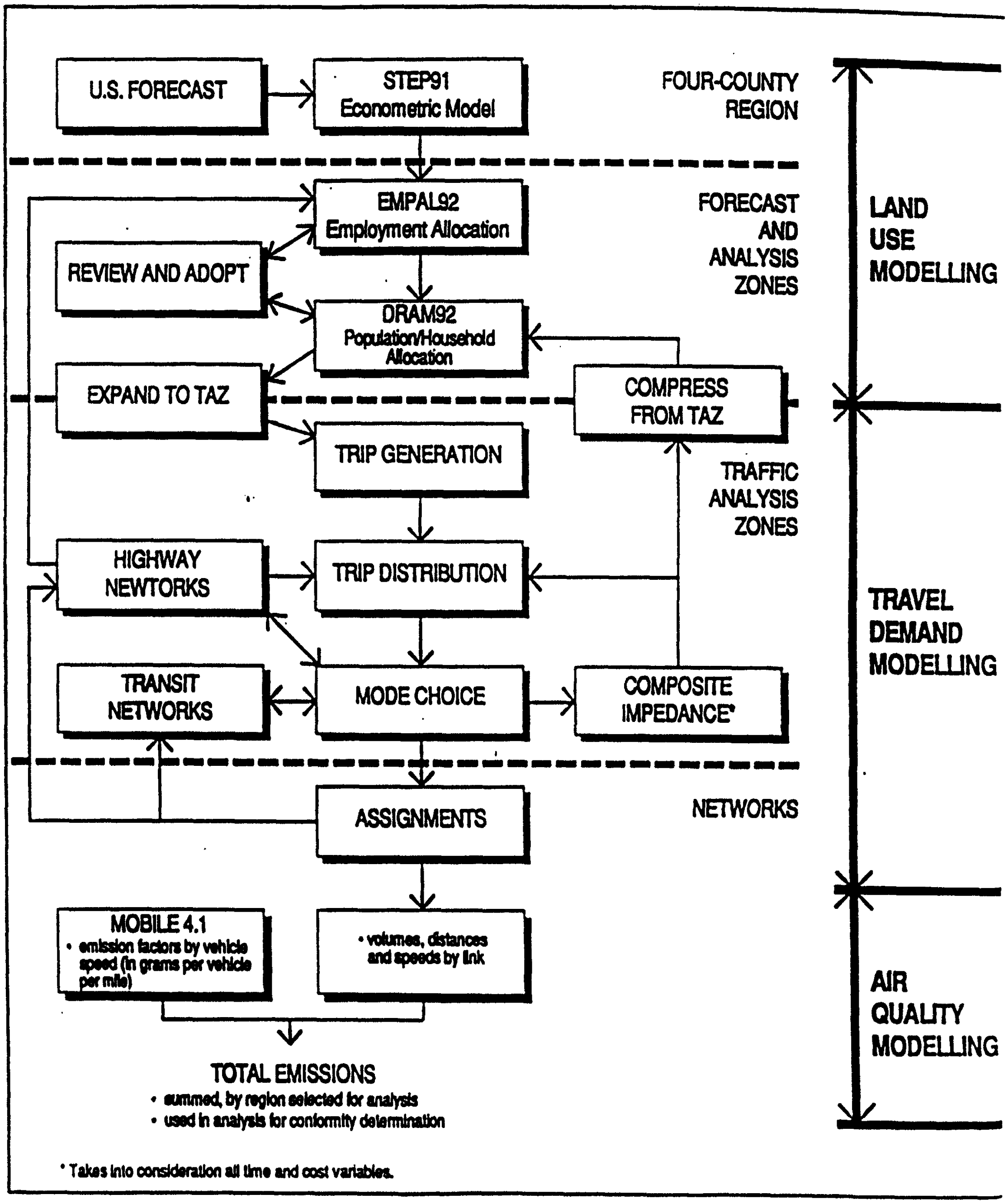
Additional inputs for cost-effectiveness:

- Capital cost of facilities to be constructed
- Purchase cost of new vehicle and number to be purchased
- O&M cost per mile of transit service
- Revenue per revenue mile of service

Calculations:

Increase in revenue vehicle miles and average percent fare decrease are used to estimate new transit trips based on historical and forecasting data. Percent of transit ridership increase that equals trip reduction is used to eliminate induced trips or trips substituted from other modes.

Figure 3.5-5: Overview of models used by PSRC to determine conformity[69]



[69] Seattle No. 5, p. 6.

3.5.7 SUMMARY AND CONCLUSIONS

The case study focuses on the 1995 TIP Project Review/Evaluation Process. It outlines the entire process, but only presents details of the methodology for quantifying air quality impacts and converting them into project scores. In addition to this discussion of TIP project selection, the study touches on TIP conformity analysis and TCMs included in the SIP.

Some interesting qualities of the Seattle Case Study include:

- The regional agency provided county agencies with control over certain funds to facilitate planning for localized needs.
- The PSRC selected analysis methods which could produce comparable results, so that the results could be used to rank projects relative to one another.
- Projects included in the TIP undergo air quality analysis twice. During the project scoring process TCM Tools was used to derive reasonably accurate estimates of air quality effects. However, a more detailed analysis methodology (a system of models which addressed land, travel, and emission impacts) was used to measure the combined air quality effects of all projects included in the TIP. The selective use of this detailed model demonstrates how certain analysis tools suit certain needs.
- Washington State has a "Growth Management Act" which recognizes the need to focus population growth in urban centers and to preserve rural areas.
- The 1993 SIP includes no TCMs, while the 1982 SIP contains 223. This is because the oxygenated fuels and inspection/maintenance programs should reduce emissions enough to bring the region into conformity. The PSRC believes TCMs will be helpful in maintaining air quality, however, once attainment has been reached.

In addition to presenting these interesting details, the Seattle Case Study also does not address certain issues:

- It does not provide the results of the air quality analysis/scoring conducted for the TIP project selection process.
- It does not include the details of how the PSRC scored criteria other than "air quality". Nor does it explain how scores in each criteria were compared (i.e. how total project scores were derived from individual criteria scores). Also unmentioned is how project scores are used to rank projects.
- It does not mention which projects were considered and which were eventually selected in the regional TIP.
- It does not discuss the 223 TCMs included in the 1982 SIP and how they were selected.

3.6 San Francisco Bay Area (SFBA)

3.6.1 WHY THIS REGION WAS INCLUDED AS A CASE STUDY

This region was included for two primary reasons. First, the San Francisco Bay Area resembles the Boston area. Like Boston, San Francisco's transportation system focuses around a variety of rail systems, a bus network, roadway networks, and ports/harbors. Also, it was recommended by FHWA staff as a region which has had significant experience with TCM programs. The extensiveness of SFBA's experience may be due to the additional requirements imposed by the California Clean Air Act, which regions in other states do not have to address.

Implementation of TCMs in the SFBA is encouraged through two air quality legislation: the California Clean Air Act (CCAA) and the federal Clean Air Act Amendments (CAAA). State and federal standards for carbon monoxide are the same, while the state standards are more stringent for ozone and PM_{10}. In terms of meeting these standards, air quality in the Bay Area has been improving over the past two decades. As of 1994, the Metropolitan Transportation Committee (MTC), the Bay Area Air Quality Management District (BAAQMD), and the Association of Bay Area Governments (ABAG) believed that the region had already achieved federal standards for ozone, and awaited concurrence from the federal EPA on this. Also, according to recent air monitoring (1994), federal standards for CO have been attained and plans are being prepared to submit a redesignation request to the EPA for this pollutant. [70]

Officially, the SFBA is in 'moderate' nonattainment of federal CO and ozone standards. In order to meet federal and state air requirements, the SFBA developed a Transportation Control Measure Plan (TCMP) in 1990, amongst other actions. This case study focuses on the 1990 TCMP.

3.6.2 BRIEF REGIONAL PROFILE

The San Francisco Bay Area consists of nine counties: San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, Sonoma, and Marin. The rather large region and its major transportation facilities are pictured in Figure 3.6-1. The region's existing transportation infrastructure includes 1,400 miles of state highways, eight major bridges, 18,000 miles of local streets and roads, and some two dozen transit operators with more than 4,000 vehicles and 200 miles of rail.[71] This extensive transportation network was being used by the regions approximately 6 million residents, as of 1990.

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[70] San Francisco No. 3, p. 32-33.
[71] San Francisco No. 3, p. 2.

Over the past few decades, the Bay Area's population has grown and decentralized, causing the number of suburban centers around urban core to increase. Jobs followed the population shift into the suburbs, creating new employment centers in central Contra Costa, Alameda, and Santa Clara counties. Inter-regional commuting also increased as Bay Area workers sought more affordable housing in communities outside the region. These changing demographic patterns created more diffuse and dispersed travel patterns for Bay Area residents. The new trips are extremely difficult for transit to serve effectively. Thus, the trend in dispersed trip-making, in combination with rising household incomes and vehicle ownership, has resulted in increased reliance on the automobile.[72]

These trends may be communicated numerically. By 2010 the regional population should be 7.5 million, 1.5 million more than in 1990. Unlike in previous years, births should account for as much as 80.4% of this growth due to the diminishing share of population growth attributable to immigration. In the case of job growth, an increase of 1.4% per year between 1990 and 2010 is predicted. This is far less than the 2.3% per year rate that occurred during the 1980's. Growth in person trips is also expected to slow in 1990-2010 relative to the 1980's, however it will not slow as much as other growth indicators. One possible explanation for this is the projected continued rise in household income and vehicle ownership. Between 1990-2010 person-trips should grow at an annual rate of 1.6, whereas between 1980-1990 they grew at a rate of 2.2%. As a result of these demographic changes, commute patterns will also transform between 1990 and 2010. Figure 3.6-2 displays the current regional commute patterns and the commute patterns expected in 2010.[73]

3.6.3 ORGANIZATIONAL STRUCTURE

The Metropolitan Transportation Commission (MTC) first convened in February 1971 to provide comprehensive regional transportation planning and programming for the nine-county San Francisco Bay Area. MTC actions are determined by MTC and its staff, along with public and private agencies, public officials, and citizens. Issues and matters for decision are referred to staff and committees for study prior to review and decision by MTC.[74] In the case of the 1990 TCMP (Transportation Control Measure Plan), much of the analytical work and methodology development was performed by Greig Harvey.

In January of 1992, MTC formed The Bay Area Partnership. The Partnership consists of top managers from 31 agencies responsible for moving goods and people around the SFBA, as well as for protecting the region's environmental quality. It attempts to be non-hierarchical and egalitarian in nature. Thus, while MTC has significant power according to federal law, it has chosen to share this power with the many agencies responsible for SFBA's transportation system.

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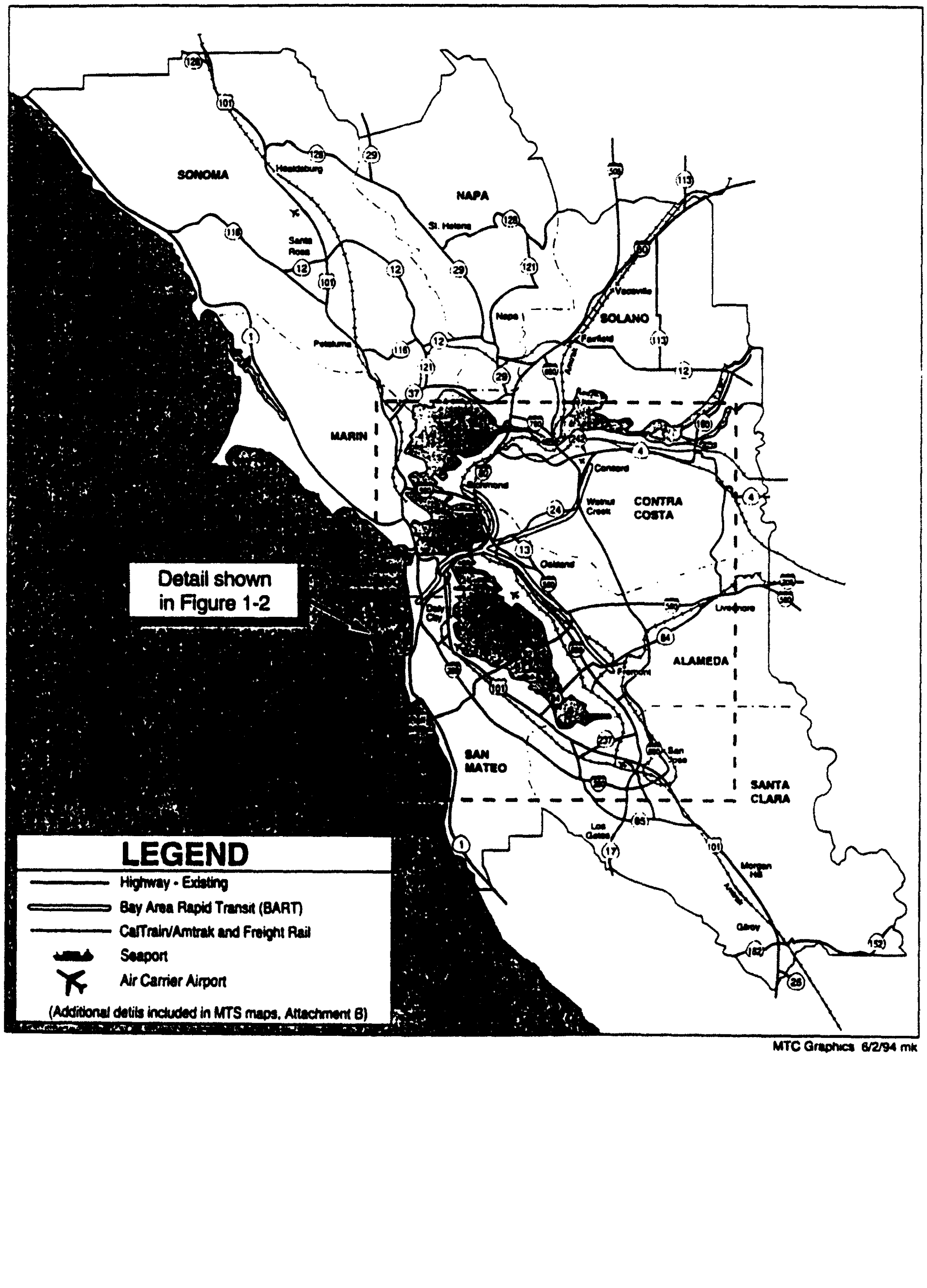
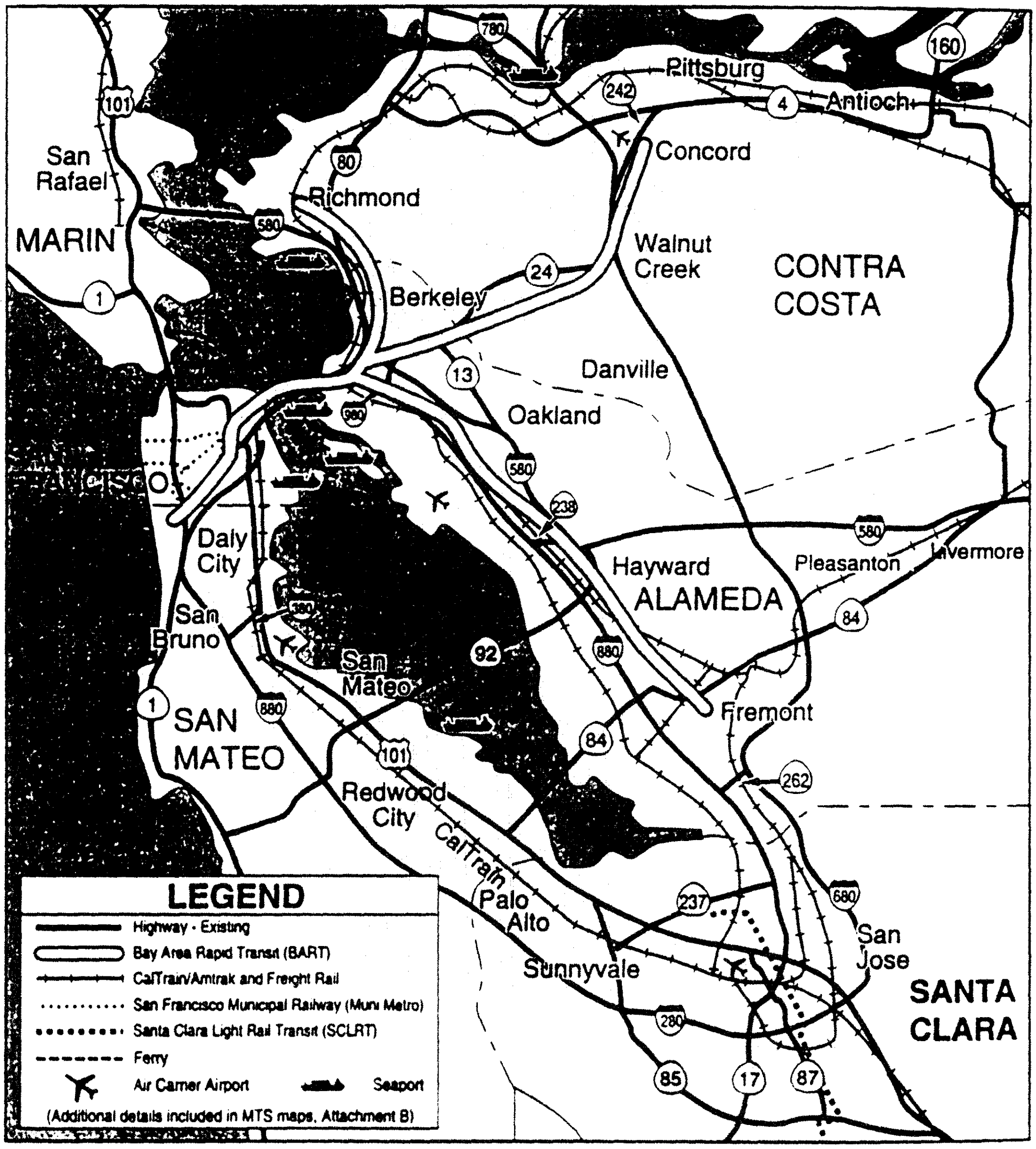
[72] San Francisco No. 3, p. 10.
[73] San Francisco No. 3, p. 11 to 24.
[74] San Francisco No. 5, p. I-1-5.

Figure 3.6-1: Bay Area Major Transportation Facilities[75]

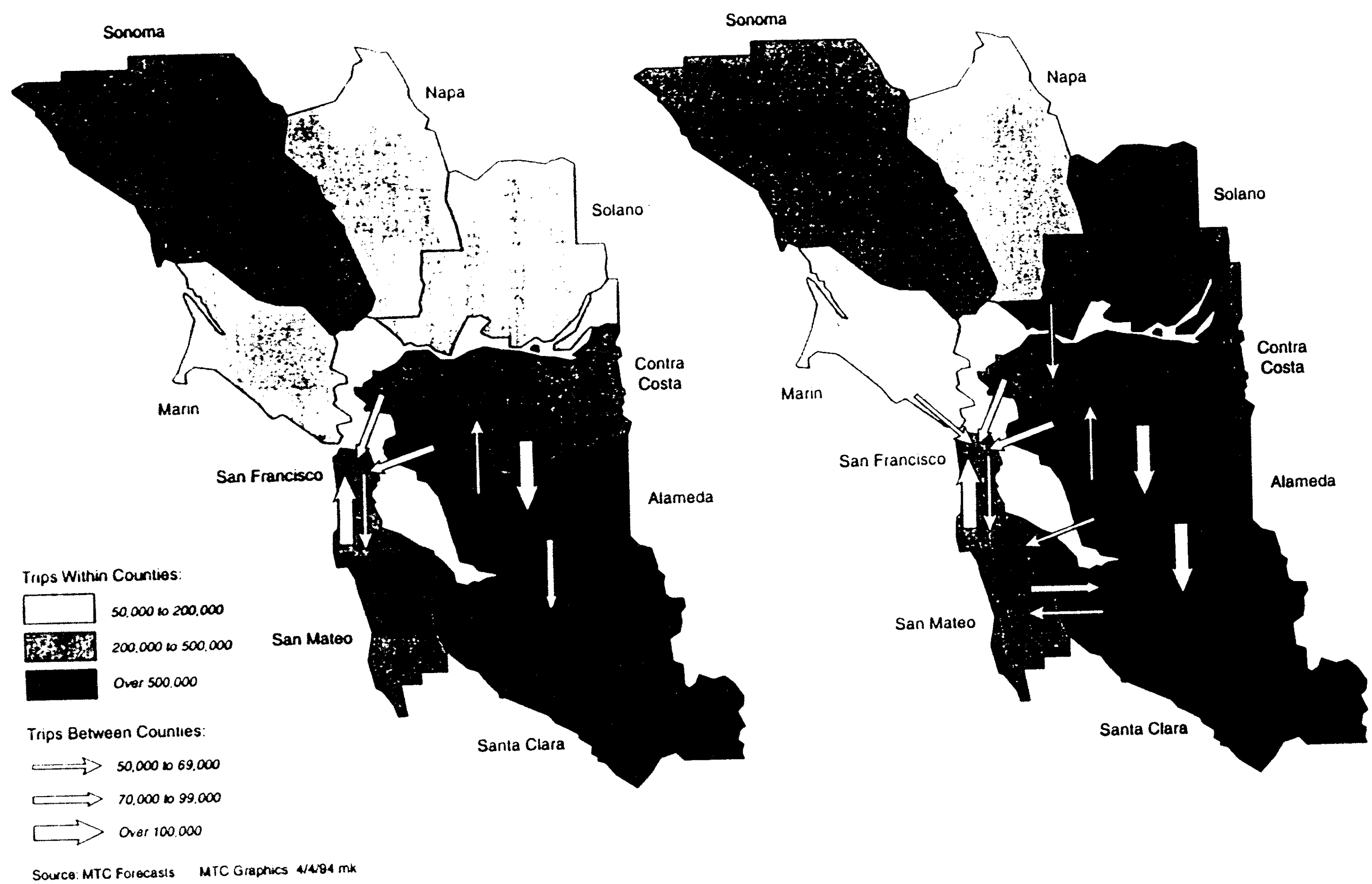


[75] San Francisco No. 3, P. 11.



MTC Graphics 6/2/94 mk

Figure 3.6-2: Greatest Volumes in Commuting: 1990 and 2010
Includes Inter-county and Intra-county Commutes over 50,000/day[76]



[76] San Francisco No. 3, p. 24.

3.6.4 DESCRIPTION AND STATUS OF CURRENT TCM RELATED PROGRAMS

The Bay Area attributes the most significant reductions in mobile source emissions to improvements in the internal combustion engine over the past 20 years. Due to advances such as "tailpipe" controls, cleaner fuels, biennial Inspection and Maintenance ("smog check") programs, cars in 1994 were about 90 percent cleaner than their counterparts of 20 years ago. The California Air Resources Board has adopted regulations that will result in even cleaner vehicles over the coming decade. Coupled with the natural turnover in the vehicle fleet, these regulations will continue to reduce mobile source emissions (except PM_{10}) in the future. In addition, the Bay Area Air Quality Management District (BAAQMD) and ABAG have adopted TCMs to help achieve air quality standards.[77]

The 1994 Regional Transportation Plan (TP) for the San Francisco Bay Area includes a number of TCMs aimed at meeting state and federal air quality regulations. These TCMs are listed in the Appendix G.[78] The TP places priority on meeting prior commitments and maintaining the existing Metropolitan Transportation System. In fact, it designated $70 billion of its $74 billion budget to this. Air quality attainment was assumed to be achieved in 1997 and therefore no CMAQ funding was assumed available in 1998 and after. MTC hopes to change federal laws so that "maintenance" areas could also receive CMAQ funds.[79]

Although CMAQ funds are assumed unavailable after 1998, a number of CMAQ funded projects are included in the 1995 TIP. Also included in the TIP are a large number of transit and other projects which probably have air quality benefits but are funded by sources other than CMAQ. All projects included in the TIP must undergo the MTC Project Review Process.[80] (see appendix S for scoring criteria used in this process) Although these processes exist, they are not the primary subject of this case study. They are but one component of the San Francisco Bay Area's lengthy history with TCM-related programs.

This case study deals with the development of the 1990 TCM Plan (TCMP). The 1990 TCMP is the MTC's proposal to the Bay Area Air Quality Management District for the TCMs necessary to implement Clean Air Act requirements for mobile source emissions. The plan was required input to the Air District, which was responsible for the development and adoption of an overall plan for the Bay Area by June 1991. This was because the California Clean Air Act required each region in the state to develop a plan for achieving air quality standards by June 30, 1991. The 1990 TCMP was adopted by the MTC on June 27, 1990, and revised on November 28, 1990 after a year and a half of extensive public input.[81]

[77] San Francisco No.3, p. 33.
[78] San Francisco No. 3, p.C-1 to C-5.
[79] San Francisco No. 3, p. 58.
[80] San Francisco No. 5, p. I-1-6 to I-1-11, I-4-1, and I-4-11.
[81] San Francisco No. 2, p. 2.

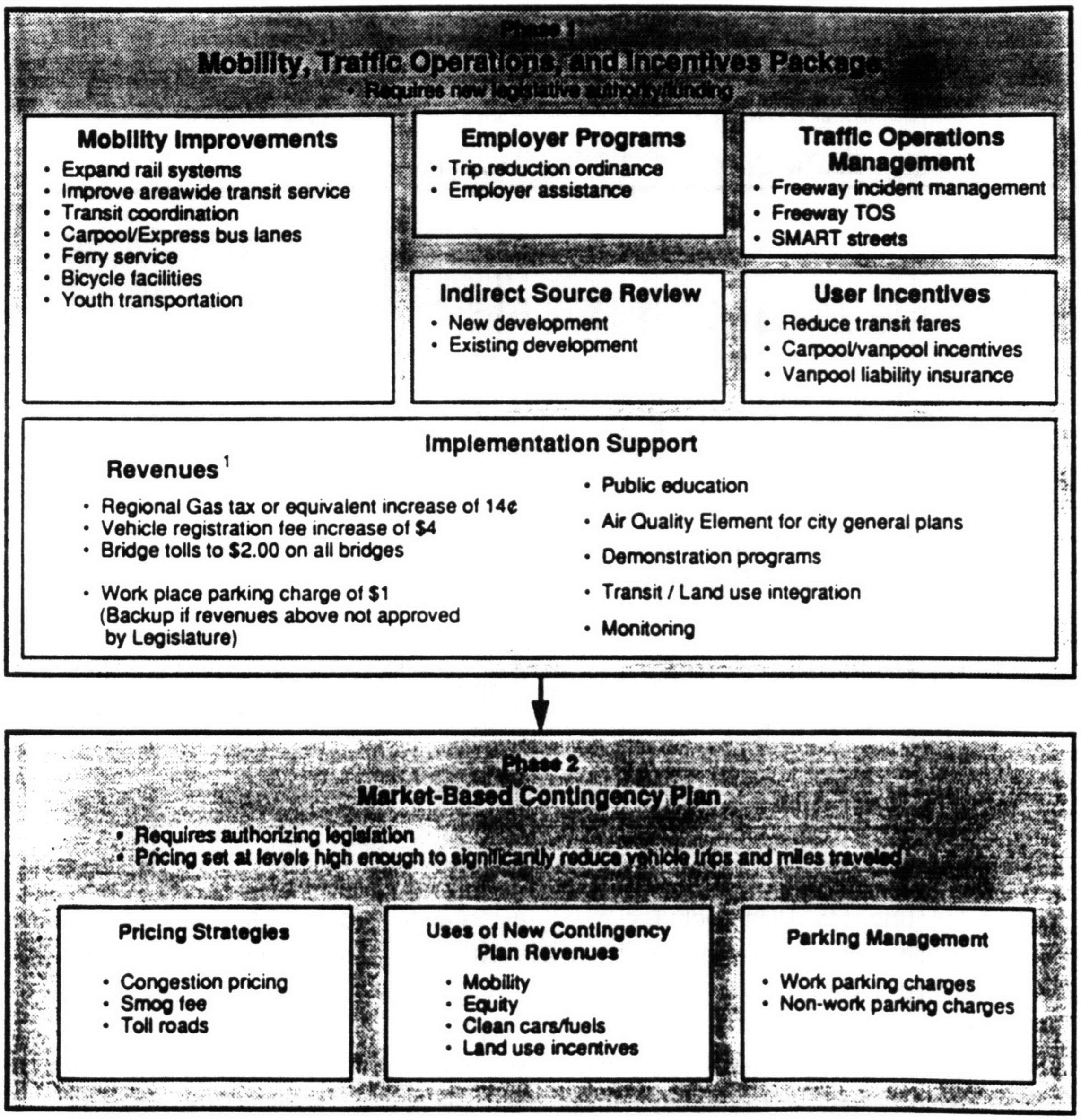
The final 1990 TCMP contains two sub-plans: the Mobility package and the Contingency Plan. Figure 3.6-3 displays this two-phased plan and the general measures included in each. It is in the Phase 1 Mobility Plan that "reasonably available" TCMs are incorporated into the plan. A total of 21 such TCMs are included:

1. Expand Employer Assistance Programs
2. Adopt Employer-Based Trip Reduction Ordinance
3. Improve Areawide Transit Service
4. Expedite and Expand Regional Rail Agreement
5. Improve Access to Rail
6. Improve Intercity Rail Service
7. Improve Ferry Service
8. Construct Carpool/Express Bus Lanes on Freeways
9. Improve Bicycle Access
10. Youth Transportation
11. Install Freeway Traffic Operations (TOS)
12. Improve Arterial Traffic Management
13. Reduce Transit Fares
14. Vanpool Liability Insurance
15. Provide Carpool Incentives
16. Conduct Indirect Source Review
17. Conduct Public Education
18. Zoning Plans for Higher Densities Near Transit Stations
19. Air Quality Element for General Plans
20. Construct Demonstration Projects
21. Implement Revenue Measures[82]

More detail on each measure (description, implementation, and schedule) is available in document "San Francisco No. 2".

[82] San Francisco No. 2, p. 13-33.

Figure 3.6-3: Revised (November 1990) TCM Plan[83]



1. Revenue set at level to fund mobility, traffic operations, and incentives package.

[83] San Francisco No. 2, p. 6.

In addition to these 21 "reasonably available" TCMs, phase 1 also provides for: (1) mobility improvements, traffic operations strategies, and user incentives, and (2) adoption of revenue measures to implement the mobility program. The primary components of the "mobility, traffic operations and incentives package" are displayed in table 3.6-1. Some revenue measures which were considered as funding sources are bridge tolls, registration fees, regional gas tax, and parking charges.[84]

Table 3.6-1: Mobility, Traffic Operations And Incentives Package[85]

	ANNUAL TOTAL (in millions $)
• **Transit Improvements (total of the 3 below)**	**397**
Rail Capital and Facility Rehabilitation	82
Transit Fare Subsidy and Service Increase	291
Transit Coordination and Information	24
• **Commute Alternatives (total of the 4 below)**	**17**
Ridesharing (RIDES, local agencies)	6
Bicycle and Pedestrian Projects	4
Demonstration and Public Education	4
Planning and Monitoring	3
• **Traffic Operations and HOV Package**	**41**
• **Youth Transportation**	**107**
• **Earthquake Retrofit of Bridges**	**20**
TOTAL (of all projects above)	582

The phase 2 Contingency Plan includes measures intended to broaden the TCMP's approach to mobile source emission controls beyond the phase 1 foundation. Some strategies suggested for consideration in the 1991 Clean Air Plan include: (1) further improvements in the State's "Smog Check" program, (2) emission-based vehicle registration fees, and (3) reformulated gasoline. Also included in the Contingency Plan are some market-based pricing and parking management strategies. These pricing strategies were left to the Contingency Plan even though they have large emission reduction potential, because of the political and public aversion to them.[86]

[84] San Francisco No. 2, p. 9.
[85] San Francisco No. 2, p. 7.
[86] San Francisco No. 2, p. 11.

More specifically, the projects included in the analysis of the Contingency Plan's emission reduction potential are:

1. Regionwide Employee Parking Charge of $3.00 Per Day
2. Subsidized Transit and Ridesharing
3. Regionwide Non-employee Parking Charge of $0.01 Per Minute
4. Subsidized Off-Peak Transit
5. Gasoline Tax Increase to $2.00 Per Gallon
6. Mileage- and Smog-Based Registration Fee (average $125 per vehicle)
7. Regionwide Congestion Pricing (LOS D)

3.6.5 METHODS USED TO PRIORITIZE AND SELECT PROJECTS

By June 1990, the Metropolitan Transportation Commission (MTC) needed to adopt a Transportation Control Measure Plan (TCMP) to meet state air quality standards and to demonstrate reasonable progress by the transportation sector. The preparation of an updated TCMP entailed five steps

1. Defining a comprehensive set of possible TCMs
2. Identifying individual measures with significant emissions reduction potential
3. Integrating feasible TCMs into a region-wide control plan (TCMP)
4. Analyzing the combined effect of measures in the TCMP
5. Assessing the institutional feasibility (social, political, and economic) of potentially effective TCMPs.

Because the second step had only been partially completed by November 1989 and the entire process needed to be completed by June 1990, the methods used in steps 2 through 5 had to be quick.

The MTC staff and the TCM Task Force worked jointly to accomplish the first step: developing a list of potential TCMs. This preliminary list is available in Appendix H.[87] The second step took the form of a screening methodology: individual measures were quickly analyzed for emission control effectiveness. In most cases, the "first-cut" analysis measured the emission reduction effectiveness of the TCM assuming that the measure would be fully implemented in all applicable markets. Implementation issues (likely degree of market penetration given political acceptability, institutional responsibilities, resource requirements, etc.) would be considered in detail for the measures which showed promise in this "optimistic", initial, "first-cut" screening. Also, more detailed quantitative analyses would be conducted as needed.[88]

[87] San Francisco No. 1, p. 1.
[88] San Francisco No. 1, p. 11.

3.6.6 ANALYSIS OF IMPACTS

Impacts were analyzed primarily in the second and fourth stages of the process. The second stage entailed a quick analysis of numerous measures for screening purposes. However, during the fourth stage, when individual TCMs had been combined into a few control plans, a more detailed and lengthy analysis was conducted. The following two subsections describe the analysis methods used in more detail.

Analysis Methods Used During the Second Stage - Screening

Because the entire process, including stage 2, had to be completed in about one year, the screening methodology used had to be quick. In particular, the time constraint on this process imposed three limitations on the methodologies available:

- Analyses needed to rely on existing tools and sources of data
- It was not practical to use the full MTC regional travel forecast model system for screening; the full model system's application procedures were designed for careful study of major transit and highway alternatives rather than rapid review of a host of possible changes to the conditions of travel.
- Even with a rapid analysis method, some judgment had to be used to pare down the list of candidate TCMs to a subset that was both representative of the full range and workable in the time available.[89]

Given these restrictions, Greig Harvey devised a screening methodology for the Bay Area to use. The methodology is based on the premise that the appropriate analysis methodology is a function of the type of effect the measure is expected to have on travelers. He identified eight major "effect" categories, each with a preferred analysis approach. Details of these categories are available in document "San Francisco No. 1", but they are, in short:

1. *Change Travel Times* - measures which reduce travel times on high occupancy modes (e.g. carpool lanes and increased transit frequencies) or measures which increase travel times on low occupancy modes.
2. *Change Travel Costs* - some examples include (1) a surcharge for worker parking, (2) tolls for use of congested facilities, and (3) increased fuel costs.
3. *Limit Travel Options* - for instance, banning single occupant autos from key facilities during a pollution episode or creating auto restricted zones.
4. *Expand Travel Options* - measures such as Bay Area Rapid Transit (BART) extensions, extending the ferry network, or increasing bus service.
5. *Alter Traveler Perception* - e.g. promotional activities
6. *Change Vehicle Technology* - e.g. modify the internal combustion engine
7. *Relieve Activity Constraints* - e.g. flextime and telecommuting
8. *Modify Land Use* - Evidence suggests that local land use regulations have kept dwelling unit densities below levels that market forces would otherwise dictate.

[89] San Francisco No. 1, p. 2.

Depending on which of the above eight categories a TCM falls into, one of five available analysis tools may be more appropriate. The five analysis tools available to the Bay Area and appropriate for these screening purposes are:

1. *Inference based on elasticities*
2. *STEP* - a software package which implements a subset of the large model system in a framework that is supposed to economize on human and computer resources. A diagram of its structure is provided in figure 3.6-4.
3. *LOCATE* - LOCATE is a software package based in the same "sample enumeration" concept as STEP, but also using new choice models developed for work mode choice, auto ownership, and residential location. See figure 3.6-5 for diagram of LOCATE's structure.
4. *CHAIN* - CHAIN is an ensemble of data files and software that supports detailed studies of the Bay Area 1981 Travel Survey. It focuses on the sequence of trips made by persons in the survey, assembling them into home-based "chains". See figure 3.6-6 for a visual descriptions. The primary use of CHAIN will be to examine the implications of vehicle fleet strategies.
5. *Inference based on case study data*

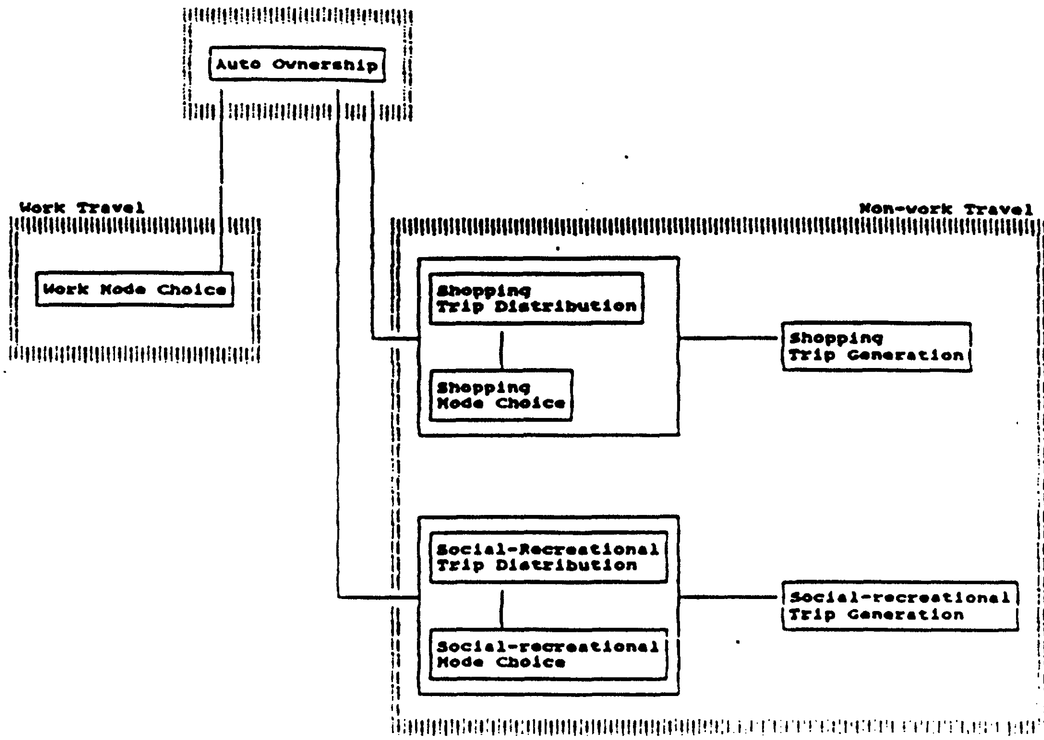
A more detailed description of these five analysis tools is available in the footnoted source.[90] Also available in that source are examples of how the screening methodology would be applied to a broad range of TCMs.

Analysis Methods Used During the Fourth Stage

By the fourth step ("analyzing the combined effect of measures in the TCMP") individual TCMs had been combined into a few control plans which the full MTC regional travel forecast model system was used to analyze.[91]

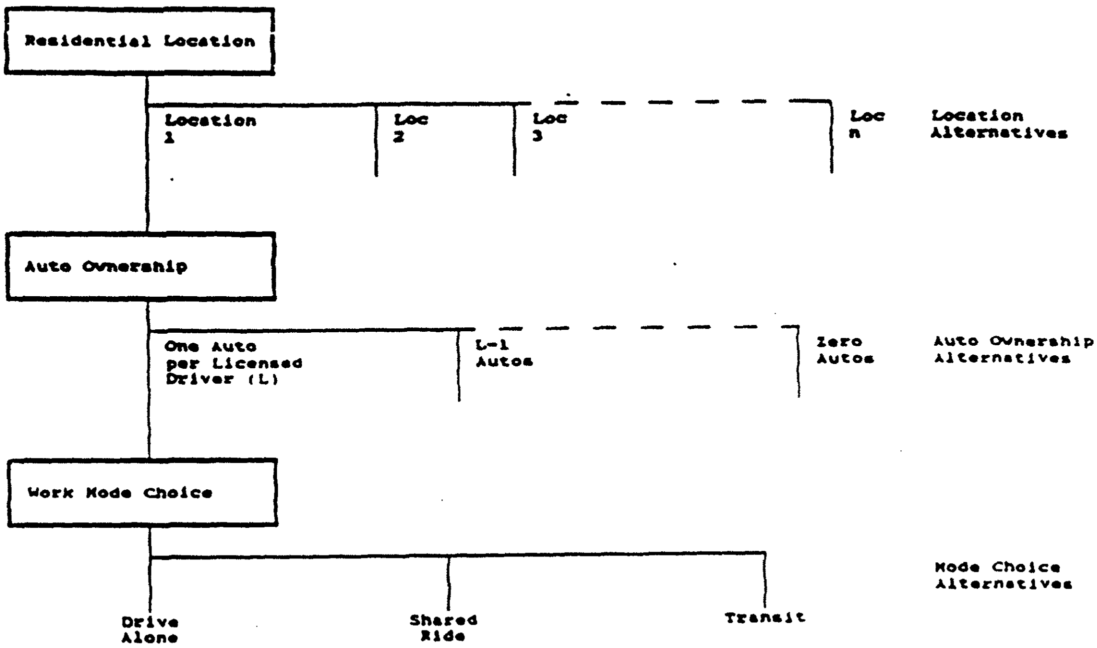
[90] San Francisco No. 1, p. 8-10.
[91] San Francisco No. 1, p. 2.

Figure 3.6-4: Structure of Demand Models in STEP[92]



[92] San Francisco No. 1, figure 1.

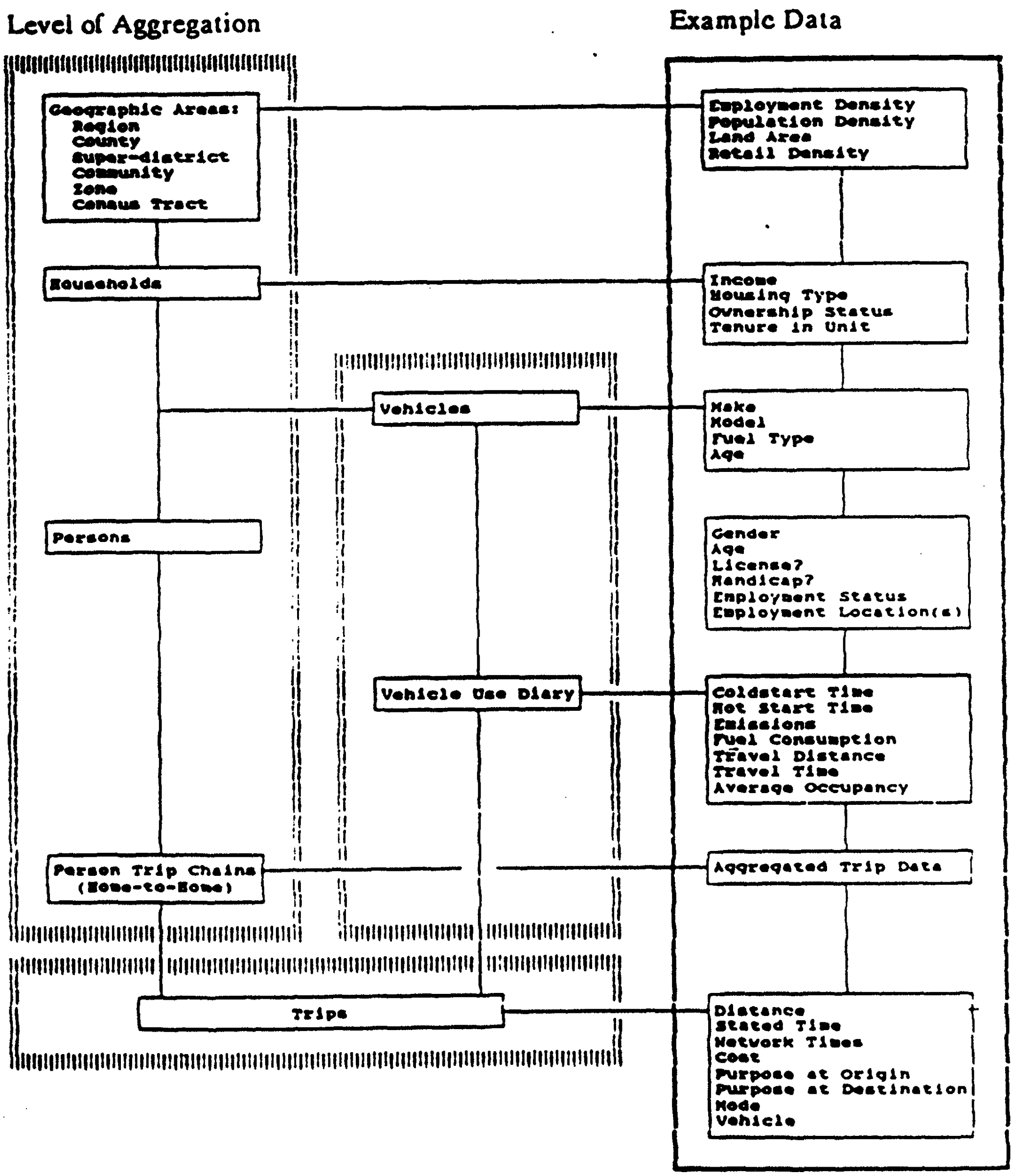
Figure 3.6-5: Structure of Demand Models in LOCATE[93]



Note: In order to simplify the figure, lower level models are shown only for the first alternative at each level. A parallel substructure applies for each upper level alternative in the figure.

[93] San Francisco No. 1, figure 2.

Figure 3.6-6: Data Hierarchy in CHAIN[94]



[94] San Francisco No. 1, figure 3.

Analysis Methods Used to Estimate Cost-Effectiveness

California state law requires an analysis of the cost-effectiveness of the TCM Plan. Thus, the cost-effectiveness of various TCMs and the Phase 1 Mobility Plan of the 1990 TCMP were calculated. Cost-effectiveness was measured in units of $/lb and $/ton and was derived from the following five calculations:

- *Emission Reductions (pounds and tons):*
  Emission reductions were based on percentage reductions, in hydrocarbons (HC), for various TCMs as estimated by Greig Harvey in the June 1990 TCM Plan or earlier work. Daily 1997 mobile source baseline emissions were estimated using the most recent Air Resources Board factors for cars (EMFAC 7E). Tonnage reductions were estimated by multiplying the baseline emissions inventory by the percentage HC reductions.

- *TCM Cost:*
  All Costs were converted into 1997 dollars using a 4% per year inflation rate. Costs represented one or more types of costs, depending on the particular measure, as follows: capital costs (annualized), operating costs, maintenance costs, or consumer out-of-pocket costs.

- *Cost per Pound/Ton:*
  Cost per pound and per ton was determined by dividing the TCM cost by the emission reduction estimated for that TCM.

- *Annual Cost:*
  Annual TCM costs were developed from daily cost through annualization factors which were subjectively determined, depending on whether the measure primarily affected weekday work trips, non-work trips, or a combination of work and non-work trips.

- *Benefits:*
  Cost-effectiveness estimates do not include adjustments for mobility and other benefits provided by the TCMs such as reduced congestion, travel time savings, decreased automobile operating costs, and energy savings.[95]

Results of Analysis of the 21 TCMs Included in the TCMP

Five measures of emission reductions were produced: VMT, Trips, HC, CO, NO_x, and CO_2. In addition to the analysis of the 21 individual TCMs, seven TCM packages were analyzed. These were (1) employer-based measures, (2) mobility improvements, (3)

[95] San Francisco No. 2, p. 44.

traffic operations management, (4) user incentives, (5) alternative revenue concepts, (6) transit/land use integration, and (7) implementation support. Each of the 21 TCMs was included in one of these seven packages. It should be noted that the combined effect of the 21 TCMs was smaller than the sum over individual measures.[96]

The implementation of all 21 TCMs would reduce hydrocarbon emissions by 8%, which is 27% below the 35% Air Districts' target. The 27% shortfall was assigned to the Contingency Plan, which would be pursued if experience/additional evaluation deemed it necessary. The analysis of the Contingency Plan implied that the proposed plan could reduce HC emissions by about 26%. Details of the Contingency Plan analysis results (in terms of VMT, Trips, HC, CO, NO_x, and CO_2 reductions) are available in Appendix I.[97]

Results of Cost-Effectiveness Estimation

The of the preliminary cost-effectiveness analysis conducted for the final 1990 TCMP are presented in figure 3.6-7.

3.6.7 INSTITUTIONAL AND POLITICAL ISSUES

A major limitation on the MTC was their lack of direct authority to implement most TCMs that were being proposed. Thus, MTC's proposed plan required additional legislation and focused on the activities which could most effectively be undertaken at the regional level by MTC and its partners.[98]

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[96] San Francisco No. 2, p. 35-41.
[97] San Francisco No. 2, p. 35 and 41.
[98] San Francisco No. 2, p. 5.

Figure 3.6-7: Preliminary Cost-Effectiveness Analysis[99]

(in ascending order by cost/lb. and cost/ton)

Rank	TCM	Cost/lb. ($'97)	Cost/ton ($'97)	Annual Cost ($'97)
1	Freeway incident management	23	46,000	25,662,000
2	Arterial operational improvements	41	82,000	39,265,000
3	Carpool/bus lanes	112	224,000	51,760,000
4	Carpool incentives $2/employee/day	117	234,000	15,630,000
5	Free transit	273	546,000	370,560,000
6	Vanpool liability insurance	288	576,000	2,100,000
7	Ferry service	420	840,000	6,054,000
8	Bicycle routes-signing, striping, etc.	444	888,000	250,000
9	Rail extensions	750	1,500,000	427,677,000
10	Double transit service	754	1,508,000	914,348,000
11	School buses	838	1,676,000	251,505,000
12	Bicycle paths-new pavement	1,286	2,572,000	724,000
13	Employer trip reduction ordinance (no $ incentive)	3,443	6,886,000	2,552,000
14	*Phase I Mobility Package*	108	216,000	723,800,000

Notes:
1) The calculations attribute the full cost to the air quality benefit, whereas other benefits would also be derived.
2) Combinations of the TCMs could be expected to have synergistic reinforcement which would increase the air quality benefits. We have not attempted to estimate these combined effects.
3) Three TCMs--"free transit", "double transit service", and "employer trip reduction ordinance" are provided for illustration purposes and vary from actual TCMs included in the mobility package.

[99] San Francisco No. 2, p. 43.

3.6.8 SUMMARY AND CONCLUSIONS

The San Francisco case study focuses on the regional 1990 Transportation Control Measure Plan (TCMP). It also briefly describes the 1994 TP, and the 1995 TIP. The following discussion deals solely with the 1990 TCMP experiences.

Because it was designed to meet both state and federal air quality regulations SFBA's TCMP has a different motivation than programs developed in other states. However, SIP-related TCM plans (i.e. "contingency plans" or "15% reduction plans") produced by non-Californian regions, probably bear the closest resemblance to the TCMP.

Some other points particular to this case study are worth noting

- A major limitation on the MTC was their lack of direct authority to implement most TCMs.
- The combined effect of the 21 TCMs included the TCMP was smaller than the sum over individual measures.
- Cost-effectiveness estimates do not factor in mobility and other non-air quality benefits provided by TCMs.
- A number of region-specific analysis methods were used in the screening-level analysis, rather than a pre-packaged analysis tool.

This case study provides certain details of the TCMP:

- The initial list of candidate measures.
- The final plan, its structure and the measures contained within it.
- Analysis methods used to determine impacts accurately enough so that they might be used for screening purposes.
- Results of the detailed analysis.

However, the discussion raises a variety of questions:

- What methods (e.g. STEP, LOCATE...) correspond to each of the eight categories (e.g. change travel times, change travel cost...)
- Do STEP, LOCATE, and the other available methodologies produce comparable results. Was producing comparable results an issue when selecting analysis methods.
- What were the details of the prioritization/project selection scheme.
- How exactly was the regional travel model used in the fourth phase: to compare the impacts of TCM packages, to analyze each of the TCMs included in the TCMP individually, or to check the combined effects of all elements of the TCM plan.
- Was a scoring system devised to help rank and select projects, or were impacts viewed in their raw form (e.g. without converting vehicle-hour reductions into a point score).

3.7 BOSTON METROPOLITAN AREA

3.7.1 WHY THIS REGION WAS INCLUDED AS A CASE STUDY

Conducting a case study of Boston would provide the background needed to produce the final objective of this research project: a methodology to be used in Boston. As a result, this case study is more detailed than the others.

Without regard to this project's eventual objective, Boston provides an interesting case study in the context of this report because it has had and will continue to have extensive experience with implementing TCMs. In particular, it has made numerous TCM commitments in order to mitigate effects of the Central Artery/Tunnel being constructed in downtown Boston. Also, Boston has had to develop plans to meet air quality standards because the entire Commonwealth of Massachusetts is classified as in serious non-attainment for ozone, and nine cities in the Boston area are classified as in moderate non-attainment for carbon monoxide. Thus, Boston has developed a plan for reducing ozone levels by 15% and its TIP must prove conformity.[100]

3.7.2 BRIEF REGIONAL PROFILE

One hundred and one cities comprise the Boston Metropolitan Area, pictured in figure 3.7-1. While almost 3 million people lived in the area as of 1990, the population is expected to decrease by about a half a percent by 2020. On the other hand the 1,110,116 households present in 1990 is expected to increase by over 11% by 2020. Likewise employment is expected to increase by over 15% in the same time period. Table 3.7-1 presents these and other summary statistics.

A multi-modal system consisting of:

- Highway
- Transit
- Rail
- Pedestrian
- Bicycle
- Air, and
- Water

facilities accommodate the region's passenger and freight transportation needs. The *highway network*, pictured in figure 3.7-2[101], experiences congestion during peak hours. In order to alleviate this problem, the Massachusetts Highway Department (MHD) has made efforts such as transportation demand strategies (TDM), HOV lanes, park-and-ride

[100]Boston No. 1, p. 5-4.
[101]see appendix R.

lots, support to programs like CARAVAN, incident management, the "SP" program and SmartTraveler. More detail on each of these is available in the footnoted source.[102]

Table 3.7-1: Some Statistics on the Current and Forecasted Boston Metropolitan Area[103]

	1990	2020	% Change
Population	2,921,708	2,906,361	-0.53
Households	1,110,116	1,238,921	11.60
Employment	1,715,037	1,979,892	15.44
Transit-Person Trips	650,438	721,554	10.93
Auto-Person Trips	8,298,738	9,207,435	10.95
Highway-Vehicle Trips	7,260,463	8,524,050	17.40
Vehicle Miles	61,063,159	76,599,776	25.44
Vehicle Hours	1,963,321	2,655,798	35.27
Operating Speed (MPH)	31.10	28.84	-7.27
VOC (Kilograms)	97,949	65,174	-33.46
CO (Kilograms)	911,320	791,475	-13.15
NOx (Kilograms)	128,325	120,580	-6.04

A major component of the regions highway network is the Central Artery. A multi-billion dollar project known as the CA/T will submerge this chunk of freeway below the city surface, improve access to Logan Airport via the newly constructed Third Harbor Tunnel, as well as provide many other enhancements. Boston will implement several billion dollars worth of TCMs, transit improvements, open space, and other measures in order to mitigate environmental repercussions of the CA/T. (see section 3.7.3 for more details on these projects)

Four modes make up the *transit network*: rapid transit (including light rail), railroad, bus, and boat. Figure 3.7-3[104] displays the rapid transit lines and portions of the commuter rail system. Table 3.7-2 summarizes the size and ridership of each transit system component.

Rail services carry both passengers and freight about the Boston area. Amtrak runs four passenger lines: the Northeast Corridor, the Inland Route, Lake Shore Limited, and the Cape Codder. These routes are shown in figure 3.7-4. The Freight Rail Network is much more extensive than the passenger one, as can be seen in figure 3.7-5. Two carriers dominate the freight rail industry in Eastern Massachusetts: Conrail and the B&M (these are the class 1 carriers).

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[102]Boston No. 1, p. 6-8 to 6-10.

[103]Boston No. 1, p. 7-3.

[104]see appendix R for figures 3.7-3-3.7-7.

Table 3.7-2: Size and Ridership of Various Transit System Components[105]

Component	Size	Weekday Ridership
Total Rapid Transit/Light Rail	125 stations	562,000 trips
Red Line	21 miles of track, 22 stations	185,000 trips
Mattapan High Speed Line	connects Red Line at Ashmont to Mattapan	
Orange Line	11 miles of track, 19 stations	127,000 trips
Blue Line	6 miles, 12 stations	54,000 trips
Green Line	23 miles of track, 13 stations, 57 surface stops, 4 branches	189,000 trips
Bus and Trackless Trolley	159 bus routes, 952 buses, 38 trackless trolleys	360,000 trips
Express Bus Routes	serving 11 communities	25,300 trips
Commuter Rail	265 miles of track, 101 stations, 11 radial lines	74,600 trips
Suburban Bus	10 communities	1,875
Cape Ann Transportation Authority		
Private Carrier Bus Route	20 private carriers, 34 routes	6,000 trips
Private Taxicab		
Paratransit	serves 51 cities with 129 MBTA vehicles and 120 contractor supplied vehicles	22,327 registered riders

A significant portion of commuters also bike or walk to work. Excluding students and persons under 15, about 8000 people bike and 100,000 people walk to work in the Boston region (survey conducted in early Spring). In Cambridge, this translates into a 3.05% bike share and 25.02% walk share. However, mode-splits in other communities are sometimes below 1% for bike and as low as 11% for walk.

Air transportation, like water transportation, serves both passengers and freight. The primary airport in the Boston area is Logan Airport which is very close to the downtown. A number of secondary airports are scattered throughout the region. (see figure 3.7-6) Likewise, the Boston region contains several ports, only nine of which are "designated port areas" because of their deep water and good landside access facilities. Figure 3.7-7 displays these ports. Boats also provide commuter and recreational services.

[105] Boston No. 1, p. 6-16 to 6-23.

Figure 3.7-1: The Boston Metropolitan Planning Organization Region[106]

[106]Boston No. 1, p. ii.

3.7.3. DESCRIPTION AND STATUS OF CURRENT TCM RELATED PROGRAMS

The most recent transportation plans and programs developed for the Boston region are:

- The 1996-1998 Boston Transportation Improvement Program (TIP)
- The 1993 Transportation Plan (TP) for the Boston Region
- The 1994 New Program for Mass Transportation (PMT)
- The 15% Emission Reduction Plan (part of the SIP).

Included within these programs are the various mitigation measures associated with the Central Artery/Third Harbor Tunnel project and TCMs included in the SIP. Many of the projects required to mitigate CA/T effects are the same projects mentioned in the SIP. Figure 3.7-8[107] lists the projects included in the 15% reduction plan (portion of the SIP) and their predicted emission benefits. Figure 3.7-9 contains a status report on TCMs included in the 1982 SIP.

Many of the TCMs included in the SIP or the CA/T mitigation are transit-related. (see figure 3.7-10) It is estimated that these MBTA projects could cost about $2.1 billion dollars.[108] (see figure 3.7-11[109]) If these CA/T mitigation and SIP projects are not feasible due to adverse engineering, environmental, or economic impacts, they may be substituted by projects offering equal or greater emission reductions.[110] The PMT points out that nearly all SIP and CA/T service improvements have positive ridership, VMT reduction, cost-effectiveness and air quality benefits. The only exceptions are four projects: 'Green Line Arborway Restoration', '400 buses', 'the Newburyport commuter rail extension', and 'two commuter boat facilities'.[111] Without addressing substitutions, figure 3.7-12 provides a summary of SIP and CA/T- mitigation service-expansion projects included in the PMT. These projects are broken down into short-term (implemented by 2000) and long-term categories. The estimated cost of these projects is around $1.6 billion dollars, and would be lower if proposed substitutions were made. (Note that this 1.6 billion is for service expansion projects only, and that other transit-related commitments would bring the total up to the 2.1 billion cost mentioned earlier)

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[107] see appendix R for figures 3.7-8 and 3.7-9.
[108] Boston No. 8, p. 2-2.
[109] see appendix R for figures 3.7-11 and 3.7-12.
[110] Boston No. 8, p. 2-3.
[111] Boston No. 8, p. 2-3.

Figure 3.7-10: Transit-Related SIP and CA/T Mitigation Projects[112]

Project	SIP	CA/T Mitigation
Old Colony Commuter Rail Restoration (underway)	√	√
Newburyport Commuter Rail Extension	√	√
Worcester Commuter Rail Extension	√	√
Lynn Station and Garage (completed)	√	
North Station High Platforms (completed)	√	
South Station Track 12	√	
North Station - South Station Link Study (completed)	√	
South Station Access to Red Line (completed)	√	
Blue Line - Red Line Connector	√	√
Blue Line Station Modernization	√	√
Green Line Extension to Tufts	√	√
Green Line Arborway Restoration	√	
Andrew Station Access (underway)		√
New Red Line Vehicles (underway)		√
New Orange Line Vehicles		√
South Station Bus Terminal (underway)	√	√
South Boston Piers Transitway	√	√
Washington Street Replacement Service		√
Circumferential Bus Study (underway)	√	√
400 New Buses		√
10,000 Additional Parking Spaces by 12/31/96	√	√
10,000 Additional Parking Spaces by 12/31/99	√	√
2 Commuter Boat Facilities (Fort Point Channel)		√

[112]Boston No. 8, p. 2-4, table 2-1.

3.7.4 ORGANIZATIONAL STRUCTURE

Transportation planning in the Boston region, in particular the TIP, is largely the responsibility of the Boston Metropolitan Planning Organization (MPO) which consists of six agencies. However, the Central Transportation Planning Staff (CTPS) and the Joint Regional Transportation Committee (JRTC) also play significant roles. Unlike other transportation planning activities, development of the transportation element of the SIP (in particular the 15% ozone reduction plan) is done largely by the Department of Environmental Protection (DEP). Brief descriptions of these agencies from the footnoted document have been reprinted below.[113]

The six agencies comprising the MPO:

1. The Executive Office of Transportation and Construction (EOTC)
The Commonwealth of Massachusetts EOTC directs and coordinates state transportation policy and guides the various agencies which fall under the Secretariat. The agencies include the Massachusetts Highway Department, Massachusetts Aeronautics Commission, Massachusetts Bay Transportation Authority, Massachusetts Port Authority, and the regional transit authorities.

2. Massachusetts Highway Department (MHD)
The Commonwealth of Massachusetts Highway Department plans, designs, constructs, and maintains highways, bridges, and related facilities of the Commonwealth. The headquarters of the MHD are located in Boston but there are five district offices located throughout the state which are the primary contact between the department and the municipality.

3. Massachusetts Port Authority
The Commonwealth of Massachusetts Port Authority has the responsibility to plan, construct, own and operate transportation and related facilities as may be necessary for the development and improvement of commerce in Boston and the surrounding metropolitan area. Among other facilities, MassPort owns and operates the seaport, Logan International Airport, Hanscom Airport and the Tobin Bridge. MassPort also provides for airport shuttle bus service and a water taxi service between Boston and the South Shore suburbs such as Hingham.

4. Massachusetts Bay Transportation Authority (MBTA)
The MBTA operates the public transportation system within the greater Boston region. They also have the responsibility to prepare the engineering and architectural designs for operating and constructing transit development projects within the area.

[113] Boston No. 5, p. 4-6.

5. Massachusetts Bay Transportation Authority Advisory Board
The Advisory Board to the MBTA is a regional body created primarily to review and approve the MBTA annual budget and the state required Program for Mass Transportation. Major bus service changes and all fare changes are reviewed by the Advisory Board. Each community has a weighted vote on the Advisory Board.

6. The Metropolitan Area Planning Council (MAPC)
The MAPC is the regional planning agency for the Boston metropolitan area. It provides general land use, transportation, environmental, economic development, and housing technical services to the MPO agencies and member communities.

Non-MPO agencies involved in transportation planning:

The Central Transportation Planning Staff (CTPS)
The Central Transportation Planning Staff provides technical and policy analysis support to the Boston MPO. CTPS provides regional modeling and forecasting studies, air quality analysis and various other technical transportation assistance.

The Joint Regional Transportation Committee (JRTC)
In addition to the six agencies, the JRTC provides policy advice to the MPO in matters of areawide concern in transportation decision-making. The JRTC is made up of public agencies, municipal representatives and citizen designees.

3.7.5 METHODS USED TO PRIORITIZE AND SELECT PROJECTS

The transportation planning process in Boston does not employ a systematic prioritization methodology to streamline planning for the region. The various planning documents are related and consistent with one another, however. The Transportation Plan which describes the long-term approach to transportation in the region, compares alternative long-term policy options and establishes a framework for projects to move from the long-term plan towards implementation, i.e. inclusion in the TIP. The TIP is the short-term transportation plan for the region. All federally funded projects to be implemented within the next three years must be included in the TIP. Thus, this broad document must include routine maintenance projects as well as SIP and CA/T mitigation commitments. Although priority is naturally given to required, commitment projects, no systematic method is used to establish priority.

The most "streamlined" planning effort may be found in the development of the PMT which addresses maintenance, service, and capital needs of the regional transit system, as well as ADA, CA/T, and SIP requirements. The PMT analyzes potential projects with a uniform set of measures before selecting its final plan. As is the case with other transportation projects, most PMT projects must be included in the TIP.

Current PMT Development Process

The new Program for Mass Transportation was developed in three phases. Phase 1 consisted of an initial study of potential transit improvements. The main component of this phase was a series of public "transportation town meetings" through which a broad list of potential improvements was collected. Phase 2 involved a preliminary screening of projects from Phase 1 to determine which projects should be analyzed in detail. The screening criteria were:

- consistency with regional and local transportation goals, policies, and objectives.
- consistency with the intent of ISTEA and the 1990 CAAA.
- the judgment of the PMT Update's "Working Committee," which was comprised of representatives of EOTC, MBTA, the MBTA Advisory Board, MHD, MAPC, the Executive Office of Communities and Development, and CTPS.

During Phase 3 projects brought forth from Phase 2 were analyzed in detail to determine which projects to include in the PMT. A procedure for amending the final PMT was also adopted so that the document would remain relevant.[114]

The process used in Phase 3 to analyze the 70 projects brought forth from Phase 2 will now be discussed in more detail. The evaluation of projects consisted of five general steps:

1. Project Definition
2. Determination of Project Characteristics
3. Calculation of Performance Measures and the Development of Qualitative Ranking
4. Interpretation of Data
5. Conclusions[115]

In the second step, <u>project characteristics</u> such as ridership, operating and capital costs, fare revenue, traffic impacts, and air quality benefits were estimated. Figure 3.7-13[116] lists the computed characteristics of each project. In the third step, the estimated characteristics from the second step were used to develop <u>evaluation measures</u> addressing utilization, cost-effectiveness, and a number of financial, air quality, and other impacts. Figure 3.7-14 lists the evaluation measures computed for each project. [117] Impacts were not translated into project scores, and projects were not systematically ranked. Rather, the quantitative and qualitative measures were developed to help achieve the following objectives:

- pursuing the most cost-effective of the proposed projects
- evaluating projects fairly and consistently
- using quantifiable performance-based standards to the maximum feasible extent

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[114]Boston No. 8, 1-2 to 1-4.
[115]Boston No. 9, appendix F, p. F-1 to F-3.
[116]see appendix R for figures 3.7-13 and 3.7-14.
[117]Boston No. 8, p. 5-3.

In light of these and other objectives, the most significant of the evaluation measures were "new transit trips", "capital costs per new transit trip", "net operating cost", "travel time savings", "percent emission reduction", and "cost per kg of VOC eliminated".[118] Phase 3 culminated in the selection of projects to included in the PMT which may be summarized by tables 3.7-3 to 3.7-6[119]. A more detailed description of the Phase 3 process is available in appendix J. Also, a detailed example of a project's analysis is provided in appendix K of this document.

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[118]Boston No. 9, p. F-9.

[119]see appendix R for tables 3.7-3 to 3.7-6.

Figure 3.7-13: Project Characteristics (based on 2020 projections)[120]

		Ridership			Amount of Service		Costs/Revenues				Air Quality	Traffic		Service Quality	
Project	Note	Total New Trips (/Weekday)	New Transit Trips (/Weekday)	Auto Reduction (/Weekday)	Veh Ser Miles (/Weekday)	Veh Ser Hours (/Weekday)	Total Capital Cost ($000s) Note 1	Ann Capital Cost ($000s)	Ann Oper Cost ($000s)	Ann Fare Revenue ($000s) Note 2	VOC Reduction (kg/WD)	VMT Reduction (/WD)	VHT Reduction (/WD)	Travel Time Savings (Hrs/WD)	Travel Time Savings (Hrs/Yr)
1. Upgrade the System															
A. Faster Commuter Rail Service (Express/Local 2010)															
• Rockport/Ipswich Line		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$870	30.6	25,063	1,288	803	200,750
• Haverhill/Reading Line		4,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,437	80.7	66,118	2,132	514	128,500
• Lowell Line		4,602	2,561	1,985	702	4	$17,052	$682	$156	$1,409	70.1	57,499	1,846	1,015	253,750
• Fitchburg Line		1,138	956	741	3,271	103	$72,906	$2,905	$4,196	$564	28.1	21,421	992	298	74,500
• Framingham Line		1,464	576	447	223	48	$18,300	$955	$1,942	$314	16.3	13,320	636	66	16,600
• Needham Line		655	158	122	333	37	$23,268	$931	$1,519	$50	1.5	1,245	83	63	15,750
• Franklin Line		2,580	1,245	965	1,643	72	$45,816	$2,033	$2,904	$711	26.6	21,788	439	143	35,750
• Attleboro/Stoughton Line		525	490	380	1,350	21	$20,790	$832	$847	$275	11.6	9,548	424	174	43,500
B. Bus Service Improvements into Downtown Boston															
• Better Downtown Bus Circulation		11,875	7,220	5,597	707	76	$6,100	$504	$1,265	$1,341	76.6	62,814	3,895	1,733	433,250
• Sumner Tunnel Approach		110	0	0	0	-5	$100	$4	($86)	$0	0.0	0	0	L	L
2. Intermodal Connections															
A. Park and Ride Expansion**															
• Intercept Stations along Major Highways		14,310	3,980	3,085	NA	NA	$60,200	$2,408	L	$2,219	69.4	56,880	1,854	465	142,290
• Other Rapid Transit Expansion		14,490	3,690	2,860	NA	NA	$128,940	$5,158	L	$535	30.6	25,092	923	246	76,276
• Other Commuter Rail Expansion		19,080	8,352	6,474	NA	NA	$89,570	$3,583	L	$2,777	120.2	98,550	2,790	315	84,735
• Other Bus		2,410	1,640	1,271	NA	NA	$2,600	$104	L	$469	26.3	21,596	404	70	20,020
B. New Commuter Rail Stations/Additional Service															
• Alewife	3	1,020	348	270	NA	NA	$7,560	$322	[illegible]	$80	4.7	3,840	196	319	85,811
• Wonderland	3	7,200	1,080	837	339	11	$9,316	$1,066	$461	$247	9.5	7,770	278	1,275	342,975
• Riverside	3	876	876	679	107	12	$4,308	$134	$444	$507	6.1	4,983	249	576	164,944
• Mattapan	3	1,680	189	147	176	5	$8,150	$333	$125	$43	1.4	1,117	63	49	13,181
• JFK/UMASS	3	952	266	206	NA	NA	$1,560	$62	[illegible]	$61	5.4	4,466	252	266	71,554
• Ruggles		984	328	254	NA	NA	$1,560	$62	[illegible]	$75	3.4	2,776	212	144	38,736
3. Urban Core Distribution															
A. New Ferry Service**															
• North Station to Fan Pier and World Trade Center	4	1,378	L	L	NA		$2,089	$104	$1,555	$0	L	L	L	L	L
• North Station to Navy Yard Pier 4 and Logan Airport	4	713	L	L	NA		$1,702	$85	$1,348	$0	L	L	L	L	L
• South Station to Long Wharf and Navy Yard Pier 4	4	1,045	L	L	NA		$1,410	$71	$1,138	$0	L	L	L	L	L
• Navy Yard Pier 4 to Long Wharf and World Trade Ctr	4	380	L	L	NA		$1,713	$86	$2,045	$0	L	L	L	L	L
• South Station to Navy Yard Pier 11	4	831	L	L	NA		$1,358	$68	$638	$0	L	L	L	L	L
B. Circumferential Transit**	4														
• Core LRT: Sullivan – Ruggles		86,700	18,213	14,119	1,593	130	$1,078,885	$29,767	$4,865	$3,232	141.4	115,913	8,350	9,400	2,876,400
• Full LRT: Airport – JFK/UMass		149,525	34,375	26,647	3,590	365	$1,430,854	$35,776	$13,703	$8,101	184.1	150,925	11,719	6,244	1,910,664
• Bus Improvements		*To be determined in MBTA Crosstown Transit Feasibility St*					$2,350	$196	$1,500	$0					

[120]Boston No. 9, p. F-5 to F-8.

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
3. Urban Core Distribution (Cont.)															
C. South Boston Piers: South Station to Boylston															
• w/High growth	5	36,000	7,800	2,100			$180,000	($1,050)	($1,594)	($40)	39.9	32,700		2,248	642,857
• w/ Lower growth	5	26,850	6,500	1,700			$180,000	$771	($456)	$280	31.8	26,100		1,733	495,567
D. N. Station–S. Station Rail Link**	4														
Phase 1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$1,853,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phase 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$1,780,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	4	57,000	23,000	17,829	37,492	[illegible]	$3,633,000	[illegible]	$47,000	$36,000	446.5	366,000	[illegible]	[illegible]	[illegible]
E. Red Line - Blue Line Connector**	4	19,210	4,972	3,354	1,480	15	$137,500	$4,580	$456	$1,480	42.4	34,770	961	2,458	752,148
F. Connections to Logan Airport															
• Bus Service from North Station		718	90	70	156	23	$1,097	$91	$438	$12	1.8	1,437	33	59	16,874
• Bus Service from South Station		1,413	45	35	192	29	$1,367	$114	$549	$6	1.0	805	14	153	43,758
• Blue Line Spur to Logan Central Terminal		7,232	2,000	1,550	625	35	$29,400	$1,080	$1,040	$355	18.6	13,601	486	2,269	694,314
• Express Bus from Newton Corner		271	124	96	412	20	$827	$69	$383	$35	1.3	1,032	51	64	18,304
• Express Bus from Waltham (Rt 128 @ Winter St)		192	124	96	634	31	$1,097	$91	$581	$53	1.7	1,356	54	68	19,448
4. New Radial Services															
A. Blue Line Extensions															
• Wonderland to Lynn		11,340	4,860	3,767	7,540	255	$275,000	$11,800	$10,251	$1,431	60.3	49,440	3,600	893	273,258
• Bowdoin to Medford Hillside (includes Blue-Red Conn.)		32,872	7,283	5,646	9,210	350	$548,430	$15,882	$10,894	$2,144	66.2	54,263	3,322	2,565	784,890
• Bowdoin to Riverside via Esplanade (Rivervision)		70,500	8,000	6,202	13,700	462	$385,500	$32,700	$11,016	$1,688	69.6	57,060	3,800	3,292	1,007,250
• Bowdoin to Riverside via Huntington Ave		81,400	8,700	6,744	14,420	455	$683,500	$33,636	$10,404	$1,864	71.6	58,660	3,900	4,847	1,483,080
• Gov't Center to Riverside via Newbury St		84,610	10,240	7,938	13,700	500	$986,000	$33,600	$12,118	$2,207	101.4	83,150	3,400	6,244	1,910,613
B. Orange Line Extensions															
• Forest Hills to Route 128		13,648	4,704	3,647	-1,715	180	$249,036	$9,454	$1,872	$957	40.2	32,921	2,522	1,525	466,650
C. Green Line Extensions															
• Lechmere to Medford Hillside**		11,560	3,661	2,838	1,170	25	$88,000	$2,875	$2,111	$1,072	47.3	38,770	1,288	1,161	355,266
• Comm Ave to Oak Square	4	32,940	1,006	780	-890	125	$93,800	$3,769	$8,609	$425	8.8	7,232	260	568	173,808
• Restoration of E Line to Arborway**	4	36,160	136	119	-1,128	-179	$56,600	$2,202	($1,484)	$23	0.9	763	54	2,260	691,560
D. Red Line Extensions															
• Ashmont to Mattapan		4,718	1,260	977	1,760	45	$54,800	$1,741	$1,331	$244	10.7	8,736	665	338	103,428
• Alewife to Lexington		8,880	2,376	1,842	7,800	230	$590,038	$12,118	$9,486	$700	43.3	35,508	1,992	737	225,522
E. Bus/Trackless Trolley Services															
• Arborway Trackless Trolley		38,697	316	245	-425	-130	$27,000	$596	($2,554)	$43	2.5	2,068	40	1,262	360,932
• Express Rt 1/128 to Boston via Route 1		2,473	1,944	1,507	761	50	$3,557	$201	$833	$724	33.1	27,094	1,472	698	199,628
• Express Rt 3/128 to Boston via 128 and I-93		3,140	2,355	1,826	916	56	$4,382	$244	$933	$877	31.9	26,163	1,541	315	90,090
• Express Rt 3/128 to Alewife via Rts 128 and 2		2,473	2,047	1,587	682	31	$3,107	$164	$516	$507	27.7	22,667	1,225	615	147,290
• Improved Express Service in the Mass Pike Corridor		523	322	250	69	5	$0	$0	$83	$120	4.2	3,479	81	29	8,294

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
4. New Radial Services (Cont.)															
F. Commuter Rail Extensions															
• Ipswich Line: Ipswich to Newburyport**	4														
Existing Line Improvements		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$870	30.6	25,063	1,288		
Newburyport Extension Segment		1,638	1,438	1,115	1,184	38	$42,800	$1,712	$1,663	$1,253	27.2	22,325	1,225		
Total		3,788	2,901	2,249	4,956	68	$61,400	$2,447	$2,880	$2,124	57.8	47,388	2,513	258	69,402
• Haverhill Line: Wakefield to Topsfield															
Existing Line Improvements		4,056	1,924	1,491	-395	2	$5,000	$167	$3,500	$957					
Topsfield Extension Segment		767	546	423	4,531	156	$87,442	$3,769	$3,117	$308					
Total		4,823	2,470	1,915	4,136	158	$92,442	$3,936	$6,617	$1,265	63.7	52,182	2,340	306	82,314
• Haverhill Line: Haverhill to Plaistow NH	4,6														
Existing Line Improvements		4,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,436					
Plaistow Extension Segment		689	286	222	144	27	$26,216	$1,046	$1,173	$283					
Total		5,226	3,172	2,459	2,357	84	$65,320	$2,577	$3,500	$1,718	NA	NA	NA	NA	NA
• Lowell Line: Lowell to Nashua, NH															
Existing Line Improvements		5,759	3,198	2,479	2,544	41	$17,052	$682	$1,785	$1,759					
Nashua Extension Segment		1,482	520	403	1,557	67	$51,652	$1,777	$2,907	$562					
Total		7,241	3,718	2,882	4,100	108	$68,704	$2,459	$4,692	$2,321	100.3	82,251	4,713	3,134	843,046
• Framingham Line: Framingham to Worcester**	4														
Existing Line Improvements		684	264	205			$0	$0		$144					
Worcester Extension Segment		6,012	3,204	2,484	5,382	166	$116,964	$4,261	$7,245	$4,563					
Total		6,696	3,468	2,688	5,382	166	$118,964	$4,261	$7,245	$4,707	81.9	67,140	2,580	1,214	326,566
• Framingham Line: Framingham to Marlborough	4									$1					
Existing Line Improvements															
Marlboro Extension Segment		1,632	774	600	6,140	196	$73,600	$4,028	$8,572	$813	31.5	25,848	1,428	287	64,336
Total															
• Franklin Line: Forge Park/495 to Milford															
Existing Line Improvements		1,928	930	721	138	-7	$45,816	$2,033	($284)	$644					
Milford Extension Segment		383	83	64	517	53	$27,973	$1,891	$2,313	$169					
Total		2,311	1,013	785	655	46	$73,789	$3,924	$2,029	$813	23.0	18,833	308	131	35,239
• Franklin Line: Walpole to Foxborough															
Existing Line Improvements		1,538	810	628	2,676	47	$13,545	$542	$1,894	$415					
Foxborough Segment		38	8	6	671	21	$14,104	$552	$908	$8					
Total		1,576	818	634	3,347	68	$27,649	$1,094	$2,802	$423	20.2	16,568	285	117	31,473
G. Other New Commuter Rail Services															
• New Bedford/Fall River Lines	4	6,465	2,820	2,186	10,670	255	$288,000	$7,665	$12,205	$2,647	83.3	68,279	NA	NA	NA
• New Mills Line		1,823	855	663	3,292	128	$66,728	$2,778	$5,565	$1,201	28.0	22,920	1,200	203	54,607
• Additional CR Service to Dedham Corporate Center		630	0	0							0.0	0	0	0	0

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
5. Suburban Circumferential Movement															
A. Route 128 Circumferential Bus Service		3,474	3,474	2,693	5,340	290	$7,906	$664	$4,823	$861	44.2	36,270	846	NA	NA
B. Feeder Bus to Rapid Transit at Riverside		690	490	380	[illegible]	48	$1,350	$113	$799	$139	9.6	7,840	120	13	3,250
C. Feeder Bus to Commuter Rail in Needham	7	340	0	0	[illegible]	18	$60	$20	$113	$0	0.0	0	0	0	0

Notes:

1. *Capital costs are in 1993 dollars.*
2. *Revenue figures are based on current (1993) fare levels.*
3. *Ridership is daily transfer volume*
4. *Parallel Study*
5. *Results from DEIS/SDEIR, November 1992. High growth scenario is comparable to 2010 PMT forecasts*
6. *Results from "Draft Report: Ridership Potential: Plaistow, NH – Boston, MA Commuter Rail Service," Frederic R. Harris, Inc., November 1992*
7. *This service is assumed to be privately operated. The capital cost of vehicles would be included in the contract cost for operations.*

Codes:

NA = Not Available or Not Applicable

L = Low or Insignificant

*** Central Artery Mitigation/SIP Project*

Figure 3.7-14: Evaluation Criteria[121]

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
1. Upgrade the System																										
A. Faster Commuter Rail Service (Express/Local 2010)																										
• Rockport/Ipswich Line	2,150	1,463	71.7	0.6	72%	$25,427	$1,005	$4	$346	0.04%	$608															
• Haverhill/Reading Line	4,537	2,886	79.1	2.1	62%	$27,099	$1,061	$12	$890	0.10%	$485															
• Lowell Line	4,602	2,561	1,198.4	6.6	904%	$13,317	$533	$3	-$1,253	0.08%	$243															
• Fitchburg Line	1,138	956	11.0	0.3	13%	$152,523	$6,077	$39	$3,632	0.03%	$2,780															
• Framingham Line	1,464	576	30.6	6.6	16%	$63,542	$3,316	$58	$1,628	0.02%	$1,126															
• Needham Line	555	158	14.8	1.7	3%	$294,532	$11,785	$59	$1,469	0.00%	$15,319															
• Franklin Line	2,580	1,245	36.0	1.6	24%	$73,600	$3,266	$57	$2,193	0.03%	$1,724															
• Attleboro/Stoughton Line	525	490	25.1	0.4	32%	$84,857	$3,394	$19	$572	0.01%	$1,785															
B. Bus Service Improvements In/to Downtown Boston																										
• Better Downtown Bus Circulation	11,875	7,220	156.3	16.8	106%	$1,690	$140	$1	-$76	0.09%	$80															
• Sumner Tunnel Approach	110	0	NA	NA	NA	NA	NA	NA	-$86	0.00%	NA															
2. Intermodal Connections																										
A. Park and Ride Expansion**																										
• Intercept Stations along Major Highways	14,310	3,980	NA	NA	NA	$30,251	$1,210	$17	NA	0.08%	$868															
• Other Rapid Transit Expansion	14,490	3,690	NA	NA	NA	$69,886	$2,795	$69	NA	0.04%	$4,212															
• Other Commuter Rail Expansion	19,080	8,352	NA	NA	NA	$21,449	$858	$42	NA	0.14%	$745															
• Other Bus	2,410	1,640	NA	NA	NA	$3,171	$127	$5	NA	0.03%	$99															
B. New Commuter Rail Stations/Additional Service																										
• Alewife	1,020	348	NA	NA	NA	$43,448	$1,853	$4	-$80	0.01%	$1,614															
• Wonderland	7,200	1,080	627.5	21.2	54%	$17,252	$1,973	$3	$214	0.01%	$983															
• Riverside	876	876	73.0	8.2	114%	$9,836	$306	$1	-$63	0.01%	$709															
• Mattapan	1,680	189	373.3	9.5	35%	$86,243	$3,524	$25	$82	0.00%	$5,981															
• JFK/UMass	952	266	NA	NA	NA	$11,729	$469	$1	-$61	0.01%	$286															
• Ruggles	984	328	NA	NA	NA	$9,512	$380	$2	-$75	0.00%	$461															
3. Urban Core Distribution																										
A. New Ferry Service**																										
• North Station to Fan Pier and World Trade Center	1,378	L	NA	NA	NA	NA	NA	NA	$1,655	L	NA															
• North Station to Navy Yard Pier 4 and Logan Airport	713	L	NA	NA	NA	NA	NA	NA	$1,348	L	NA															
• South Station to Long Wharf and Navy Yard Pier 4	1,045	L	NA	NA	NA	NA	NA	NA	$1,138	L	NA															
• Navy Yard Pier 4 to Long Wharf and World Trade C	380	L	NA	NA	NA	NA	NA	NA	$2,045	L	NA															
• South Station to Navy Yard Pier 11	831	L	NA	NA	NA	NA	NA	NA	$638	L	NA															
B. Circumferential Transit**																										
• Core LRT: Sullivan – Ruggles	86,700	18,213	666.9	54.4	66%	$118,474	$3,269	$10	$1,633	0.17%	$7,629															
• Full LRT: Airport – JFK/UMass	149,525	34,375	409.7	41.7	45%	$83,250	$2,082	$19	$7,602	0.22%	$7,771															
• Bus Improvements	*To be determined in MBTA Crosstown Transit Feasibility Study*																									

[121] Boston No. 9, p. F-10 to F-13.

	Utilization: Total New Trips	Utilization: New Transit Trips (Weekday)	Utilization: Riders/Vehicle Service Hour	Utilization: Riders/Vehicle Service Mile	Cost-Effectiveness: Farebox Ratio	Cost-Effectiveness: Investment/New Daily Transit User	Cost-Effectiveness: Annualized Cost/New Daily Transit User	Cost-Effectiveness: Annualized Cost/Hr of Travel Time Savings	Cost-Effectiveness: Annual Operating Subsidy (000s)	Air Quality Impacts: % Emissions Reduction	Air Quality Impacts: Capital Cost/kg VOC Eliminated (000s)
3. Urban Core Distribution (Cont.)											
C. South Boston Piers: South Station to Boylston											
• w/High growth	36,000	7,800	NA	NA	3%	$46,154	-$269	-$2	-$1,554	0.05%	$4,512
• w/Lower growth	26,850	6,500	NA	NA	-61%	$55,385	$237	$2	-$736	0.04%	$5,653
D. N. Station–S. Station Rail Link**	57,000	23,000	NA	1.5	77%	$315,913	$0	NA	$11,000	0.54%	$8,136
E. Red Line - Blue Line Connector**	19,210	4,972	1,260.7	13.0	325%	$55,310	$1,842	$6	-$1,024	0.05%	$3,241
F. Connections to Logan Airport											
• Bus Service from North Station	718	90	31.2	4.6	3%	$24,378	$2,024	$5	$426	L	NA
• Bus Service from South Station	1,413	45	48.7	7.4	1%	$60,756	$5,049	$3	$543	L	NA
• Blue Line Spur to Logan Central Terminal	7,232	2,000	206.6	11.6	34%	$29,400	$1,080	$2	$685	0.02%	$1,772
• Express Bus from Newton Corner	271	124	13.6	0.7	9%	$13,339	$1,106	$4	$348	0.00%	$657
• Express Bus from Waltham (Rt 128 @ Winter St)	192	124	6.2	0.3	9%	$17,694	$1,469	$5	$528	0.00%	$663
4. New Radial Services											
A. Blue Line Extensions											
• Wonderland to Lynn	11,340	4,860	44.5	1.5	14%	$113,169	$4,856	$43	$8,820	0.07%	$4,559
• Bowdoin to Medford Hillside	32,872	7,283	93.9	3.6	20%	$150,606	$4,361	$20	$8,750	0.08%	$8,284
• Bowdoin to Riverside via Esplanade (Rivervision)	70,500	8,000	152.6	5.1	15%	$246,375	$8,175	$32	$9,328	0.08%	$14,157
• Bowdoin to Riverside via Huntington Ave	81,400	8,700	178.9	5.6	18%	$203,103	$7,732	$23	$8,540	0.09%	$12,345
• Gov't Center to Riverside via Newbury St	84,610	10,240	169.2	6.2	18%	$192,578	$6,563	$18	$9,911	0.12%	$9,720
B. Orange Line Extensions											
• Forest Hills to Route 128	13,648	4,704	75.8	-8.0	51%	$105,882	$4,019	$20	$915	0.05%	$6,201
C. Green Line Extensions											
• Lechmere to Medford Hillside**	11,560	3,661	462.4	9.9	51%	$48,074	$1,571	$8	$1,039	0.06%	$1,860
• Comm Ave to Oak Square	32,940	1,006	263.5	-37.0	5%	$186,481	$7,493	$22	$8,184	0.01%	$10,631
• Restoration of E Line to Arborway**	36,160	136	-202.0	-32.1	-2%	$834,808	$32,478	$3	$1,507	0.00%	$60,824
D. Red Line Extensions											
• Ashmont to Mattapan	4,718	1,260	104.8	2.7	18%	$86,984	$2,763	$17	$1,087	0.01%	$5,142
• Alewife to Lexington	8,880	2,376	38.6	1.1	7%	$496,665	$10,200	$54	$8,786	0.05%	$13,621
E. Bus/Trackless Trolley Services											
• Arborway Trackless Trolley	38,697	316	-297.7	-91.1	-2%	$170,886	$3,770	$2	-$2,597	0.00%	$10,702
• Express Rt 1/128 to Boston via Route 1	2,473	1,944	49.5	3.2	67%	$3,660	$207	$1	$109	0.04%	$108
• Express Rt 3/128 to Boston via 128 and I-93	3,140	2,355	56.1	3.4	94%	$3,721	$207	$3	$56	0.04%	$137
• Express Rt 3/128 to Alewife via Rts 128 and 2	2,473	2,047	79.8	3.6	98%	$3,036	$160	$1	$9	0.03%	$112
• Improved Express Service in the Mass Pike Corridor	523	322	104.6	7.6	144%	$0	$0	$0	-$37	0.01%	$0

	Utilization: Total New Trips	Utilization: New Transit Trips (Weekday)	Utilization: Riders/Vehicle Service Hour	Utilization: Riders/Vehicle Service Mile	Cost-Effectiveness: Farebox Ratio	Cost-Effectiveness: Investment/New Daily Transit User	Cost-Effectiveness: Annualized Cost/New Daily Transit User	Cost-Effectiveness: Annualized Cost/Hr of Travel Time Savings	Cost-Effectiveness: Annual Operating Subsidy (000s)	Air Quality Impacts: % Emissions Reduction	Air Quality Impacts: Capital Cost/kg VOC Eliminated (000s)
4. New Radial Services											
F. Commuter Rail Extensions											
• **Ipswich Line: Ipswich to Newburyport****											
Existing Line Improvements	2,150	1,463	71.7	0.6	72%	$25,427	$1,005	NA	$347	0.04%	$608
Newburyport Extension Segment	1,638	1,438	43.0	1.4	75%	$59,527	$2,381	NA	$410	0.03%	$1,571
Total	3,788	2,901	55.6	0.8	74%	$42,330	$1,687	$35	$756	0.07%	$1,062
• **Haverhill Line: Wakefield to Topsfield**											
Existing Line Improvements	4,056	1,924	2,385.9	-10.3	27%	$5,198	$174	NA	$2,543	NA	NA
Topsfield Extension Segment	767	546	4.9	0.2	10%	$320,299	$13,806	NA	$2,810	NA	NA
Total	4,823	2,470	30.6	1.2	19%	$74,851	$3,187	$48	$5,352	0.08%	$1,452
• **Haverhill Line: Haverhill to Plaistow NH**											
Existing Line Improvements	4,537	2,886	79.1	2.1	62%	$27,099	$1,061	NA	$891	NA	NA
Plaistow Extension Segment	689	286	25.6	4.8	24%	$183,326	$7,314	NA	$891	NA	NA
Total	5,226	3,172	62.0	2.2	49%	$41,185	$1,625	NA	$1,781	NA	NA
• **Lowell Line: Lowell to Nashua, NH**											
Existing Line Improvements	5,759	3,198	140.8	2.3	99%	$10,664	$427	NA	$26	NA	NA
Nashua Extension Segment	1,482	520	22.3	1.0	19%	$198,662	$6,835	NA	$2,345	NA	NA
Total	7,241	3,718	67.4	1.8	49%	$36,958	$1,323	$3	$2,371	0.12%	$685
• **Framingham Line: Framingham to Worcester****											
Existing Line Improvements	684	264	NA	NA	NA	NA	NA	NA	NA	NA	NA
Worcester Extension Segment	6,012	3,204	36.2	1.1	63%	$74,260	$2,660	NA	$2,538	NA	NA
Total	6,696	3,468	40.3	1.2	65%	$68,607	$2,457	$13	$2,538	0.10%	$1,452
• **Framingham Line: Framingham to Marlborough**											
Marlboro Extension	1,632	774	8.3	0.3	9%	$190,181	$10,408	$63	$7,759	0.04%	$2,334
• **Franklin Line: Forge Park/495 to Milford**											
Existing Line Improvements	1,928	930	-275.4	14.0	-227%	$98,529	$4,372	NA	-$928	NA	NA
Milford Extension Segment	383	83	7.2	0.7	7%	$674,048	$45,566	NA	$2,144	NA	NA
Total	2,311	1,013	50.2	3.5	40%	$145,684	$7,747	$111	$1,216	0.03%	$3,212
• **Franklin Line: Walpole to Foxborough**											
Existing Line Improvements	1,538	810	32.9	0.6	22%	$33,444	$1,338	NA	$1,479	NA	NA
Foxborough Segment	38	8	1.8	0.1	1%	$3,526,050	$138,000	NA	$900	NA	NA
Total	1,576	818	23.3	0.5	15%	$67,602	$2,675	$35	$2,379	0.02%	$1,368
G. Other New Commuter Rail Services											
• **New Bedford/Fall River Lines**	6,465	2,820	25.4	0.6	22%	$204,255	$5,436	NA	$9,558	0.10%	$3,457
• **New Mills Line**	1,823	855	14.3	0.6	22%	$156,089	$6,498	$51	$4,364	0.03%	$2,386
• **Additional Service to Dedham Corporate Center**	630	0	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Service Quality and Coverage: Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Impact on System: Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Impacts: Economic Development Potential	Potential for Private-Sector Participation	Land Use Impacts: Supports Urban Core	Supports Suburban Compact Development

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
5. Suburban Circumferential Movement																										
A. Route 128 Circumferential Bus Service	3,474	3,474	12.0	0.7	18%	$4,552	$382	NA	$3,962	0.05%	$179															
B. Feeder Bus to Rapid Transit at Riverside	690	490	14.4	NA	17%	$5,510	$459	$35	$650	0.01%	$141															
C. Feeder Bus to Commuter Rail in Needham	340	0	18.9	NA	0%	NA	NA	NA	$113	0.00%	NA															

Key:
- ☐ = no improvement, no likely impact, or negative impact
- (lightly shaded) = small improvement or small positive impact
- ■ = significant improvement, or possible large positive impact

L= low or negligible effect
NA= not applicable or not available
**= required by amendments to the State Implementation Plan/Central Artery agreement

Current TIP Development Process

No systematic scoring, ranking, or prioritization process was used to generate the 1996-1998 Boston TIP. In order to be included in the TIP, projects follow the following general process:

- The 101 cities and towns in the region submit project proposals to the MAPC
- The MAPC weeds out proposals that can not be implemented within the next three years. This usually means that many details such as right-of-way and planning must be sorted out in order for a project to be accepted. These projects are collected into a draft TIP
- The MPO, with the aid of CTPS, financially constrains this draft TIP and sends out the revised TIP for public review. A sample of the financial constraints governing the 1996-1998 TIP are provided in appendix L.
- Public review entails publishing the TIP in the paper and receiving/responding to comments sent in by interested parties.
- The TIP then is reexamined by the MPO until it meets their approval. A final TIP is made.
- Any amendments to this TIP must also go out for public review.[122]

Some prioritization does occur in the sense that SIP projects are required to receive funding. This does not necessarily mean that they are the first projects to be implemented, however. More detail on the sequence of events leading to a projects inclusion in the TIP and forms used in the process are provided in appendix M.

Current SIP Development Process

Like the TIP process, the SIP development process does not employ any systematic project evaluation method. Although non-systematic, analysis and evaluation of potential projects is performed.

Current TP Development Process

Like the TIP and SIP, the TP is not generated from a systematic evaluation process. However, evaluation of alternative approaches and a prioritization framework were involved. Seven alternative development approaches were analyzed using the regions transportation and land use models. The projects included in each alternative were not the projects which would actually be implemented if that approach were selected. Rather seven model runs were used to determine the relative effects of scenarios with broadly different policy emphases: highway emphasis, transit emphasis, multi-modal, Metroplan

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[122] Boston Interview No. 1.

base, Metroplan Intervention, and Metroplan forced. Figure 3.7-15[123] displays the projects assumed in each of these model runs.

The modeling effort conducted for the 1993 TP was subject to time constraints and model availability. Had more time been available more scenarios might have been analyzed. Also, DRAM/EMPAL (an integrated transportation-land use model) could have been used more to understand the land use impacts of the various transportation scenarios. The MPO has agreed to update the 1993 plan no later than January 1995, and could improve its analysis of alternative scenarios.

The analysis predicted the air quality and transportation impacts of the seven scenarios. Figures 3.7-16 and 3.7-17 present these impacts relative to the 1990 existing case and 2020 base case. The figures point out how the impacts of each 2020 scenario relative to one another are much smaller than the difference between 1990 existing conditions and the 2020 base case. In terms of selecting a plan the multi-modal scenario stands out because it is multi-modal, meets air quality goals, and will help reduce congestion. However, a land-use strategy also has much potential. Before defining its policy approach in detail, the MPO will analyze additional scenarios.[124]

While the analysis of alternate scenarios helped determine the policy orientation of the plan, its four-level structure helped prioritize/organize projects as they moved towards inclusion in the TIP. This structure is summarized in figure 3.7-18. Also, certain screening criteria are used to move projects between levels. More detail on these are available in a companion report entitled "Documentation and Analysis of Massachusetts State and Regional Transportation Plans and Programs".

Future Attempts at Prioritization

1. TIP Project Evaluation and Prioritization

Although project prioritization methodologies have been suggested and abandoned in the past, the Boston MPO is currently trying to devise an effective one.[125]

[123]see appendix R for figures 3.7-15 to 3.7-18.
[124]Boston No. 1, p. 7-32.
[125]Boston Interview No. 1 and 2.

2. *Management Systems*

As required by ISTEA, MHD and MBTA are developing six management systems:

- Congestion Management System
- Highway Safety Management
- Bridge Management System
- Pavement Management System
- Public Transportation Management System
- Intermodal Management System

In the next version of the Boston Transportation Plan, these systems will help determine investment need, choice of investment, conditions/requirements for implementation, and performance evaluation. In particular, the Congestion Management System "is intended to be a system that provides information on transportation systems performance to decision-makers for selecting and implementing cost-effective strategies to manage new and existing facilities..."[126]

3.7.6 ANALYSIS OF IMPACTS

Most quantitative transportation analysis for the Boston region is performed by CTPS. A memorandum prepared by Karl Quackenbush (Document No. 7) describes the methods CTPS might use to analyze TCMs and the method most suitable for specific TCMs. This memo is available in appendix N. In short, three analysis approaches might be taken: regional model-based, partially regional model-based, and non-regional model-based.

The CTPS Regional Model described within the memo is constantly being updated. Some recent model updates:

- it was calibrated using new data,
- it is a single comprehensive model for highway, transit, and HOV forecasting, whereas three separate sets of travel models had been used for these modes in the past.
- a land use allocation model has been integrated with the transportation models. Now, not only can the impacts of population and employment on transportation be forecasted, but also the impacts of transportation on population/employment.
- Regional employment forecasts for 1990-2020 employment growth in central Boston are only 7-8%, whereas they had been around 30% for 1987-2010 in the old model.[127]

The five-step (not four-step since it now includes a land use component) model process is summarized by figure 3.7-18[128].

Since the land use allocation model was not described in the CTPS memo, a brief description (taken from the TP) is provided here. The land use allocation model spatially

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[126] Boston No. 1, p. 6-11.

[127] Boston No. 2, p. B-3.

[128] see appendix R

allocates forecasts of total regional population and employment among traffic analysis zones. Employment for a given forecast year is allocated to a given zone on the basis of historical levels of employment and population in that zone, total land area in the zone and the accessibility of that zone from other zones where people live. Population is allocated to a given zone based on its historical population, forecast employment level, amount of residential land, vacant developable land, and the accessibility of that zone to other zones where people work.

3.7.7 SUMMARY AND CONCLUSIONS

Boston is a unique example of transportation planning since one project, the CA/T, commands most of the regions attention. Related to the CA/T are a number of mitigation measures, namely $2.1 billion worth of TCMs. Some of these and other environmentally advantageous transportation projects are committed to in its SIP. This case study details the SIP and CA/T TCMs and the methods used to program them into the regional transportation plans: TIP, TP, and PMT. Each of these plans was generated through a different process.

Boston may have learned much about what works and does not work from its previous attempts at TIP prioritization schemes. Although it does not currently employ one, the issue is currently receiving renewed attention.

Currently, the most "systematic" process used by Boston for transportation planning seems to be in the PMT development. In this process, a series of evaluation measures are computed and used to compare competing transit projects. Unlike processes described in other case studies, the Boston PMT process does not employ project scoring or quantitative ranking to compare projects. Rather, it compares proejcts based on raw evaluation measure and qualitative analysis.

Whether or not scores are worth computing is questionable. Similarly questionable, is the value of a "systematic" TIP prioritization process since financial and timing constraints often narrow the list of potential projects sufficiently. A main financial constraint is that a large portion of regional funds must be devoted to CA/T, SIP, and maintenance/operation needs. Also, a major time constraint is that projects ready for implementation within the TIP time-frame are often scarce.[129]

As in SFBA's TIP process, during Boston's TIP process project proposals are made by a variety of regional, local, and private agencies. Also, SFBA agencies are given "bid targets" to help them develop a feasible number of project proposals, although agencies will not necessarily be allocated all of the targeted funds. Similarly, Boston provides funding estimates to regional planning agencies.

[129] Boston Interview No. 2.

APPENDIX B

Documentation and Analysis of Ten Methods Currently Available for Quantifying the Emission and Travel Impacts of TCMs.

Source: This is an excerpt from a companion report entitled "Documentation and Analysis of Technical Methods Currently Available for Quantifying the Emission Effects of Transportation Control Measures" listed as Document No. 45.

SECTION 4 DESCRIPTION OF THE METHODOLOGIES

4.1 Approach adopted in detailing the various methodologies

The purpose of this document, as stated before, is one of providing a brief overview of the various methodologies available for analyzing the effects of TCMs. The objective is one of trying to provide the reader with a tool for determining which methodology might be most appropriate given his requirements and constraints. In documenting the various methodologies available, the procedure adopted is one of trying to identify those pieces of information most relevant to achieving this objective. Thus, the analysis of each methodology takes the form of highlighting the various features of the methodology in terms of: what is the level of analysis provided, what TCMs can it analyze, does it have the facility to analyze groups of TCMs, what are the data requirements, what form does the output take, what are the practical restrictions to using the methodology, as well as some discussion of the structure of the methodology. More specifically, the format is as follows:

1. What TCMs can be analyzed using this methodology and at what level of detail

(a) Level of analysis provided by the methodology

In this section we identify what level of analysis is provided by the methodology. Generally, the answer to this will take the form of one of the terms: Screening, Sketch-Planning or Detailed Analysis. A description of these terms has already been provided in section 3.3. The information provided here should give some indication to the reader of how rigorous the methodology is and as such, what level of decisions could be made based on the output.

(b) What TCMs has the methodology been designed to analyze

This section is generally a listing of all the TCMs amenable to analysis using this methodology, in cases where such information was available. Thus, the reader can determine for himself, given that he seeks to analyze a particular TCM or TCMs, whether the methodology is appropriate for his needs.

(c) Does the methodology support the analysis of groups of TCMs

In some cases, the reader may need to analyze a number of TCMs whose impacts are interdependent. In such instances, a methodology which accounts for the effects of interacting measures will be appropriate. This section identifies whether the methodology has the facility to analyze packages of TCMs.

2. Structure, inputs and outputs of the methodology

This section provides a brief overview of the methodology in terms of its structure, input requirements, and resultant outputs. In some cases a methodology will consist of a totally integrated whole of a number of modules. These modules may be aimed at analyzing transportation, emissions and cost-effectiveness impacts as well as other possibilities. Other methodologies will consist of perhaps only a transportation component and in such cases emissions effects etc. would require the use of other means, or integration with other methods. This section highlights what exactly the methodology is made up of, what it is capable of analyzing, and what output it provides.

3. Practical Restrictions

(a) How easy is it to obtain the data required for the methodology

A major element in the decision to use any methodology is whether or not the data is available to actually use it. This section indicates how easy it is to obtain the data required of the methodology and where this information would typically come from. For some methodologies, the data requirements are quite extensive and would thus be very expensive to collect. In other cases, the data may be readily available and so the use of this methodology might be very practical. The decision on which methodology to adopt will also be interrelated with the level of analysis required and the seriousness of the decisions which need to be made based on the output.

(b) Computer hardware and software required to use the methodology

This section identifies what the computer requirements (if any) of the methodology are. The potential user will obviously be constrained by the computer resources available to him and this will be an obvious determinant in his choice of methodology.

(c) Technical skills required to operate the methodology

This section indicates the necessary computer experience or skills required to use the various methodologies. Some methodologies are very user-friendly whereas others require programming experience or other expertise.

(d) Is the methodology designed to be region-specific or broadly applicable

Some methodologies are designed to be very region-specific. Their alteration to facilitate their use in another region may be very difficult or impractical. Other methodologies may be very amenable to use in various regions or may contain default variables that can easily be altered to reflect the characteristics of any particular region.

4.2 Four-Step Regional Travel Model

4.2.1 What TCMs can be analyzed using this methodology and at what level of detail

4.2.1.1 Level of analysis provided by the methodology

Regional travel models are effective tools for detailed analysis provided that sufficient region-specific data is available to calibrate a model and that the TCM impacts will not be absorbed by the model's error terms. Four-step models only estimate the travel impacts of a TCM, and therefore must be used in conjunction with other methodologies to determine emission impacts.

4.2.1.2 What TCMs has the methodology been designed to analyze

Regional travel models are not typically designed for TCM analysis but, TCMs can be analyzed with them. This is done by inputting the change to the transportation system brought about by the TCM and observing how the model re-equilibrates. For instance, they can model TCMs which affect travel times and costs. However, the effects of some TCMs are small enough to be absorbed in the error terms of the model. In those cases, a regional model would not be an appropriate analysis tool.

4.2.1.3 Does the methodology support the analysis of groups of TCMs

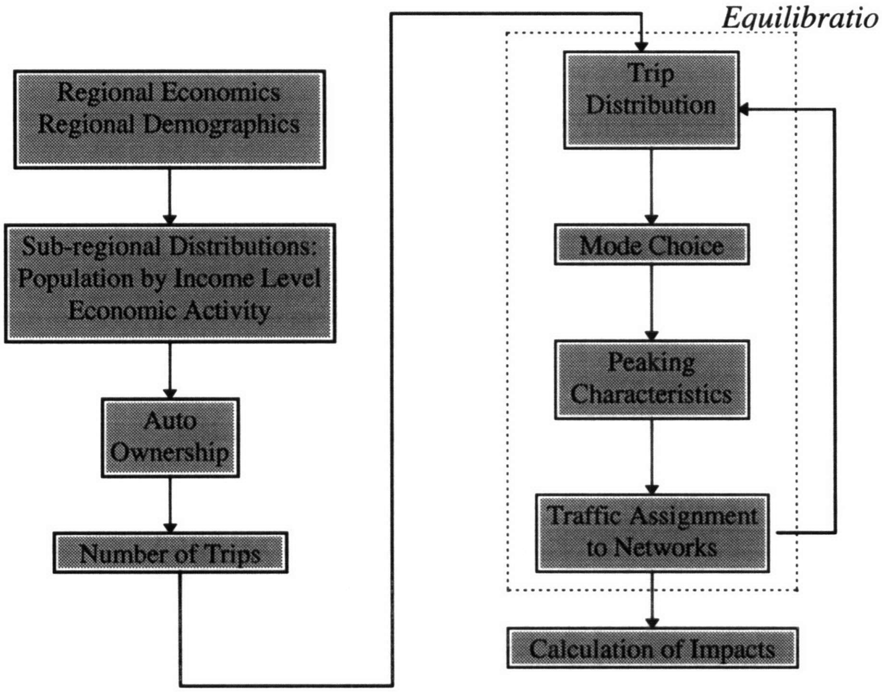
Regional models are good tools for TCM package analyses. Because multiple input parameters may be changed at once it is easy to reflect the transportation changes brought about by the TCM package. Overlap or synergies between TCM effects can thus be accounted for.

4.2.2 Structure, Inputs, and Outputs to the Methodology

Regional travel models may be used to estimate the travel impacts of TCMs. Unlike other methodologies described in this report, regional models do not attempt to translate these travel impacts into emission impacts.

Regional travel models generally include four stages: trip generation, trip distribution, mode choice, and traffic assignment. Figure 4-1 depicts the format of a conventional regional travel model described in Document No. 10.

Figure 4-1



Document No. 10 describes each component of the model in detail in sections 3.3.1 to 3.3.9. It also provides a summary which is reworded here.

Regional ***economic and population forecasts*** may be obtained from federal sources, state sources, or regional projections. However, the common practice is to use federal or state regional growth estimates.

Local plans or land use allocation models are usually used to ***forecast land use and development patterns***.

Current maps, inventories, or future plans all help agencies develop ***network descriptions***. Generalizations and assumptions used to represent networks are very region specific.

Vehicle Ownership is generally estimated form survey data using cross classification or regression methods. Income and household size are common data elements used. Also used, but less common are number of workers, transit accessibility, highway accessibility, and so on.

Cross classification and regression are also common techniques for conducting ***trip generation***. Some agencies choose to use more sophisticated methods such as travel frequency choice. Trip generation models usually output the daily trips produced by zone or by a household. Trip estimates are broken down into at least the following three trip-purposes: home-based work trips, home-based non-work trips, and non-home-based trips.

Productions and attractions are often estimated using separate models. Some common variables used to estimate trip productions are household size, number of workers, income, auto ownership, residential density, and distance of zone from central business district. Some common variables used to estimate trip attractions include employment levels, floor space, and accessibility to the work force.

Trip distribution requires a "gravity" model or growth factor method, typically, or a "destination choice" model, less typically. Destination-choice models compute the probability of selecting each location where the purpose of a trip could be fulfilled. The most commonly used growth factor method is the Fratar method which is more a projection technique than a trip distribution model. It forecasts the number of trips from zone i to zone j. The most common trip distribution model is the gravity model. It also predicts the number of trips between zones i and j.

All of these approaches consider variables such as time, distance, and costs of travel between zonal centroids. Origin-destination pair data, or traffic counts less typically, are used to calibrate the matching of productions and attractions.

Mode split is usually carried out with choice models. More advanced models include nested logit. Common variables in mode choice models include travel time, travel cost, household or individual income, number of workers in the household, and household auto ownership.

Counts at key locations or travel survey data are required to produce ***peaking and time of travel distributions***. Advanced methods such as behavioral models of time of travel are sometimes used.

Traffic assignment is done using incremental assignment methods, although advanced algorithms which estimate network equilibrium directly are also available. The main output from this stage are the traffic volumes on each network link by time period. Traffic assignment determines link speeds and VMT, two key components in TCM emission analysis.

4.2.3. Practical Restrictions

4.2.3.1 How easy it is to obtain data required by the methodology

This methodology is very data intensive and requires relatively large amounts of region-specific inputs and survey data. (see section 4.2.2)

4.2.3.2 Computer hardware and software required to use the methodology

The four-step regional modeling process requires either a mainframe, workstation, or personal computer. Some common programs include the Urban Transportation Planning System (for mainframes), MinUTP (for PCs), Transplan (for PCs), EMME/2 (for workstations), TransCAD (for workstations), and System 2 (for workstations).[1]

4.2.3.3 Technical skills required to operate the methodology

The Urban Transportation Planning System, a common mainframe program, requires a user who has programming skills and who is familiar with the hardware. The PC software replicates the mainframe software, generally, as does the workstation software. However, workstation software often utilizes the unique graphical capabilities of workstations to facilitate network and database maintenance.[2]

4.2.3.4 Is the methodology region-specific or broadly applicable

The four-step travel modeling method can be applied to any region so long as sufficient region-specific data is available for calibrating the model. Many regions have developed / calibrated their own regional travel models. For example, a model of the Boston region has been developed by the Central Transportation Planning Staff.

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[1] Document No. 10, p3-5.
[2] Document No. 10, p3-6.

4.3 TCM Tools

(also known as the SANDAG Methodology since it was originally developed for the San Diego Association of Governments by Sierra Research and JHK in 1991)

4.3.1 What TCMs can be analyzed using this methodology and at what level of detail

4.3.1.1 Level of analysis provided by the methodology

This model is used for screening purposes with a county as the area being analyzed.[3] In the 1991 version, the analysis of subareas was not possible.[4]

4.3.1.2 What TCMs has the methodology been designed to analyze[5]

Demand Management
Ridesharing Program
Bicycle Improvements
Pedestrian Improvements
Trip Reduction Ordinances
Non-Commute TRO

Transit Improvements
Transit Service Increases
Park and Ride Lots

Freeway Management
HOV Lanes
Motorist Information
Incident Management and Response

Traffic Flow Improvements
Traffic Signal Improvements
Capacity Increases

Alternative Work Schedules
Telecommuting
Compressed Work Week
Flexible Work Hours
Staggered Work Hours

Pricing Strategies
Employee Transit Pass Subsidy
Parking Pricing (Commute)(
Non-Commute Parking Pricing
Gas Tax/Cost Increase
VMT Tax
Road Pricing

Land Use Management
Jobs/Housing Balance
Densification
Mixed-Use Development
Growth Controls

Goods Movement
Delivery Timing
Loading Facility Improvements

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[3] Document No. 1, p 3-4 and Table A-1.
[4] Document No. 16, p.28.
[5] Document No. 11, 4th page.

4.3.1.3 Does the methodology support analysis of groups of TCMs

The transportation module can be utilized in a sequential manner such that the user can determine the impacts of packages of measures.[6]

4.3.2 Structure, inputs and outputs of the methodology[7]

The methodology consists of three separate modules; travel impact, emissions impact and cost-effectiveness. (please see figure 4-2)

The *transportation module* is designed to estimate the effects of each TCM on numbers of trips, vehicle miles traveled, and speed. A feature of the module is that it can be utilized in a sequential manner such that the user can determine the impacts of packages of measures.

This module requires three types of inputs; Baseline Travel Characteristics, TCM Specific Parameters, and Assumptions. The baseline travel characteristics defining the travel patterns in the area of implementation are input by the user but remain the same for all TCMs in a given analysis year. Information must also be entered regarding the particular TCM being implemented. Some examples are the amount of the gas tax, or the number of employees affected by an employer-based program. The assumptions used in the module generally use elasticities to provide some quantification of the effect of travel changes by the TCM, and these can be altered depending on the area of analysis. The outputs from the module include the baseline travel characteristics and the effects of each TCM on peak and off-peak period trips, VMT and speed. These outputs are used in the emissions and cost-effectiveness modules.

The *emissions module* uses the output from the transportation module and combines it with emission factors from EMFAC7E and BURDEN7C (these are California Air Resources Board's emissions factor models) to determine an estimate of baseline emissions and pollutant reductions for each TCM. As detailed before, determining the emissions benefits of a particular TCM with accuracy, depends largely on how much detail is known about the measure's effects on vehicle operations. Emissions vary greatly with vehicle class and vehicle activity. For this reason, the decision was made to calculate the baseline motor vehicle emissions at a disaggregate level, accounting for trip type, vehicle class, hour of the day, and operating mode. Once all of this information has been entered, the module program estimates the area's baseline pollutant emissions: reactive organic gases (ROG), carbon monoxide (CO), nitrogen oxide (NOx) and particulate matter (PM). The module outputs what the emissions would be if the TCM were implemented. Using these values with baseline figures, the TCMs emission reduction potential can be computed.

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[6] Document No. 11, p4.

[7] Document No. 2, Chapter 4.

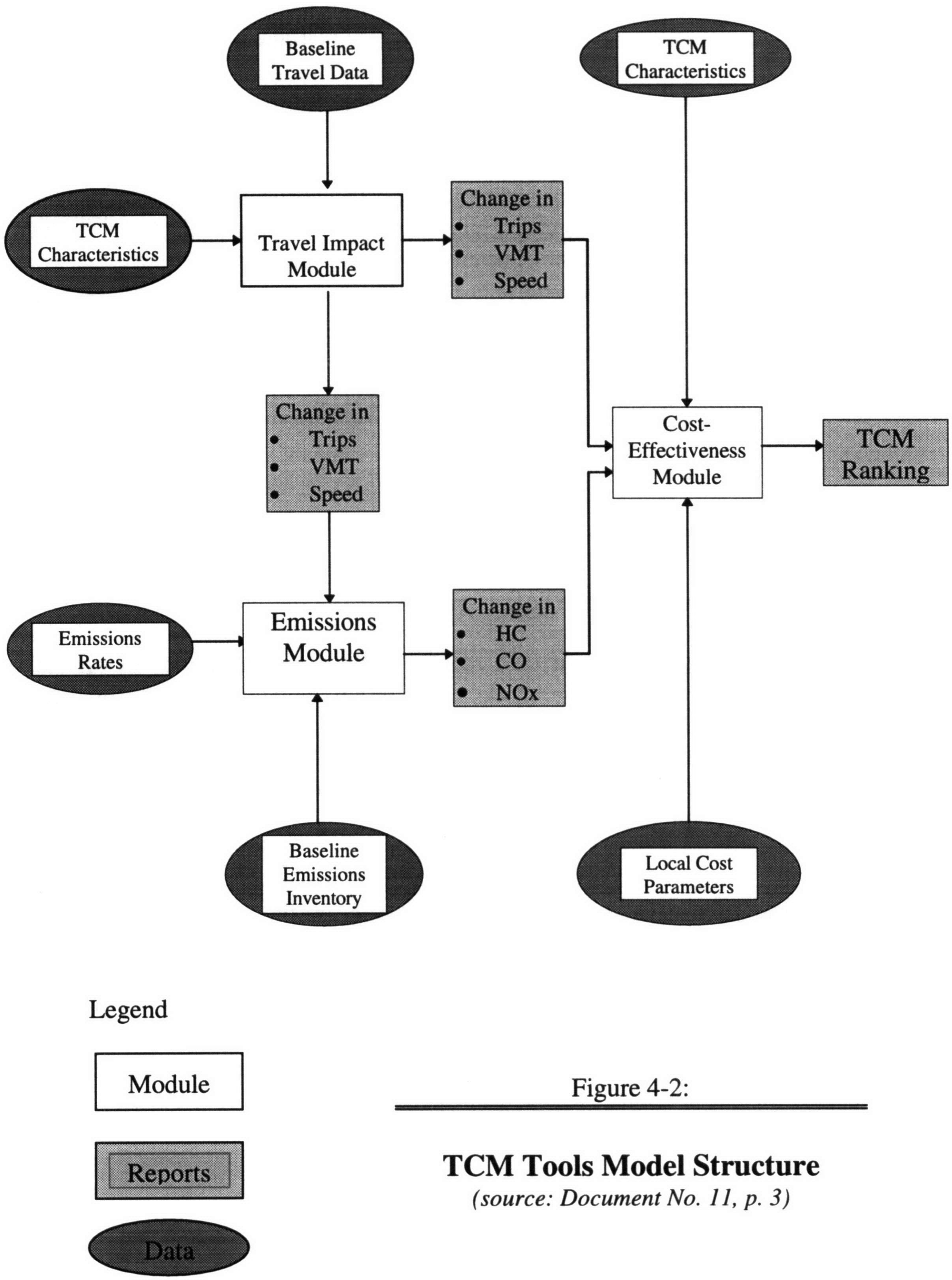

Figure 4-2:

TCM Tools Model Structure

(source: Document No. 11, p. 3)

The *cost-effectiveness* module uses the outputs from the transportation and emissions modules and combines this with other data in the form of baseline parameters and default parameters. The baseline parameters are input by the user and concern such items as the study year, study area, pollutants of interest and daily emissions totals for each of these pollutants. The default parameters include basic cost per unit data and other factors, and can be modified by the user to be more area specific if such information is available. Using this information, the module calculates the costs and the cost-effectiveness of the specified TCMs. The actual calculation of cost-effectiveness is divided into three steps: the calculation of costs, emissions and cost-effectiveness. The costs involved in implementing a TCM are divided into three cost sectors; public, private and individual. For each sector the cost, revenue and avoided cost incurred by the implementation of the TCM are determined. The emissions module outputs the estimated emissions reductions for the four pollutants HC, CO, NOx and PM. Finally, the actual cost-effectiveness calculation involves the allocation of the costs to the pollutant reductions. The module then outputs both gross (expenses minus revenues) and net (gross minus avoided costs) cost-effectiveness estimates for each pollutant, for each TCM.

4.3.3 Practical Restrictions

4.3.3.1 How easy is it to obtain the data required for the methodology

It is considered that the travel input data requirements of this methodology should be readily available from a regional travel model. In addition, default values are supplied for many of the input variables, cost rates, etc. but these will vary depending on the region of application and may be difficult to estimate in some cases. Also, for some TCMs the user is required to generate estimates of trips and VMT, and home-based-work trips (HBW) must be converted to commute trips.

4.3.3.2 Computer hardware and software required to use the methodology

The software requirements are an MS-DOS operating system, Version 3.3 or greater and a Lotus 1-2-3 spreadsheet package, Release 2.0 or greater. Hardware requirements consist of an IBM-compatible PC with 640 KB of main memory, 16 MHz 80286 system with 80287 Math coprocessor. A Hard disk file storage capacity of 1.6 MB is also necessary.[8]

[8] Document No. 1, Table A-1.

4.3.3.3 Technical skills required to operate the methodology

This is a user-friendly package requiring only basic knowledge of Lotus 1-2-3. In addition, user manuals are available for each module.

4.3.3.4 Is the methodology region-specific or broadly applicable

This methodology was originally designed for use in the San Diego area and the default values and emissions factors reflect the characteristics of that area. The facility exists to alter these values to represent the characteristics of any particular region. However, the emission rates cannot be changed by the user.[9] A modified version of the original model developed for SANDAG in 1991 will make the emission module nationally applicable. [10]The transportation and cost-effectiveness modules are applicable to any region.

4.4 CM/AQ Evaluation Model

4.4.1 What TCMs can be analyzed using this methodology and at what level of detail

4.4.1.1 Level of analysis provided by the methodology

The CMAQ Evaluation Model is designed for screening purposes only. It aims to provide a quick and effective analysis of a TCM as well as providing some means of comparing or ranking different measures. The methodology outputs a rating for each project eligible for CMAQ funding.

4.4.1.2 What TCMs has the methodology been designed to analyze

A complete listing of the strategies capable of being analyzed using the CMAQ Evaluation Model includes the following[11]

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[9] Document No. 1, Table A-1.

[10] Document No. 16, p. 28.

[11] Document No. 11, Table 1.

Improved Public Transit
- Increased Transit Service
- Express Buses
- Paratransit Programs
- Light Rail
- Bus Signal Pre-emption
- Activity Center Shuttles
- Transit Shelters
- Transit Advanced Traveler Information Systems

HOV Facilities
Freeway HOV Lanes
Arterial HOV Lanes
Ramp Meter Bypass for HOVs

Employer Based Strategies
- Transit Pass subsidy
- Employee Transportation Coordinator
- Education/Information Dissemination
- Guaranteed Ride Home
- Trip Reduction Ordinances

Traffic Improvement Projects
- Traffic Signal Timing and Coordination Improvements
- Traffic Operations Center
- Courtesy Patrol
- Other Incident Detection and Response Programs
- Motorist Information
- Intersection Improvements (widening)
- Ramp Metering
- Reversible Lanes

Park-n-Ride Lots
- Transit-oriented
- Car/Vanpool-oriented
- Bike to Park-n-Ride Program

Auto/Truck Restrictions
- Restricted Times for Goods Delivery
- Auto Restricted Zones

Congestion Pricing
- VMT Tax
- Tolls

Rideshare Programs/Services
- Regional or Neighborhood-Based Rideshare Program
- Transportation Management Associations
- Vanpool Programs

Non-Motorized Facilities
- Pedestrian Improvements
- Bicycle Amenities (lockers, showers, secure storage)
- Bicycle Lanes, Paths
- Public Education Campaign
- Bicycle/Pedestrian Coordinator Positions

Vehicle Idling Controls
- Drive-through Restrictions
- Curb-side idling restrictions
- Vehicle idling restrictions by buses and trucks

Alternative Work Schedules
- Compressed Work Week
- Flexible Work Hours
- Staggered Work Hours

Alternative Fuels Incentive Programs
- Public Fleet Compressed Natural Gas
- Reformulated Gasoline/Diesel

PM_{10} Reduction Measures
- Enhanced Street Sweeping
- Road Sanding/Salting Alternatives
- Diesel Control Programs

Telecommunications
- Home-Based Telecommuting
- Satellite Work Center
- Teleconferencing

Parking Management
- Restricted Parking Supply
- Parking Charges (commute and all trips)
- Preferential Parking for Carpools and Vanpools

Other Transportation Projects
- Promising Technologies
- Feasible Approaches
- Projects not in strategy listing

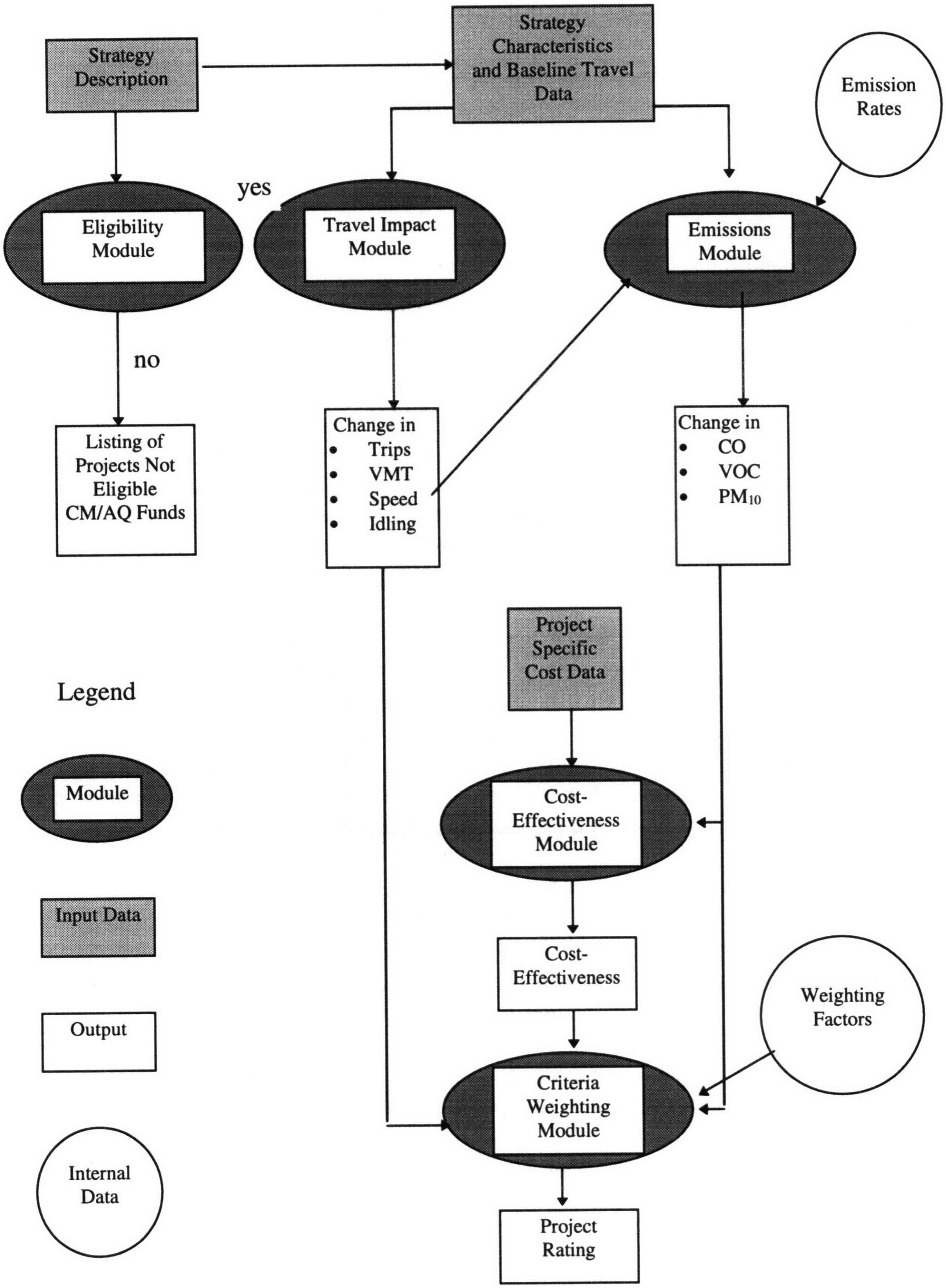

Figure 4-3: CM/AQ Evaluation Model Structure

(source: Document No. 11, p. 10)

4.4.2 Structure, inputs and outputs of the methodology

The model was developed as five separate modules:[12]

- Eligibility
- Travel Impacts
- Emissions
- Cost-Effectiveness
- Criteria Weighting

Figure 4-3 illustrates the basic structure of the model, but separate calculations were developed for each strategy to better capture the particular ways they impact travel, emissions and cost-effectiveness.

The *Eligibility Module* determines whether or not a project is eligible for CM/AQ funding as specified under U.S.DOT/FHWA guidelines. The fundamental prerequisite for CM/AQ funding requires that projects come from a conforming transportation plan and TIP, and be consistent with the conformity provisions contained in Section 176(c) of the Clean Air Act. Projects must also comply with NEPA requirements.

The *Travel Impact Module* assesses impacts on vehicle trips, vehicles miles traveled, average travel speed and vehicle idling time. The impacts of each project on travel behavior are necessary as inputs to the emissions and cost-effectiveness calculations. In general, VMT reductions are calculated by combining the estimated trip reduction with the affected average trip length, and average speed changes for a particular area are based on the estimated VMT reduction. For each particular strategy however, a separate set of parametric equations was developed to assess the effects of that strategy on travel.

The *Emissions Module* first establishes a baseline estimate of emissions by pollutant type and from this determines the improvement brought about by a particular strategy. CO, VOC and PM_{10} emissions changes are estimated for each project. Separate emission rates are determined for trip-based emissions, running emissions, and idling emissions in order to assess the differing impacts of changes in travel characteristics.

The *Cost-Effectiveness Module* estimates the cost of each project to the public sector, and the cost-effectiveness in terms of the cost per kilogram of pollutants reduced. The public sector costs of any particular strategy comprises of the daily labor costs, daily capital costs, daily direct operational costs and daily overhead costs. This is offset against the daily revenues that may result from the implementation of the strategy. By combining these figures a total cost estimate is arrived at. Cost-Effectiveness calculations are performed for each of the three pollutants CO, VOC, and PM_{10} separately by dividing the total costs by the emission reductions.

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[12] Document No. 1

The *Criteria Weighting Module* aims to rate the overall effectiveness of each eligible project and then compare them to each other. The important issue is the weighting factors that are selected to reflect the relative importance of the various criteria which could include Travel Impacts, Pollutant Emission Impacts, Cost-Effectiveness, Early Project Effectiveness.

4.4.3 Practical Restrictions

4.4.3.1 How easy is it to obtain the data required for the methodology

This model is similar to TCM Tools in its data requirements, utilizing location-specific data which should be readily available from a regional travel model. In addition, the model also uses reported experience as a basis for the selection of default values for some input variables. In addition to the usual travel and emission impacts components, the model also includes a means of rating projects, which requires the use of weighting factors to reflect the relative importance of a variety of criteria. These factors would be selected based on the importance attached to the different criteria by a particular region. For instance, some regions may consider air quality improvement to be their main priority and as such a greater weighting would be given to real air quality benefits than would be given to congestion mitigation effects. Another important data input of the model are the cost rates such as the daily labor, capital, direct operational and overhead costs which would require some effort to obtain good estimates of.

4.4.3.2 Computer hardware and software required to use the methodology

The model was developed in Paradox 4.02, a PC - based database management software package, and can be operated in later DOS - based versions as well.

4.4.3.3 Technical skills required to operate the methodology

This is a user-friendly PC - based model.

4.4.3.4 Is the methodology region-specific or broadly applicable

The model has the facility to be updated and customized to be applicable to various regions. Customization could be as simple as changing the weighting factors to reflect more closely the criteria of a particular region. Other updates might include the addition of more strategies, the revision of emission rates, or the alteration of selection criteria.

4.5 EPA-SAI Methodology

4.5.1 What TCMs can be analyzed using this methodology and at what level of detail

4.5.1.1 Level of analysis provided by the methodology

The EPA-SAI methodology is a sketch planning technique which approximates the effects of TCMs. Transportation modeling probably provides more accurate estimates. The EPA-SAI techniques should be used:

- if a transportation model is not readily available or calibrated for the region
- for screening purposes; to see if modeling is worthwhile
- if the effect of the TCM is small enough to be captured within a model's margin of error.[13]

The method for TCM package analysis involves creating a model of the region's mode choice decision making. It is not, however, an empirical model statistically calibrated from an extensive database. If such a detailed travel model has been or could be easily calibrated for the region, the EPA-SAI report recommends its use. The main advantage of the EPA-SAI method is its minimal data requirements relative to a detailed travel model. The main disadvantage is the loss of accuracy.[14]

4.5.1.2 What TCMs has this methodology been designed to analyze

A general method for estimating travel impacts of a TCM is presented. This method is applied to six sample TCMs.

1. Telecommuting
2. Flextime
3. Compressed Work Weeks
4. Ridesharing
5. Parking Management
6. Transit Improvements
   a) decreased fares
   b) increased service

[13] Document No. 5, p1-2.
[14] Document No. 5, p4-9.

These examples should provide enough insight on how to use the methodology to estimate the impacts of price, behavioral, or system changes brought about by TCMs, so that the analyst may apply the methods to TCMs other than the six listed above.[15]

In general, if the TCM's impacts on speed, trips, and VMT are known, then the emission impacts of that TCM may be estimated with the EPA-SAI method. This is because VMT, trips, and speed impacts, as well as Mobile emission factors, are the main inputs needed to calculate emission effects using this method.

4.5.1.3 Does the methodology support the analysis of groups of TCMs

Chapter 4 of the EPA/SAI methodology (Document No. 5) describes a method for analyzing TCM packages. However, the authors recommend the method only when a detailed regional travel model is not readily available.

4.5.2 Structure, inputs, and outputs of the methodology

This methodology is two-staged. First it estimates the travel impacts of TCMs and then it converts them into emission impacts. Unlike other methodologies, the EPA-SAI method does not provide a means for converting emissions and travel impacts into cost-effectiveness measures. Also, unlike some other methodologies, this one addresses the issue of TCM package analysis.

Stage 1a: Assessing the Travel Impacts of Individual TCMs

Inputs

Appendix A lists the input data needed to estimate the travel impacts of the 6 TCMs discussed in detail by the report. The analyst should note that:

- not all data items are needed to analyze each TCM
- analyzing a TCM other than the 6 discussed might require data inputs not listed.

Also listed in appendix A are examples of potential data sources. If region specific data is unavailable, "standard" values may be found in appendix B. The EPA-SAI report strongly encourages the use of region-specific data, however. The sample calculations presented in the report are often based on data from the San Francisco / Bay Area, rather than on "standard" data.[16]

[15] Document No. 5, p2-4, 2-5.
[16] Document No. 5, p2-6.

Output:

The travel impacts of interest when calculating emission effects of a TCM are (1) changes in VMT, (2) changes in speed, and (3) changes in trips. Nine steps are followed to produce this output as is shown in Table 4-1.[17]

Table 4-1: Nine-Step Process Used to Calculate Travel Impacts

STEP	*EXAMPLE*
1. Identify potential direct trip effect and affected trip type.	Number of employees allowed to telecommute.
2. Calculate direct trip reductions.	Number of trips eliminated through telecommuting.
3. Calculate indirect trip reductions.	Number of additional trips due to availability of auto to members of telecommuter's households.
4. Determine peak/off-peak period trip shifts.	Portion of trip changes that occur in the peak versus the off-peak periods.
5. Calculate total trip changes.	Net effect of measures and decreases.
6. Calculate VMT changes due to trip changes.	Multiply average work trip length by number of work trips reduced.
7. Calculate VMT changes due to trip length changes.	Multiply difference between average work trip length and satellite work stations by number of telecommuters working at satellite stations.
8. Determine total VMT changes.	Net VMT changes.
9. Calculate speed changes.	Speed increases due to decreased volumes.

Stage 1b: Assessing the Travel Impacts of TCM Packages

This stage has two components:[18]

1. Estimating the effect of the TCM package on mode split.
2. Using the mode split data and the method described for Stage 1a, estimating the travel impacts of each TCM individually.

[17] Document No. 5, p2-3.
[18] Document No. 5, p4-1, 4-2.

Component 1

Because the method used to estimate mode split is not an empirical model statistically calibrated from an extensive database, the method requires minimal data inputs. As has been noted, if a detailed travel model is readily available it should be used instead of this method because it will most likely provide more accurate results. The only data required to use this method are:

- current mode splits
- costs of each mode
- travel times of each mode.

Although the data requirements are minimal relative to a detailed travel model, use of this method does require a fairly detailed knowledge of the transportation system.

This component estimates the changes in mode split resulting from a TCM package. This output serves as input data for component 2.

Component 2

Except for the new mode split data computed in component 1, this component has the same input and output as was needed in Stage 1a.

Stage 2: Converting Travel Impacts into Emission Impacts

The emissions analysis methodology assumes the following relationships between travel impacts and emissions categories:

- Trip changes affect hot-start and cold-start exhaust, hot soak, and diurnal emissions.
- VMT changes affect hot-stabilized exhaust, running loss, crankcase, and refueling emissions.
- Speed changes affect hot stabilized exhaust and running loss emissions.

In order to convert these travel impacts into their impacts on HC, CO, and NOx emissions, four steps are followed. First the emission impact of trip changes is calculated, second the impacts of VMT changes is computed, and third the impacts of overall fleet speed changes are calculated. In the fourth step, results from the first three stages are summed to produce an estimate of total emission changes.

Table 4-2 provides a listing of inputs to the emission module. The MOBILE emission factors may be substituted by EMFAC emission factors so long as the units are compatible. MOBILE requires inputs such as vehicle fleet information, vehicle fuel information, vehicle operating conditions, temperature data, and vehicle inspection data. Region-specific data should be used, although national average data is sometimes provided as default values.[19] The second column of inputs are values calculated in Stage 1a of the methodology, which is described above. The third column includes input values which must be obtained from regional sources, standard values, or reasonable assumption. For example, the report suggests that the fraction of cold-started work trips is close to 1.[20]

Table 4-2: Three Categories of Inputs to Emission Module[21]

Emission Factors Produced by MOBILE	*Inputs From Travel Impact Estimation*	*Other Inputs*
1. exhaust HC, hot-start mode (given in grams per mile and must be converted)	1. total work peak trip changes	1. distribution of trips among the vehicle classes. Report assumes that LDGVs and LDGT1s are the primary classes affected by the TCMs analyzed.
2. exhaust HC, cold-start mode	2. total work off-peak trip changes	2. fraction of trips begun in the cold start (rather than hot start) operating mode
3. exhaust CO, hot-start mode	3. total non-work peak trip changes	3. number of work trips per vehicle commute day
4. exhaust CO, cold-start mode	4. total non-work off-peak changes	4. number of non-work trips per day per vehicle
5. exhaust NOx, hot-start mode	5. change in total peak period VMT	5. the fraction of VMT s which are from a specific vehicle class.
6. exhaust NOx, cold-start mode	6. change in total off-peak VMT	6. speed for peak period prior to TCM implementation
7. hot soak emission factor (grams of HC per trip)	7. change in peak period speed	7. speed for off-peak period prior to TCM implementation
8. multi day diurnal emission factor	8. change in off-peak period speed	
9. weighted diurnal emission factor		
10. hot stabilized peak period emission factor		
11. hot stabilized off-peak emission factor		
12. running loss emission factor(grams per mile)		
13. crankcase emission factor (grams per mile)		
14. refueling emission factor (grams per mile)		

[19] Document No. 5, p3-2.

[20] Document No. 5, p3-8.

[21] Document No. 5, p3-6 to 3-26.

Outputs

The primary outputs from the emission module of this methodology is the change in CO, HC, and NOx emissions resulting from the speed, VMT, and trip impacts of a TCM.

4.5.3 Practical Restrictions

4.5.3.1 How easy it is to obtain data required by the methodology

Stage 1a: Example sources of regional data are listed. Although the use of regional data is strongly suggested, the report recognizes that not all agencies will have region-specific data available to them , and therefore sources of standard input values are also listed.

Stage 1b: Data requirements for the mode split method used are minimal relative to those of a detailed travel model. However, knowledge of current regional mode split, as well as relative travel times and costs of regional modal options, are required and should be available from regional sources.

Stage 2: MOBILE emission factors should be region-specific, although default inputs are provided by MOBILE. Reasonable assumptions are often suggested for other inputs which may be difficult to obtain. For instance, data on the ratio of cold to hot starts is often unavailable and must therefore be assumed.

4.5.3.2 Computer hardware and software required to use the methodology

The EPA-SAI methodology requires only a hand held calculator.[22] However, mode split calculations for analysis of TCM packages may be most easily conducted using a spreadsheet or a simple FORTRAN program.[23] MOBILE or EMFAC emission models must be used in order to obtain necessary inputs to the emission module of the methodology.

4.5.3.3 Technical skills required to operate the methodology

Given all the necessary input data, in particular MOBILE emission factors, only simple computational skills are required to employ this methodology.

4.5.3.4 Is the methodology region-specific or broadly applicable

The methodology is designed to be broadly applicable, although most examples are based on data specific to the San Francisco / Bay Area. The method for TCM package analysis is applied to both the City of San Francisco and the Maricopa County Metropolitan Area in Arizona.

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[22] Document No. 5, p1-2.
[23] Document No. 5, p4-3.

4.6 Pivot Point Model[24]

4.6.1 What TCMs can be analyzed using this methodology and at what level of detail

4.6.1.1 Level of analysis provided by the methodology

This methodology is for screening and sketch planning purposes and applies to measures that impact travel time and cost.

4.6.1.2 What TCMs has the methodology been designed to analyze

Examples of TCMs which may be analyzed using this methodology include the following:

Applicability of model to specific TDM measures:
Reduced Transit Fares
Increased Transit Service
Parking Pricing
Preferential Parking
Employee Transit Pass Subsidies
Transportation Allowance
Direct Monetary Incentives
Integrated Bicycle Lane System
Increases in Gasoline Tax
Emission Based Changes

Applicability of model to specific TSM measures:
Signal Optimization

Applicability of Model to specific Facilities Development Measures:
Arterial HOV Lanes
Freeway HOV Lanes
Fixed Guideways

4.6.2 Structure, inputs and outputs of the methodology

The Pivot Point Model consists of a Transportation module. The model is applicable to sketch planning analysis of TCMs that effect work trips and their travel time or cost, where their impact is on mode choice. The input requirements include average household

[24] Document No. 1

characteristics, base work trip modal shares, average carpool size and average trip lengths. The model has no emissions capability.

4.6.3 Practical Restrictions

4.6.3.1 How easy is it to obtain the data required for the methodology

The baseline travel data should be readily available, possibly from a regional travel model.

4.6.3.2 Computer hardware and software required to use the methodology

The software requirements are an MS-DOS operating system, Version 2.0 or greater if using a PC or, on a limited basis for Macintosh IIsi and above. Hardware requirements are a 286-level IBM compatible PC and math coprocessor.

4.6.3.3 Technical skills required to operate the methodology

Simple, easy to use methodology.

4.6.3.4 Is the methodology designed to be region-specific or broadly applicable

The elasticities for travel times and costs can be changed, using simple programming language provided in the documentation, to represent the characteristics of any particular region.

4.7 TRIPS[25]

4.7.1 What TCMs can be analyzed using this methodology and at what level of detail

4.7.1.1 Level of analysis provided by the methodology

This model can be used for screening, sketch planning and detailed network analysis of TCMs that impact travel time and cost.

[25] Document No. 1

4.7.1.2 What TCMs has the methodology been designed to analyze

The measures that can be analyzed using this methodology include the following:

Applicability of models to specific TDM measures:
Reduced Transit Fares
Increased Transit Service
Parking Pricing
Preferential Parking
Employee Transit Pass Subsidies
Transportation Allowance
Direct Monetary Incentives
Integrated Bicycle Lane System
Increases in Gasoline Tax
Emission Based Charges

Applicability of models to specific TSM measures
Signal Optimization

Applicability of models to specific facilities development measures
Arterial HOV Lanes
Freeway HOV Lanes
Fixed Guideways

4.7.2 Structure, inputs and outputs of the methodology

TRIPS comprises transportation, emissions, fuel consumption and residential location components. It was developed to examine pricing policies in particular, and is most suited to these TCMs. The data inputs require conducting a large household interview survey and there are factors which relate the survey values to the regional population.

The package estimates emissions reductions internally using EMFAC emission rates, but when linked to a regional travel model, DTIM or other emissions estimation software can be applied.

4.7.3 Practical Restrictions

4.7.3.1 How easy is it to obtain the data required for the methodology

The model has been set up for the Southern California Association of Governments (SCAG) using information obtained from a household interview survey conducted in 1976. The collection and formatting of new data would require significant effort.

4.7.3.2 Computer hardware and software required to use the methodology

The Software requirements are an MS-DOS operating system with spreadsheet software recommended to format the output. Hardware requirements are an IBM-compatible PC, AT or above.

4.7.3.3 Technical skills required to operate the methodology

The package consists of a simple menu-based, line-oriented interface for most common analysis tasks. However, a lot of programming skill and effort is required to set up the model and analyze complex TCMs.

4.7.3.4 Is the methodology designed to be region-specific or broadly applicable

All of the assumptions and elasticities are imbedded in the program, and would require a programmer to make the changes. As such, the methodology is not broadly applicable.

4.8 COMSIS TDM Model[26]

4.8.1 What TCMs can be analyzed using this methodology and at what level of detail.

4.8.1.1 Level of analysis provided by the methodology

This methodology can be used for either Screening, Sketch Planning or Detailed Network analysis of transportation demand management measures that impact home-based work trips.

[26] Document No. 1

4.8.1.2 What TCMs has the methodology been designed to analyze

Examples of the TCMs that may be analyzed using this methodology include the following:

Applicability of model to specific TDM measures
Reduced Transit Fares
Increased Transit Service
Parking Pricing
Preferential Parking
Employee Transit Pass Subsidies
Direct Monetary Incentives
Increases in Gasoline Tax
Emission Based Charges

Applicability of model to specific facilities development measures:
Arterial HOV Lanes
Freeway HOV Lanes

4.8.1.3 Does the methodology support the analysis of groups of TCMs

The model is designed to evaluate specific measures, and a separate methodology is included for each measure.

4.8.2 Structure, inputs and outputs of the methodology

The COMSIS TDM Model only has a transportation module. The data requirements are trip tables containing information by purpose and mode, and a highway distance matrix from a regional travel model. The model also requires knowledge of the location of employers by size of firm. The model can operate directly off of trip tables from a network model and can be specified for a region, sub-region, or site.

The model can be linked to a regional travel model, and DTIM or other emissions estimation software can be applied in order to develop emissions impact estimates.

4.8.3 Practical Restrictions

4.8.3.1 How easy is it to obtain the data required for the methodology

The trip tables should be readily available from a regional travel model or a local travel model, and default values are available for other inputs if they are difficult to obtain.

4.8.3.2 Computer hardware and software required to use the methodology

The software requirements are an MS-DOS operating system, Version 3.1 or greater. Hardware necessities are a 386-level IBM-compatible PC, with math coprocessor and EGA color monitor and laser printer (optional for graphics).

4.8.3.3 Technical skills required to operate the methodology

This is a user-friendly package, which is menu-driven. Additionally, a user's manual is included with the software.

4.8.3.4 Is the methodology region-specific or broadly applicable

Any of the input data and sensitivity factors in the model can be modified by the user and so the methodology can be altered to be applicable to the region under consideration.

4.9 Sacramento Air Quality Management District (SMAQMD) Methodology[27]

4.9.1 What TCMs can be analyzed using this methodology and at what level of detail

4.9.1.1 Level of analysis provided by the methodology

The SMAQMD methodology described in Document No. 5 has not been fully developed. It is Volume 5 of SMAQMD's 1991 Air Quality Attainment Plan. It begins with a qualitative screening analysis in which TCMs are ranked by effectiveness and feasibility. The iterative screening process produced a list of 38 measures deemed worthy of more detailed analysis. These measures were further subdivided amongst three terms of implementation: near term (1991-1993), mid-term (1994-1996), and long-term (1997-2010). A methodology combining qualitative and quantitative analysis techniques was then used to analyze the joint effects of the 20 near-term projects. This more detailed methodology is described below.

[27]The entire discussion of the SMAQMD methodology is based on a summary provided in Document No. 5.

4.9.1.2 What TCMs has this methodology been designed to analyze

SMAQMD used their methodology to analyze a set of 20 TCMs, whose exact descriptions are available in the footnoted source.[28] This methodology is designed to analyze packages of TCMs. Also, shifts in commuter mode choice were the main TCM travel impacts considered. For instance, the analysis did not consider the ability of TCMs to indirectly generate new trips by increasing a vehicle's accessibility.

4.9.1.3 Does the methodology support the analysis of groups of TCMs

The methodology only analyzes TCM packages. No method is provided for the analysis of individual TCMs. Also, if the set of TCMs included in the package is altered, the entire modeling procedure must be redone.

4.9.2 Structure, inputs, and outputs of the methodology

The entire methodology rests on the basic assumption that an entire TCM package will be implemented according to a pre-determined schedule.

The methodology consists of three stages: estimation of travel impacts, estimation of emission impacts, and calculation of cost-effectiveness measures. The travel impacts considered include cold start trip, hot-start trip, VMT, idling time, average speed, and time of day changes. SMAQMD subdivides its travel market into six sections: **G**oods Movement, **R**ecreation, **A**ctivity Center, **C**ommercial, **I**nstitutional, and **E**mployment (abbreviated GRACIE.) The effects of TCMs on the entire travel market is broken down into their effects on each GRACIE sub-market.

The primary emission impacts considered include change in CO, NOx, and ROG (reactive organic gases) emissions. These are estimated for each of four travel aspects (VMT emissions, cold-start emissions, hot-start emissions, hot-soak emissions) and each of five years (1987, 1991, 1997, 2000, 2010.) Estimates for each year between 1987 and 2010 are interpolated from these.

Cost-effectiveness is measured in units of $/ ton per day in 1987 dollars using a simple spreadsheet program. These measures are based on inputs from previous sections of the methodology and on calculations of the TCMs' net present values. Finally the measures are used to rank the 20 TCMs analyzed.

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[28]Ornelus, L. 1990. Sacramento Metropolitan Air Quality Management District. "Sacramento Air Quality Attainment Plan Volume Five: Transportation Control Measures Program."

A sequence of five qualitative/quantitative phases comprise the three broad stages described above:

1. TCMARK - Because a TCM does not impact all GRACIE sub-markets, this computer model is used to determine which sub-markets are impacted by a particular TCM.

2. TCMPACT - Qualitatively analyzes the potential of TCMs to reduce emissions. Ranks each TCM on a scale of 1 to 6, 6 being the best.

3. TRAVDEM - This is a travel demand forecasting model used to evaluate transportation and cost-effectiveness impacts of each TCM.

4. EMISSION - This model produces an inventory of on road mobile source emissions using BURDEN/EMFAC emission factors and inputs from previous phases of the methodology.

5. Cost-effectiveness - a cost-effectiveness value is calculated so that TCMs may be ranked.

4.9.3 Practical Restrictions

4.9.3.1 How easy is it to obtain the data required for the methodology

Document No. 5 points out that there are several parts of the methodology in which the lack of sufficient, accurate data is mentioned. Whether this is the opinion of EPA-SAI writers or if it is a shortage noted by SMAQMD itself, is unclear.

4.9.3.2 Is the methodology region-specific or broadly applicable

The SMAQMD methodology is region-specific and would be difficult to adapt to other regions, according to Document No. 5.

4.10 AQAT-3 (Air Quality Analysis Tools)[29]

4.10.1 TCMs that can be analyzed using this methodology and at what level of detail

4.10.1.1 Level of analysis provided by the methodology

According to Document No. 5, this methodology is best used for screening purposes. Attributes of the methodology which add uncertainty to its results include:

- Insufficient documentation on how to convert mode share changes into trip, VMT, and speed changes.
- Pivot Point, a methodology used to analyze travel impacts, addresses mainly work trip changes.
- Pivot Point uses regression coefficients from a 1968 Washington, DC travel survey which may be outdated or inappropriate for other regions.
- The calculation of emission factors is based on generalized fleet characteristics

4.10.2 Structure, inputs, and outputs of the methodology

This methodology links four computer tools in order to analyze the air quality impacts of transportation programs. UBREMIS estimates changes in vehicle emissions due to new or modified land usage by using inputs such as changes in the number of trips associated with a particular land usage. EMFAC7PC estimates on-road emission factors. The inputs to EMFAC7PC are less rigorous than those needed for EMFAC. CALINE4 calculates pollutant concentrations near roadways. Finally, PIVOT POINT, a sketch planning method originally developed by Cambridge Systematics, estimates the impact of TCMs on the use of different travel modes.

4.10.3 Practical Restrictions

4.10.3.1 Computer hardware and software required to use the methodology

The set of four computer programs: URBREMIS, EMFAC, CALINE4, and PIVOT POINT, can be contained on two diskettes. Use of this software requires an IBM compatible microcomputer with 128K of memory, a color graphics video adapter, and a disk drive.

[29]This discussion is based on a summary of AQAT-3 provided in Document No. 5.

4.10.3.2 Is the methodology region-specific or broadly applicable

Developed by the California Air Resources Board Stationary Source Division, this methodology is very specific to California. MOBILE, rather than EMFAC, is used in most other states. Also, CALINE4 was developed by Caltrans. As is implied by these reasons and is stated by Document No. 5, this methodology would not be easily adapted to other regions.

4.11 SAI/CARB Methodology

(Systems Applications International / California Air Resources Board)

4.11.1 TCMs that can be analyzed using this methodology and at what level of detail

The EPA/SAI methodology described in section 4.5 is the "second generation" of the methodology described below. The discussion which follows is based on a summary provided in the EPA/SAI methodology's report, Document No. 5.

4.11.1.1 Level of analysis provided by the methodology

This is a sketch planning method that may be appropriate only for screening in certain cases. In particular, travel impacts estimated using elasticities should be noted since elasticities are very region-specific values.

4.11.1.2 TCMs this methodology has been designed to analyze

A few TCMs are described in detail:

- Ridesharing
- Telecommuting
- Parking Management
- Flextime / Staggered work hours
- Compressed Work Weeks
- Traffic Flow Improvements
- Traffic Signal Synchronization

Other TCMs could be analyzed by modifying the methods used to analyze the above TCMs. However, Document No. 5 points out that methods for doing this are not discussed in detail.

4.11.1.3 Does the methodology support the analysis of groups of TCMs

A method for TCM package analysis which accounts for overlap and synergy between certain measures, is included in the methodology. Document No. 5 points out that the packaging methodology requires several qualitative judgments which could make the calculation of multiple scenarios difficult.

4.11.2 Structure, inputs, and outputs of the methodology

The structure of the SAI/CARB methodology is very similar to that of the EPA/SAI methodology. However, a detailed description is N/A.

4.11.3 Practical Restrictions

4.11.3.1 How easy is it to obtain the data required for the methodology

Like the EPA/SAI methodology, this methodology is fairly data intensive. Because the results are only as legitimate as the input data, the availability of region-specific data should be considered before using this method. Also, professional judgment is often used to determine key input values such as the utility of cost, convenience, and time.

4.11.3.2 Computer hardware and software required to use the methodology

EMFAC7E emission factors are used. Further information is N/A.

4.11.3.3 Is the methodology designed to be region-specific or broadly applicable

The methodology was designed for the California Air Resources Board and uses EMFAC7E which is used primarily in California.

APPENDIX C

Example Methodologies Used By Dallas-Fort Worth

Source: Texas No. 4, pages I-29, I-33 to I-39.

Evaluation of Roadway Projects

Roadway projects were evaluated and scored using the five criteria approved by the Regional Transportation Council. This process is briefly outlined below:

Cost-Effectiveness

Current cost-effectiveness of roadway projects was calculated by estimating the travel time savings of motorists using the proposed facility if it were built today. Travel time savings of new facilities was estimated from the average travel time saved by motorists traveling similar facilities in areas where the new facilities would be built. Future cost-effectiveness was calculated by estimating the travel time savings of motorists using the proposed facility if it were built in the future (year 2010). Cost-effectiveness is a function of annual travel time benefits (hours of travel saved * value of time) and the total annualized dollar cost of making the proposed roadway improvements. A maximum 25- and 20-point rating scale was used to determine the scores for projects, for the 1993 TIP under the current and future cost-effectiveness criteria, respectively. As noted previously, these criteria have been refined in the 1995 TIP development process. Tables 7 and 8 contain the new criteria and maximum point ratings. Detailed assumptions are contained in Table 9.

TABLE 9

CALCULATION OF BENEFIT/COST RATIO FOR ARTERIAL WIDENINGS

ASSUMPTIONS:

Cost of Congestion/Person Hour	=	$8.92
Average Auto Occupancy	=	1.20
Number of Days/Year	=	260
Capital Recovery Factor for 40 Years @ 6 Percent	=	0.06646
Truck Factor	=	1.0
Peak-Hour Directional Split	=	60 Percent
Equivalent Peak-Hour Volume Factor	=	10 Percent (DDHV Factor = .06)
Free Speeds	=	90 Percent of Speed Limits
Delay/Mile (in minutes)	=	0.015 * Exp. (4.0 * V/C)
Hours of Congestion/Day	=	8.33

EQUATIONS:

Benefit/Cost Ratio = Annualized Travel Time Savings ($) / Annualized Total Project Costs

Annualized Total Project Costs = Total Project Costs * Capital Recovery Factor @ 6 Percent for 40 Years

Annualized Travel Time Savings = Daily Travel Time Savings (Personal Hours) * Value of Time * Number of Days/Year

Daily Travel Time Savings = Directional Design Hourly Volume (DDHV) * Auto Occupancy * Reduction in Delay Due to Road Widening * Hours of Congestion/Day

DDHV = Equivalent Peak-Hour Volume Factor * Peak-Hour Directional Split * Truck Factor * 24-Hour Traffic Volumes

Air Quality/Energy Conservation

Air quality benefits were calculated from the difference in vehicle emissions caused by an improvement in vehicle speeds due to the construction of the proposed roadway facility in 19_0. Reduced network circuity with the implementation of new roadway facilities also decreases vehicle miles of travel and mobile source emissions. Vehicle emissions are a function of vehicle miles of travel (VMT) and volatile organic compounds (VOC) emissions per VMT at different vehicle speeds.

Project Commitment/Local Cost Participation

Local cost participation was calculated as a ratio of local funds available and total project cost. Project submittal forms were consulted for comments to determine Principal Arterial Street System/Federal Aid Urban System (PASS/FAUS), thoroughfare plan, and Minute Order projects. Projects were scored using the appropriate rating scales and given the higher score of either local cost participation or project commitment. When this criteria was revised for the 1995 TIP, the number of points became proportional to local cost as a percent of the total project cost.

Intermodal/Multimodal Projects/Social Mobility

Roadway capacity improvement projects were assumed to support mainly single-occupancy vehicle travel and were assigned a score of 0.

Evaluation Process for Transit, Travel Demand Management, and Miscellaneous

Transit projects were evaluated for cost-effectiveness by determining the vehicle-hours removed from the main traffic stream. This is different than travel time savings methodologies used for roadway projects in that the users of the project or program do not, in most cases, receive any travel time savings. These types of projects could not be evaluated using the traditional travel time savings methodology. However, there are obvious benefits to these types of projects such as reducing vehicle travel and reducing congestion The procedure used was to determine the number of person-hours of travel removed from the main traffic stream for each project. This value was multiplied by the value of time and annualized. The total cost of the project was then annualized using the capital recovery factor for an appropriate number of years. The annual benefits were divided by the annual cost to arrive at the benefit/cost (B/C) ratio for that project. For these projects, the current and future B/C ratios were equal to the calculated ratio.

The air quality benefits were similarly evaluated using the VOC reduction of the vehicle-miles removed from the main traffic stream The annual cost was divided by the annual VOC reduction to determine the cost-effectiveness of the emission reduction For detailed assumptions, see Table 10

TABLE 10

DETAILED ASSUMPTIONS FOR EVALUATION OF TRANSIT, TRAVEL DEMAND MANAGEMENT, AND MISCELLANEOUS PROJECTS

COST-EFFECTIVENESS FOR TRANSIT, TRAVEL DEMAND MANAGEMENT, MISCELLANEOUS

- Person hours removed from roadway

$$\frac{\text{PHRS Saved}}{\text{YR}} = \frac{V \times AO \times TL \times Days}{SPD}$$

where: V = volume (vehicles removed daily) (in some cases, peak-period)
AO = auto occupancy
TL = average trip length (miles)
Days = impacted days per year
SPD = speed of removed vehicles

AIR QUALITY BENEFITS OF TRANSIT, TDM, MISC.

- #HC removed from roadway

removed = V x TL x [HCB - HCA]

where: HCx = #s HC @ a given speed per vehicle-mile before & after (after may be 0 in many cases)

ASSUMPTIONS:

Auto Occupancy = 1.0-1.3
Trip Length = 7-15 miles
Days/Yr = 260-300
Speed = 15-50 mph
HCx = 1.3-3 g/mi
Cost Recovery Factor = 0.2374-.06646 (5-40 yrs)

NOTE. Values for each project are used as appropriate for the type of project.

Evaluation Process for HOV Lanes

High occupancy vehicle (HOV) lanes were evaluated using a traditional travel time savings method. Using data obtained from the existing R.L. Thornton HOV lane and each corridor's projected HOV volume. the travel time savings for HOV users (auto and bus) was calculated in terms of person-hours saved. The travel time savings was multiplied by the value of time and annualized. The total cost of the project was then annualized using the capital recovery factor for an appropriate number of years. The annual benefits were divided by the annual cost to arrive at the benefit/cost ratio for that project. For these projects, the current and future B/C ratios were equal to the calculated ratio.

The air quality benefits were similarly evaluated using the VOC reduction of the vehicles on the HOV lanes due to the increased speed and auto occupancy. The annual cost was divided by the annual VOC reduction to determine the cost-effectiveness of the emission reduction.

Evaluation Process for Intersection Improvements

Intersections were evaluated using a traditional travel time savings method. Using the total traffic volume passing through the intersection, assuming a 0.1 mile intersection approach and an average travel speed through the intersection before the improvement was made, the average person-hours of travel before the improvement was determined. Next, depending on the type of intersection improvement, a new speed was used to determine the average person-hours of travel after the improvement was made. For new grade separations, the same methodology was used with a longer approach length and a higher final speed. The person-hours reduced was then multiplied by the value of time and annualized. The total cost of the project was then annualized using the capital recovery factor for an appropriate number of years. The annual benefits were divided by the annual cost to arrive at the benefit/cost ratio for that project. For these projects, the current and future B/C ratios were calculated individually using current and future traffic volumes.

The air quality benefits were similarly evaluated using the VOC reduction of the vehicles passing through the intersection due to the increased speed. The annual cost was divided by the annual VOC reduction to determine the cost-effectiveness of VOC reduction.

Evaluation Process for Bicycle Mobility Projects and Other Miscellaneous Enhancements

Cost-Effectiveness

Bicycle transportation projects were evaluated for cost-effectiveness by estimating the vehicle hours of travel that would be removed from congested vehicular traffic flow. The projects were located by area type and congestion level. If a project was not in a relatively congested part of the four-county area, it was not scored for present or future year cost benefit because of the lack of mobility benefits. For bicycle projects in congested areas, the number of persons exposed to the bicycle facility was calculated for each project by using the average population density for each area type and the length of the proposed project. To then convert the exposed population to bicycle vehicle hours of travel, an average round trip length of twice the project length or seven miles, whichever was less, was assumed, along with a bicycle mode share of 1 percent. This estimate of bicycle travel was then multiplied by the value of time and annualized and compared with an annualized estimate of the total project cost. A project life of 20 years was assumed for all proposed bicycle projects. The benefit/cost ratio for the present and future years was determined and varied by the change in population density and area type that is anticipated between now and the year 2010. Miscellaneous enhancement projects that provided no mobility benefits to the congested vehicular traffic areas of the region received no points under the cost-effectiveness criteria. Detailed assumptions are provided as Table 11.

Air Quality/Energy Conservation

The estimates of bicycle vehicle miles developed for the cost-effectiveness calculations were used to calculate the air quality benefits for each congested area project. It was assumed that the bicycle trips were replacing a roadway trip that would travel an average of 30 miles per hour, resulting in a certain level of VOC emissions reduced. The annual project cost was then divided by the pounds of VOC reduced to obtain the air quality score for the project. Again, miscellaneous enhancement projects that provided no mobility benefits to congested areas of the region received no points under the air quality criteria.

Local Cost Participation/Project Commitment

Irregardless of the location of a project, if the submittal included any indication that the project was contained in an approved bicycle or city park plan or that any local funds were committed to the project, the appropriate score was given for the level of commitment indicated. Bicycle plans or city park plans were assumed to be equivalent to council-approved transportation plans and given ten points.

Intermodal/Multimodal Projects/Social Mobility

Projects including bicycle or pedestrian improvements, irregardless of their location in the four-county area, or those facilitating intermodal connections were scored accordingly.

COST OVERRUNS AND PROGRAM AMENDMENTS

The 1995 Transportation Improvement Program list of projects is constrained against available resources. In addition, all projects in Year 1 are of equal high priority. Since the Program is balanced to available resources, cost overruns would result in the potential of high priority projects being delayed into Year 2. Several other types of actions result in the need to have a dynamic TIP monitoring program. Such items as cost underruns, local governments unable to meet local match requirements, lawsuits, delays in right-of-way or utility clearances, and local governments not endorsing either federal environmental or State design requirements and wishing to pursue the project with local funds are additional examples of potential changes that could occur during the TIP implementation process.

TABLE 11

DETAILED ASSUMPTIONS FOR EVALUATION OF BICYCLE MOBILITY PROJECTS

Calculation of Bicycle Miles of Travel Based On: -1986 and 2010 population density by area type -round trip length of seven miles or twice the project length, whichever was less -area exposed to bicycle facility equal to a one-mile radius surrounding the project -bicycle mode share of 1 percent
Calculation of Bicycle Vehicle Hours of Travel Based On: -average bicycle speed
Calculation of Bicycle Benefits Based On: -value of time of $8.92 per hour -annualized assuming 260 travel days per year
Calculation of Annual Bicycle Project Cost Based On: -project life of 20 years -capital recovery factor of 0.08718
Calculation of Air Quality Benefits Based On: -average speed of vehicles being removed from roadway traffic assumed at 30 mph -factor of pounds of HC reduced at 30 mph of 0.00402

The current policy of the RTC is higher scored projects will be implemented first only if early construction is feasible and funding caps are not violated. Therefore, changes listed above could lead to projects being expedited or delayed. Diligent monitoring with frequent regular briefings to the Regional Transportation Council is essential. The following RTC policy permits administrative amendments to the TIP by the NCTCOG Director of Transportation between regularly scheduled RTC meetings:

Project included in the first three years of the TIP may be amended by the RTC at any time. Revisions are usually first submitted for review by the Surface Transportation Technical Committee or the Travel Demand Management Committee. The Technical Committees recommend a position on each revision to the RTC. The RTC then acts on the Committees' recommendations.

A revision can be submitted directly to the RTC to preclude the normal review processing sequence if rapid turnaround is important. If the project is approved by the RTC, it is submitted to GARC for TRACS review and then to the Executive Board for final action.

The TIP is intended to be a current and accurate listing of transportation projects proposed for federal funding. This document is using by federal agencies to assure that local governments support projects for which federal funding has been requested. Timely revisions to the TIP are important to avoid funding delays. Therefore, the RTC has endorsed the following administrative amendment policy.

Administrative amendments are permitted:

- For up to 20 percent of any project up to $3,000,000 and
- For up to 15 percent of any project over $3,000,000.

Administrative amendments would <u>not</u> be permitted in the following situations:

- Adding a previously unprogrammed project
- Completely eliminating or deleting a project
- Substantially changing the nature of a project

It may be necessary to change the priority of a project under cost overrun conditions. However, federal law only allows priorities to change during the course of the fiscal year for projects listed in the first three years of the TIP. Furthermore, TxDOT would first permit higher spending for the MPO from TxDOT funding caps. All efforts would be made to fund any cost overruns through existing TIP surplus before delaying other projects. Both STTC and the RTC would be notified of an administrative amendment at their next meeting.

APPENDIX D

CMAQ Projects Included in the Dallas-Fort Worth 1995 TIP

(project scores, funding sources)

Note: projects for Eastern and Western Sub-regions presented separately

Source: Texas No. 4, pages I-5 to I-17, I-20 to I-28.

1.5

1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
EASTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	DATE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	[illegible]	[illegible]
2644	TXDOT/DART	VARIOUS	HOV LANES ON US 75	IH 635	PARK BLVD	REVERSIBLE HOV LN	96	8409	1396	7013						7013	
2644	TXDOT/DART	VARIOUS	HOV LANES ON US 75	IH 635	PARK BLVD	REVERSIBLE HOV LN	96	8409	1396	7013						7013	
2703	TXDOT	DALLAS	IH 35E (N FLT)	S OF US 67	INDUSTRIAL BLVD.	CONTRAFLOW HOV LANE	95	10640	1640	9000				9000			
2703	TXDOT/DART	DALLAS	IH 35E (N FLT)	S OF US 67	INDUSTRIAL BLVD	CONTRAFLOW HOV LANE	95	10640	1640	9000				9000			
2700	TXDOT/DART	DALLAS	IH 635 (LBJ)	US 75	IH 35E	2 WAY HOV LANES (SEE 4270) + DART	94	10000	2000	8000			8000				
2700	TXDOT/DART	DALLAS	IH 635 (LBJ)	US 75	IH 35E	2 WAY HOV LANES (SEE 4270) + DART	70	16700	2700	14000			14000				
2071	TXDOT	DALLAS	SH 48	@ SIMPSON STUART		SIGNAL IMPROVEMENTS	93	88	0	88	88						
2071	TXDOT	DALLAS	SH 48	@ SIMPSON STUART RT.		SIGNAL IMPROVEMENTS	93	88	0	88	88						
2000	TXDOT	VARIOUS	IH 30	TARRANT COUNTY LINE	IH 35E	REVERSIBLE HOV	90	19162	7162	12000						12000	
2005	TXDOT/DART	VARIOUS	IH 30	TARRANT COUNTY LINE	IH 35E	REVERSIBLE HOV	97	19162	19162	0						0	
2612	TXDOT/DART	DALLAS	IH 30 (E FLT)	DOLPHIN RD	JIM MILLER RD.	CONTRAFLOW EXT.	90	5482	1080	4402	4402						
2612	TXDOT/DART	DALLAS	IH 30 (E FLT)	DOLPHIN RD	JIM MILLER RD	CONTRAFLOW EXT.	90	6362	660	4402	2376		2026				
2640	TXDOT/DART	VARIOUS	IH 35E STEMMONS HOV	TRINITY MILLS	IH 635	PERMANENT HOV	90	14300	2300	12000						12000	
2640	TXDOT/DART	VARIOUS	IH 35E STEMMONS HOV	TRINITY MILLS	IH 635	PERMANENT HOV	90	14300	14300	0						0	
2638	TXDOT/DART	VARIOUS	IH 35E STEMMONS HOV	BH 121	IH 635	CONCURRENT FLOW	90	16120	3220	12900			9700	3200			
2638	TXDOT/DART	VARIOUS	IH 35E/STEMMONS HOV	BH 121/TRINITY MILLS	IH 635	CONCURRENT FLOW	90	16120	3220	12900			9700	3200			
2787	TXDOT/DART	DALLAS	IH 30 (E FLT)	IH 45	IH 45	CONTRAFLOW EXT	96	240	40	200	200						
2787	TXDOT/DART	DALLAS	IH 30 (E FLT)	IH 45	IH 45	CONTRAFLOW EXT	95	308	41	267	267						
3132	DALLAS CO.	IRVING	SIGNAL IMPROVEMENTS	ON BELT LINE RD		10 INTERSECTIONS (PASS)	93	21	4	17		17					
3132	DALLAS CO.	IRVING	SIGNAL IMPROVEMENTS	ON BELT LINE RD		10 INTERSECTIONS (PASS)	98	21	4	17			17				
3101	DALLAS CO	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			42 INTERSECTIONS	95	1164	240	924		64		400		460	
3101	DALLAS CO	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			42 INTERSECTIONS	95	1154	240	914			54	400		460	
2478	DART	VARIOUS	VANPOOL SUPPORT			RIDER REBATE	93	94	18	76	76						
2478	DART	VARIOUS	VANPOOL SUPPORT			RIDER REBATE	95	188	38	150	76		76				
3090	DALLAS COUNTY	DE SOTO	SIGNAL IMPROVEMENTS			4 INTERSECTIONS	95	104	21	83		83					
3090	DALLAS COUNTY	DE SOTO	SIGNAL IMPROVEMENTS			4 INTERSECTIONS	96	104	21	83		83					
3044	TXDOT	DALLAS	PLANO RD.	AT @ OF FM	FOREST LANE	SIGNALS	93	300	0	300	300						
3045	TXDOT	DALLAS	SH 341 (PLANO RD)	AT @ OF FM	FOREST LANE	SIGNALS	95	208	0	208	208						
776/3007	DALLAS	DALLAS	FAIR PARK, OAK CLIFF, OAK LAWN SUBAREAS			147 SIGNAL IMP	95/76	3750	750	3000	3000						
776/3007A	DALLAS	DALLAS	FAIR PARK AND OAK CLIFF SUBAREAS			130 SIGNAL IMP	97/76	3159	632	2527	2527						
776/3007	DALLAS	DALLAS	LOVE FIELD, FAR NORTH, N. CENTRAL, PLEASANT GROVE CORRIDOR SUBAREAS			261 SIGNAL IMP.	96/76	2600	600	2000		2000					
776/3007B	DALLAS	DALLAS	CBD, LOVE FIELD, FAR NORTH, NEAR NW, PLEASANT GROVE SUBAREAS			375 SIGNAL IMP.	95/76	4094	818	3276	76		3200				
776/3007	DALLAS	DALLAS	NEAR NW, FAR NE, NEAR SW, FAR SW SUBAREAS			218 SIGNAL IMP.	95/75	2500	500	2000			2000				
776/3007C	DALLAS	DALLAS	FAR NE, NEAR SW, FAR SW N CENTRAL CORRIDOR SUBAREAS			246 SIGNAL IMP	95/76	2531	506	2025				2025			
776/3007	DALLAS	DALLAS	CBD, NEAR NE, STEMMONS/INDUSTRIAL, FAR OAK CLIFF SUBAREAS			236 SIGNAL IMP.	96/75	2600	600	2000				2000			
776/3007D	DALLAS	DALLAS	NEAR NE, STEMMONS/INDUSTRIAL, FAR OAK CLIFF SUBAREAS			99 SIGNAL IMP.	96/76	2070	394	1676					1676		
776/3007	DALLAS	DALLAS	CITYWIDE SIGNAL/INTERSECTION TECHNOLOGY				95/76	9725	1725	8000						3279	3821
776/3007E	DALLAS	DALLAS	CITYWIDE SIGNAL/INTERSECTION TECHNOLOGY/CHANGEABLE MESSAGE SIGNS				96/76	7631	1605	6026			1200			1164	3671
770	DALLAS	DALLAS	US 75 SURVEILLANCE	IH 635	DALLAS CBD	INCIDENT RESPONSE	93	2088	0	2088	1040	208	280	280	280		
770	DALLAS	DALLAS	US 75 SURVEILLANCE	IH 635	DALLAS CBD	INCIDENT RESPONSE (SEE STP-MM)	93	1200	0	1200	994	206					
3082	TXDOT	DALLAS	FOREST LN.	IH 635	AUDELIA	SIGNAL IMPROVEMENTS	90	128	0	128	128						
3082	TXDOT	DALLAS	SH 410 (FOREST LN)	IH 635	AUDELIA	SIGNAL IMPROVEMENTS	90	48	0	48	48						
3100	DALLAS CO.	DALLAS COUNTY	SIGNAL IMPROVEMENTS			4 LOCATIONS	90	114	23	91		91					
3100	DALLAS CO.	DALLAS COUNTY	SIGNAL IMPROVEMENTS			4 LOCATIONS	90	114	23	91			91				

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CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
EASTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 COMMIT	1994 CP	1995	1996	1997	[illegible]	[illegible]
814	DALLAS	DALLAS	INWOOD RD	@ HARVARD BLVD		INTERSECTION IMP.	80	166	36	120			120				
814	DALLAS	DALLAS	INWOOD RD	@ HARVARD BLVD		INTERSECTION IMP.	80	166	36	120						120	
2218	DALLAS CO.	DALLAS	KELLER SPRINGS	@ PRESTON RD		INTERSECTION IMP.	83	296	40	160			160				
2218	DALLAS CO.	DALLAS	KELLER SPRINGS	@ PRESTON RD		INTERSECTION IMP.	83	200	40	160					160		
625	DALLAS	DALLAS	LEMMON AVE	INWOOD RD	OAK LAWN	INTERSECTION IMP. (METRO PASS)	80	1125	626	600		600					
625	TXDOT/DART	DALLAS	LEMMON AVE	INWOOD RD	OAK LAWN	INTERSECTION IMP. (TRANSIT PASS)	83	1125	625	600				605			
3048	TXDOT	GARLAND	PLANO RD.	BUCKINGHAM	FOREST LN.	SIGNAL IMPROVEMENTS (TPASS)	85	776	350	426		426					
3048	TXDOT/DART	GARLAND	PLANO RD.	BUCKINGHAM	FOREST LN.	SIGNAL IMPROVEMENTS (TRANSIT PASS)	85	776	350	426				426			
2292	DALLAS CO.	DALLAS	ROYAL LN	@ DALLAS N TOLLWAY		INTERSECTION IMP.	83	106	22	86		86					
2292	DALLAS CO.	DALLAS	ROYAL LN	@ DALLAS N TOLLWAY		INTERSECTION IMP.	83	106	22	86				86			
2621	TXDOT	GARLAND	SH 78	@ FIRST	& O CREST	SIGNAL IMPROVEMENTS	80	300	0	300	300						
2621	TXDOT	GARLAND	SH 78	@ FIRST, CASTLE, [illegible], & CREST		SIGNAL IMPROVEMENTS	80	146	0	146	146						
3187	DALLAS CO.	SUNNYVALE	BELT LINE	@ TOWN EAST		SIGNAL IMPROVEMENTS	83	23	6	18		18					
3187	DALLAS CO.	SUNNYVALE	BELT LINE	@ TOWN EAST		SIGNAL IMPROVEMENTS	83	23	6	17				17			
3098	DALLAS CO.	DUNCANVILLE	SIGNAL IMPROVEMENTS			7 INTERSECTIONS	80	173	35	135		135					
3098	DALLAS CO.	DUNCANVILLE	SIGNAL IMPROVEMENTS			7 INTERSECTIONS	80	173	35	138				137			
3130	DALLAS CO.	GARLAND	SIGNAL IMPROVEMENTS			30 INTERSECTIONS	83	126	25	101		101					
3130	DALLAS CO.	GARLAND	SIGNAL IMPROVEMENTS			30 INTERSECTIONS	83	126	2	101				101			
3183	DALLAS CO.	LANCASTER	SIGNAL IMPROVEMENTS			8 INTERSECTIONS	80	194	39	155		155					
3183	DALLAS CO.	LANCASTER	SIGNAL IMPROVEMENTS			8 INTERSECTIONS	83	194	39	155				155			
3106	DALLAS CO.	ROWLETT	SIGNAL IMPROVEMENTS			6 INTERSECTIONS	80	104	21	83		83					
3106	DALLAS CO.	ROWLETT	SIGNAL IMPROVEMENTS			6 INTERSECTIONS	80	104	21	83				83			
3046	TXDOT	DALLAS	BULLMAN	MERRIMAN	IH 635	SIGNAL IMPROVEMENTS	85	540	108	432	432						
3046	TXDOT	DALLAS	BULLMAN	MERRIMAN	IH 635	SIGNAL IMPROVEMENTS	85	242	108	134	134						
2227	DALLAS CO.	DALLAS	SPRING VALLEY	@ PRESTON RD		INTERSECTION IMP.	80	270	61	210			210				
2227	DALLAS CO.	DALLAS	SPRING VALLEY	@ PRESTON RD		INTERSECTION IMP.	80	270	64	210			20	80	106		
1800	MESQUITE	MESQUITE	TOWN EAST BLVD.			SIGNAL PROGRESSION	80	310	150	160		160					
1800	MESQUITE	MESQUITE	TOWN EAST BLVD			SIGNAL PROGRESSION	80	310	150	160			160				
2477	DART	VARIOUS	TRANSIT DISCOUNT PROGRAM			REDUCE MONTHLY PASS	80	470	94	376	376						
2477	DART	VARIOUS	TRANSIT DISCOUNT PROGRAM			REDUCE MONTHLY PASS	80	940	188	752	376		376				
832	DALLAS	DALLAS	SH 635	@ MIDWAY		INTERSECTION IMP.	80	500	100	400						400	
832	DALLAS	DALLAS	SH 635	@ MIDWAY		INTERSECTION IMP.	80	500	100	400						400	
646/2218	DALLAS	DALLAS	NORTHWEST HIGHWAY	SH 114	IH 635	IMMEDIATE ACTION PLAN	80	2763	553	2210			724	1486			
2227/2029A	DALLAS	DALLAS	NORTHWEST HIGHWAY/LOOP 12	SH 114	IH 635	IMMEDIATE ACTION PLAN	80	2763	553	2210				724	1486		
646/2218	DALLAS	DALLAS	NORTHWEST HIGHWAY	SH 114	IH 635	SHORT-TERM ACTION PLAN	80	8488	1698	6790					4763		2027
2227/2029B	DALLAS	DALLAS	NORTHWEST HIGHWAY/LOOP 12	SH 114	IH 635	SHORT-TERM ACTION PLAN	80	8488	1698	6790						4763	2027
2488	DART/TXDOT	VARIOUS	MOBILITY ASSIST. PROGRAM	IN DALLAS COUNTY		IH 30-IH 35E-IH 635-US 67-IH 45-WOODALL RODGE	77	2700	0	2700	1600		1100				
2488	DART/TXDOT	VARIOUS	MOBILITY ASSIST. PROGRAM	IN DALLAS COUNTY		IH 30-IH 35E-IH 635-US 67-IH 45-WOODALL RODGE	77	2360	0	2360	1260		1100				
1487	GRAND PRAIRIE	GRAND PRAIRIE	8TH/9TH ST.	HUNTER FERRELL RD	IH 20	SEVERAL INTERSECTIONS	76	667	371	296		296					
1487	GRAND PRAIRIE	GRAND PRAIRIE	8TH/9TH ST.	HUNTER FERRELL RD	IH 20	SEVERAL INTERSECTIONS	76	667	371	296				296			
786	DALLAS	DALLAS	AIRDROME	@ LEMMON AVE		INTERSECTION IMP. (TPASS)	76	2440	2200	240			240				
786	TXDOT/DART	DALLAS	AIRDROME	@ LEMMON AVE		INTERSECTION IMP. (TRANSIT PASS)	76	2440	2200	240				240			
787	DALLAS	DALLAS	ALMAZAN DR.	@ MARSH		INTERSECTION IMP.	76	56	11	46		46					
787	DALLAS	DALLAS	ALMAZAN DR.	@ MARSH		INTERSECTION IMP.	76	56	11	46		46					

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
EASTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CARRYOVER	1995 CAT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
719	DALLAS	DALLAS	ALPHA RD	@ HILLCREST ST		INTERSECTION IMP	75	20	4	16			16				
719	DALLAS	DALLAS	ALPHA RD	@ HILLCREST ST		INTERSECTION IMP	75	20	4	16			16				
792	DALLAS	DALLAS	ARAPAHO RD.	@ MEANDERING WAY		INTERSECTION IMP	76	15	3	12			12				
792	DALLAS	DALLAS	ARAPAHO RD.	@ MEANDERING WAY		INTERSECTION IMP	76	15	3	12			12				
3011	TXDOT	GARLAND	BELT LINE RD	GARLAND CS	[illegible]	SIGNAL IMPROVEMENTS (METRO PASS)	75	454	200	254		154			100		
3071	TXDOT/DART	GARLAND	BELT LINE RD (M H)	GARLAND CS	[illegible]	SIGNAL IMPROVEMENTS (TRANSIT PASS)	7?	454	200	254			254				
3078	TXDOT	ADDISON	BELT LINE RD	@ QUORUM DR. & @ MIDWAY RD		INTERSECTION IMP. (METRO PASS)	76	1123	702	421			421				
3078	TXDOT/DART/ADDI	ADDISON	BELT LINE RD	@ QUORUM DR. & @ MIDWAY RD		INTERSECTION IMP. (TRANSIT PASS)	76	1123	702	421			421				
814	DALLAS	DALLAS	CAMPBELL	@ MEANDERING WAY		INTERSECTION IMP	75	76	15	61		61					
814	DALLAS	DALLAS	CAMPBELL	@ MEANDERING WAY		INTERSECTION IMP	76	75	15	60		60					
1048	DENTON	DENTON	CARROLL	@ US 380		INTERSECTION IMP	76	20	4	16		16					
1048	DENTON	DENTON	CARROLL	@ US 380		INTERSECTION IMP	75	20	4	16		16					
1210	DUNCANVILLE	DUNCANVILLE	CEDAR RIDGE	@ CAMP WISDOM		INTERSECTION IMP	75	16	3	13		13					
1210	DUNCANVILLE	DUNCANVILLE	CEDAR RIDGE	@ CAMP WISDOM		INTERSECTION IMP	75	16	3	13		13					
844	DALLAS	DALLAS	DALLAS NORTH TOLLWAY	@ TRINITY MILLS		INTERSECTION IMP	75	100	20	80			80				
844	DALLAS	DALLAS	DALLAS NORTH TOLLWAY	@ TRINITY MILLS		INTERSECTION IMP	75	100	20	80			80				
848	DALLAS	DALLAS	DENTON DR.	@ [illegible]		INTERSECTION IMP	75	100	20	80						8?	
848	DALLAS	DALLAS	DENTON DR.	@ [illegible]		INTERSECTION IMP	75	100	20	80				80			
3008	TXDOT	VARIOUS	FM 1171	FM 2499	[illegible]	SIGNAL IMPROVEMENTS	75	448	0	448	448						
3008	TXDOT	FLOWER MOUND/L	FM 1171	FM 2499	[illegible]	8 SIGNAL IMPROVEMENTS	76	643	0	643	643						
3006	TXDOT	LEWISVILLE	FM 407	6 INTERSECTIONS		SIGNAL IMPROVEMENTS	76	200	0	200	200						
3006	TXDOT	LEWISVILLE	FM 407	@ 6 INTERSECTIONS		SIGNAL IMPROVEMENTS	75	186	0	186	186						
1889	MESQUITE	MESQUITE	GALLOWAY	@ TOWN EAST BLVD.		SIGNAL IMPROVEMENTS	76	50	25	25		25					
1889	MESQUITE	MESQUITE	GALLOWAY	@ TOWN EAST BLVD		SIGNAL IMPROVEMENTS	75	50	25	25			25				
874	DALLAS	DALLAS	GARLAND	@ IH 635		INTERSECTION IMP	75	50	10	40			40				
874	DALLAS	DALLAS	GARLAND	@ IH 635		INTERSECTION IMP	75	50	10	40					40		
883	DALLAS	DALLAS	GREENVILLE AVE.	@ SOUTHWESTERN		INTERSECTION IMP. (TPASS)	75	100	20	80		80					
883	DALLAS	DALLAS	GREENVILLE AVE.	@ SOUTHWESTERN		INTERSECTION IMP.	76	100	20	80		80					
1884	MESQUITE	MESQUITE	GROSS RD	@ SCYENE		SIGNAL IMPROVEMENTS	75	60	30	30		30					
1884	MESQUITE	MESQUITE	GROSS RD	@ SCYENE		SIGNAL IMPROVEMENTS	75	60	30	30			30				
801	DALLAS	DALLAS	IH 635	@ MARSH LN		INTERSECTION IMP.	76	200	40	160				160			
801	DALLAS	DALLAS	IH 635	@ MARSH LN.		INTERSECTION IMP.	76	200	40	160			20	140			
804	DALLAS	DALLAS	IH 635	@ PRESTON RD		INTERSECTION IMP	75	350	70	280				280			
804	DALLAS	DALLAS	IH 635	@ PRESTON RD		INTERSECTION IMP	75	350	70	280			30	125	125		
3024	TXDOT	BALCH SPRINGS	VARIOUS LOCATIONS			3 SIGNAL IMPROVEMENTS	75	160	0	160						160	
3024	TXDOT	BALCH SPRINGS	VARIOUS LOCATIONS	ON I.H. 635 FRONTAGE RD		3 SIGNAL IMPROVEMENTS	75	160	0	160						160	
2248	DALLAS CO.	CARROLLTON	JOSEY LN	@ WALNUT PLAZA		INTERSECTION IMP.	76	300	60	240		24	216				
2248	DALLAS CO	CARROLLTON	JOSEY LN	@ WALNUT PLAZA		INTERSECTION IMP	76	300	60	240		24	100	116			
828	DALLAS	DALLAS	JOSEY LN.	@ IH 635		INTERSECTION IMP.	76	29	6	23			23				
828	DALLAS	DALLAS	JOSEY LN.	@ IH 635		INTERSECTION IMP.	75	29	6	23				23			
830	DALLAS	DALLAS	LEMMON AVE.	BLUFFVIEW		CORRIDOR IMPROVEMENT (PASS)	76	500	100	400			400				
830	DALLAS	DALLAS	LEMMON AVE.	BLUFFVIEW		CORRIDOR IMPROVEMENT	75	500	100	400				400			
3016	TXDOT	DENTON	LOOP 288	@ COLORADO		SIGNAL IMPROVEMENTS	76	92	0	92		92					
3016	TXDOT	DENTON	LOOP 288	@ COLORADO		SIGNAL IMPROVEMENTS	76	92	0	92		92					

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 [illegible]	1994 C/O	1995	1996	1997	1998	2000 [illegible]
3016	TXDOT	DENTON	LOOP 288	@ US 380		SIGNAL IMPROVEMENTS	76	105	5	100			100				
3016	TXDOT	DENTON	LOOP 288	@ US 380		SIGNAL IMPROVEMENTS (CANCELLED)	77	0	0	0							
2706	TXDOT	DALLAS	MOCKINGBIRD LN	@ HARRY HINES BLVD		INTERSECTION IMP. (METRO PASS)	75	1126	626	500			140				
2706	TXDOT/DART	DALLAS	MOCKINGBIRD LN	@ HARRY HINES BLVD		INTERSECTION IMP. (TRANSIT PASS) [illegible]	76	1126	626	500				500			
[illegible]	TXDOT	PLANO	[illegible]	[illegible]	[illegible]	SIGNAL IMPROVEMENTS	75	[illegible]	0	[illegible]		100					
2941	TXDOT	PLANO	[illegible]	@ SH 289	@ LEGACY D	SIGNAL IMPROVEMENTS	76	100	0	[illegible]			100				
2036	TXDOT	THE COLONY	SH 121	@ BLAIR OAKS		SIGNAL IMPROVEMENTS	76	64	0	64	64						
2036	TXDOT	THE COLONY	SH 121	@ BLAIR OAKS		SIGNAL IMPROVEMENTS	77	64	0	64	64						
2037	TXDOT	LEWISVILLE	SH 121	@ BELLAIRE, [illegible] & CORPORATE D		SIGNAL IMPROVEMENTS	77	240	0	240	240						
2037	TXDOT	LEWISVILLE	SH 121	@ BENNETT, BELLAIRE, [illegible] & CORPORATE DR		SIGNAL IMPROVEMENTS	77	183	0	183	183						
2227	DALLAS CO.	DALLAS	SH 289 (PRESTON)	@ BELT LINE RD		INTERSECTION IMP	76	1550	300	1250				1250			
2227	DALLAS CO	DALLAS	SH 289 (PRESTON)	@ BELT LINE RD		INTERSECTION IMP	77	1550	300	1250					1250		
2012	TXDOT	GARLAND	[illegible]	[illegible]	FOREST LN	CORRIDOR IMPROVEMENTS [illegible]	77	3132	1190	1942				1942			
2012	TXDOT/DART	GARLAND	SH 78 (GARLAND [illegible])	[illegible]	FOREST LN	CORRIDOR IMPROVEMENTS (TRANSIT PASS)	76	3132	1190	1942				1942			
3006	DALLAS CO.	COPPELL	SANDY LAKE RD	@ MOORE		INTERSECTION IMPROVEMENTS	76	554	111	443		443					
3006	DALLAS CO./COPP	COPPELL	SANDY LAKE RD	@ MOORE		INTERSECTION IMPROVEMENTS	75	554	111	443			224	216			
1842	GRAND PRAIRIE	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			8 SIGNAL IMP.	77	560	140	420						420	
1842	GRAND PRAIRIE	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			8 SIGNAL IMP.	78	560	140	420						420	
1846	GRAND PRAIRIE	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			4 SIGNAL IMP.	76	586	240	346		100	246				
1846	GRAND PRAIRIE	GRAND PRAIRIE	SIGNAL IMPROVEMENTS			4 SIGNAL IMP.	77	586	240	346			346				
3104	DALLAS CO	MESQUITE	SIGNAL IMPROVEMENTS			11 SIGNAL IMPROVEMENTS	76	320	64	256		100	156				
3104	DALLAS CO	MESQUITE	SIGNAL IMPROVEMENTS			11 SIGNAL IMPROVEMENTS	76	320	64	256				256			
1294	FARMERS BRANCH	FARMERS BRANCH	SIGNAL INTERCONNECT			13 INTERSECTIONS	76	150	50	100	100						
1294	FARMERS BRANCH	FARMERS BRANCH	SIGNAL INTERCONNECT			13 SIGNAL IMPROVEMENTS	77	150	50	100	100						
1620	GRAND PRAIRIE	GRAND PRAIRIE	BELT LINE	SH 183	HUNTER-FERRELL	SIGNAL IMPROVEMENTS	75	236	116	116		116					
1620	GRAND PRAIRIE	GRAND PRAIRIE	BELT LINE	SH 183	HUNTER-FERRELL	SIGNAL IMPROVEMENTS	75	236	118	116			116				
2223	DALLAS CO.	CARROLLTON	TRINITY MILLS	@ IH 35E		INTERSECTION IMP	76	200	40	160			160				
2223	DALLAS CO.	CARROLLTON	TRINITY MILLS	@ IH 35E		INTERSECTION IMP.	76	200	40	160				160			
1804	MESQUITE	MESQUITE	TRIPP RD	@ FRANKLIN DR.		SIGNAL IMPROVEMENTS	76	56	30	26		26					
1804	MESQUITE	MESQUITE	TRIPP RD	@ FRANKLIN DR.		SIGNAL IMPROVEMENTS	78	56	30	26			26				
1048	DENTON	DENTON	US 380	IH 35E	LOOP 288	SIGNAL IMPROVEMENTS (TXDOT SPLIT)	76	60	0	60		60					
1048	DENTON	DENTON	US 380	IH 35E	LOOP 288	SIGNAL IMPROVEMENTS (TXDOT SPLIT)	76	60	0	60			60				
2006	TXDOT	DENTON	US 77	RIO GRANDE	TEASLEY	INTERSECTION IMP	76	30	6	26	26						
2006	TXDOT	DENTON	US 77	RIO GRANDE	TEASLEY	INTERSECTION IMP	76	30	6	26	26						
1807	MESQUITE	MESQUITE	US 80	@ BELT LINE RD		SIGNAL IMPROVEMENTS	76	76	40	36			36				
1807	MESQUITE	MESQUITE	US 80	@ BELT LINE RD		SIGNAL IMPROVEMENTS	76	76	40	36					36		
1216	DUNCANVILLE	DUNCANVILLE	WEST RIDGE	@ CEDAR RIDGE		INTERSECTION IMP	75	11	2	9		9					
1216	DUNCANVILLE	DUNCANVILLE	WEST RIDGE	@ CEDAR RIDGE		INTERSECTION IMP	75	11	11	0		0					
1061	DENTON	DENTON	WILLOW SPRINGS	@ US 77		INTERSECTION IMP.	75	15	3	12		12					
1061	DENTON	DENTON	WILLOW SPRINGS	@ US 77		INTERSECTION IMP.	75	15	3	12		12					
2229	DALLAS CO	VARIOUS	INTERSECTION IMPROVEMENTS			PREVIOUS 100% FUNDED	75	20876	4176	16700		4350	6176	6176			
2229	DALLAS CO	VARIOUS	INTERSECTION IMPROVEMENTS			PREVIOUS 100% FUNDED	75	20876	4176	16700		3600		3600		9100	
2704	TXDOT	DALLAS	IH 30 (E FLT)	@ FERGUSON		HOV RAMP	74	3600	600	3000			3000				
2704	TXDOT/DART	DALLAS	IH 30 (E FLT)	@ FERGUSON		HOV RAMP	74	3600	600	3000				3000			

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CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 CAQ	1995	1996	1997	Later year A ([illegible])	Later year B ([illegible])
777	DALLAS	DALLAS	IH 635	IH 35E	US 75	INCID. MANAG.	73	3200	0	3200	640		320	320	320	640	640
777	DALLAS	DALLAS	IH 635	IH 35E	US 75	INCID. MANAG. (FREEWAY [illegible])	73	648	0	648	648						
2461	DART	VARIOUS	INSPECTION SITE			RIDESHARE EDUCATION	73	50	10	40	40						
2461	DART	VARIOUS	INSPECTION SITE			RIDESHARE EDUCATION	73	50	10	40	40						
2478	DART	VARIOUS	VANPOOL PROGRAM			QUICK START PROGRAM	72	63	13	50	50						
2478	DART	VARIOUS	VANPOOL PROGRAM			QUICK START PROGRAM	72	125	25	100	50		50				
1890	MESQUITE	MESQUITE	BELT LINE RD	@ [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30		30					
1890	MESQUITE	MESQUITE	BELT LINE RD.	@ [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30			30				
1886	MESQUITE	MESQUITE	GUS THOMASSON	@ MOON		SIGNAL IMPROVEMENTS	71	55	25	30		30					
1886	MESQUITE	MESQUITE	GUS THOMASSON	@ MOON		SIGNAL IMPROVEMENTS	71	55	25	30			30				
1899	MESQUITE	MESQUITE	GUS THOMASSON	@ LIVE OAK [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30		30					
1899	MESQUITE	MESQUITE	GUS THOMASSON	@ LIVE OAK [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30			30				
1888	MESQUITE	MESQUITE	GATES	@ SARAZEN		SIGNAL IMPROVEMENTS	71	55	25	30		30					
1888	MESQUITE	MESQUITE	GATES	@ SARAZEN		SIGNAL IMPROVEMENTS	71	55	25	30			30				
1890	MESQUITE	MESQUITE	GATES	@ [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30		30					
1890	MESQUITE	MESQUITE	GATES	@ [illegible]		SIGNAL IMPROVEMENTS	71	55	25	30			30				
704	DALLAS	DALLAS	ABRAMS RD	@ SKILLMAN ST		INTERSECTION IMP.	70	75	15	60			60				
704	DALLAS	DALLAS	ABRAMS RD	@ SKILLMAN ST		INTERSECTION IMP.	70	75	15	60			60				
704	DALLAS	DALLAS	ARAPAHO RD.	@ PRESTON RD.		INTERSECTION IMP.	70	146	29	116			116				
704	DALLAS	DALLAS	ARAPAHO RD.	@ PRESTON RD		INTERSECTION IMP.	70	146	29	116			116				
1204	DENTON	DENTON	BELL	@ MCKINNEY		INTERSECTION IMP.	70	15	3	12		12					
1204	DENTON	DENTON	BELL	@ MCKINNEY		INTERSECTION IMP.	70	15	3	12		12					
608	DALLAS	DALLAS	BELT LINE RD	@ HILLCREST RD		INTERSECTION IMP.	70	100	20	80			80				
608	DALLAS	DALLAS	BELT LINE RD.	@ HILLCREST RD		INTERSECTION IMP.	70	100	20	80			80				
700	DALLAS	DALLAS	BELT LINE RD	@ DALLAS N. TOLLWAY		INTERSECTION IMP.	70	50	10	40		40					
700	DALLAS	DALLAS	BELT LINE RD	@ DALLAS N. TOLLWAY		INTERSECTION IMP.	70	50	10	40		40					
808	DALLAS	DALLAS	BRUTON RD.	@ BUCKNER BLVD.		INTERSECTION IMP.	70	120	24	96		96					
808	DALLAS	DALLAS	BRUTON RD.	@ BUCKNER BLVD.		INTERSECTION IMP.	70	120	24	96				96			
813	DALLAS	DALLAS	CAMPBELL RD	@ HILLCREST RD		INTERSECTION IMP.	70	50	10	40			40				
813	DALLAS	DALLAS	CAMPBELL RD.	@ HILLCREST RD		INTERSECTION IMP.	70	50	10	40			40				
1818	GRAND PRAIRIE	GRAND PRAIRIE	CARRIER PKWY.			SIGNAL IMPROVEMENTS	70	1100	570	530		200		330			
1818	GRAND PRAIRIE	GRAND PRAIRIE	CARRIER PKWY.			SIGNAL IMPROVEMENTS	70	1100	570	530			200	330			
818	DALLAS	DALLAS	CEDAR SPRINGS RD	@ DOUGLAS AVE. &	@ WYCLIFF AVE	2 INTERSECTIONS IMP.	70	150	30	120			120				
818	DALLAS	DALLAS	CEDAR SPRINGS RD	@ DOUGLAS AVE. &	@ WYCLIFF AVE.	2 INTERSECTIONS IMP.	70	150	30	120			20	100			
810	DALLAS	DALLAS	CEDAR SPRINGS RD	@ INWOOD RD.		INTERSECTION IMP.	70	100	20	80		80					
810	DALLAS	DALLAS	CEDAR SPRINGS RD.	@ INWOOD RD.		INTERSECTION IMP.	70	100	20	80		80					
1222	DUNCANVILLE	DUNCANVILLE	COCKRELL HILL RD	@ CAMP WISDOM		INTERSECTION IMP.	70	100	20	80		80					
1222	DUNCANVILLE	DUNCANVILLE	COCKRELL HILL RD	@ CAMP WISDOM		INTERSECTION IMP.	70	100	20	80		80					
832	DALLAS	DALLAS	COIT RD.	@ SPRING VALLEY		INTERSECTION IMP.	70	50	10	40			40				
832	DALLAS	DALLAS	COIT RD.	@ SPRING VALLEY		INTERSECTION IMP.	70	50	10	40			40				
830	DALLAS	DALLAS	COIT RD	@ FRANKFORD RD		INTERSECTION IMP.	70	100	20	80			80				
830	DALLAS	DALLAS	COIT RD	@ FRANKFORD RD		INTERSECTION IMP.	70	100	20	80			80				
831	DALLAS	DALLAS	COIT RD.	@ IH 635		INTERSECTION IMP.	70	100	20	80					80		
831	DALLAS	DALLAS	COIT RD.	@ IH 635		INTERSECTION IMP.	70	100	20	80						80	

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 COUNTER	1994 C/O	1995	1996	1997	[illegible]	[illegible]
630	DALLAS	DALLAS	COMPORITE DR.	@ WALNUT HILL		INTERSECTION IMP.	70	100	20	80			80				
630	DALLAS	DALLAS	COMPORITE DR.	@ WALNUT HILL		INTERSECTION IMP.	70	100	20	80			80				
648	DALLAS	DALLAS	DENTON DR.	@ WALNUT HILL		INTERSECTION IMP.	75	100	20	80			80				
648	DALLAS	DALLAS	DENTON DR.	@ WALNUT HILL		INTERSECTION IMP.	75	100	20	80			80				
[illegible]	DALLAS	DALLAS	[illegible]	@ [illegible]		INTERSECTION IMP.	70	100	20	80		80					
[illegible]	DALLAS	DALLAS	[illegible]	@ [illegible]		INTERSECTION IMP.	70	100	20	80				80			
1010	LEWISVILLE	LEWISVILLE	FM 1171	@ VALLEY PKWY		INTERSECTION IMP.	70	110	22	88		88					
1010	LEWISVILLE	LEWISVILLE	FM 1171	@ VALLEY PKWY		INTERSECTION IMP.	70	110	22	88		88					
640	DALLAS	DALLAS	FOREST LN	@ [illegible]		INTERSECTION IMP.	70	100	20	80		80					
640	DALLAS	DALLAS	FOREST LN	@ [illegible]		INTERSECTION IMP.	70	100	20	80		80					
600	DALLAS	DALLAS	FRANKFORD RD.	@ PRESTON RD		INTERSECTION IMP.	70	800	160	640			640				
600	DALLAS	DALLAS	FRANKFORD RD	@ PRESTON RD		INTERSECTION IMP.	70	800	160	640					640		
[illegible]	DALLAS	DALLAS	GREENVILLE AVE.	@ ROYAL LN		INTERSECTION IMP.	70	100	20	80			80				
[illegible]	DALLAS	DALLAS	GREENVILLE AVE.	@ ROYAL LN		INTERSECTION IMP.	70	100	20	80			80				
[illegible]	DALLAS	DALLAS	GREENVILLE AVE.	@ WALNUT HILL		INTERSECTION IMP.	75	150	30	120			120				
[illegible]	DALLAS	DALLAS	GREENVILLE AVE.	@ WALNUT HILL		INTERSECTION IMP.	70	150	30	120			120				
681	DALLAS	DALLAS	GREENVILLE AVE.	@ PARK LN		INTERSECTION IMP.	75	80	16	64		64					
681	DALLAS	DALLAS	GREENVILLE AVE.	@ PARK LN		INTERSECTION IMP.	70	80	16	64		64					
684	DALLAS	DALLAS	GREENVILLE AVE.	@ UNIVERSITY BLVD		INTERSECTION IMP.	70	150	30	120		120					
684	DALLAS	DALLAS	GREENVILLE AVE.	@ UNIVERSITY BLVD		INTERSECTION IMP.	75	150	30	120		120					
[illegible]	DALLAS	DALLAS	HARRY HINES BLVD	@ [illegible]		INTERSECTION IMP. (TPA)	70	80	16	64	64						
[illegible]	DALLAS	DALLAS	HARRY HINES BLVD	@ [illegible]		INTERSECTION IMP. - LOCAL FUND	70	80	80	0	0						
[illegible]	DALLAS	DALLAS	HARVEST HILL RD	@ PRESTON RD		INTERSECTION IMP.	70	50	10	40			40				
[illegible]	DALLAS	DALLAS	HARVEST HILL RD	@ PRESTON RD		INTERSECTION IMP.	70	50	10	40			40				
2018	TXDOT	DALLAS	IH 30 FRTG RD	@ LOOP 12		SIGNAL IMPROVEMENTS	70	170	0	170				170			
2018	TXDOT	DALLAS	IH 30 FRTG RD	@ LOOP 12		SIGNAL IMPROVEMENTS (CANCELLED)	70	0	0	0							
[illegible]	DALLAS	DALLAS	INWOOD RD.	@ MAPLE AVE.		INTERSECTION IMP.	70	130	26	104		104					
[illegible]	DALLAS	DALLAS	INWOOD RD.	@ MAPLE AVE.		INTERSECTION IMP.	70	130	26	104		104					
961	DALLAS	DALLAS	LIVE OAK ST.	@ ROSS AVE.		INTERSECTION IMP.	70	108	22	86			86				
961	DALLAS	DALLAS	LIVE OAK ST.	@ ROSS AVE.		INTERSECTION IMP.	70	108	22	86			86				
[illegible]	DALLAS	DALLAS	MAPLE AVE.	@ WYCLIFF AVE.		INTERSECTION IMP.	70	100	20	80			80				
[illegible]	DALLAS	DALLAS	MAPLE AVE.	@ WYCLIFF AVE.		INTERSECTION IMP.	70	100	20	80			80				
[illegible]	DALLAS	DALLAS	MCCREE RD	@ NORTHWEST HWY.		INTERSECTION IMP.	70	150	30	120				120			
[illegible]	DALLAS	DALLAS	MCCREE RD	@ NORTHWEST HWY.		INTERSECTION IMP.	70	150	30	120				120			
[illegible]	DALLAS	DALLAS	MOCKINGBIRD LN.	@ N. ROCKAWAY		INTERSECTION IMP.	70	30	6	24			24				
[illegible]	DALLAS	DALLAS	MOCKINGBIRD LN.	@ N. ROCKAWAY		INTERSECTION IMP.	70	30	6	24			24				
970	DALLAS	DALLAS	MOCKINGBIRD LN	@ YOSEMITE LN		INTERSECTION IMP.	70	30	6	24			24				
970	DALLAS	DALLAS	MOCKINGBIRD LN	@ YOSEMITE LN		INTERSECTION IMP.	70	30	6	24			24				
973	DALLAS	DALLAS	MOTOR ST.	@ HARRY HINES BLVD		INTERSECTION IMP.	70	50	10	40				40			
973	DALLAS	DALLAS	MOTOR ST.	@ HARRY HINES BLVD		INTERSECTION IMP.	70	50	10	40				40			
978	DALLAS	DALLAS	NOEL RD	@ SPRING VALLEY		INTERSECTION IMP.	70	150	30	120				120			
978	DALLAS	DALLAS	NOEL RD	@ SPRING VALLEY		INTERSECTION IMP.	70	150	30	120				120			
979	DALLAS	DALLAS	NORTHWEST HWY.	@ EXECUTIVE DR.		INTERSECTION IMP.	70	100	20	80				80			
979	DALLAS	DALLAS	NORTHWEST HWY.	@ EXECUTIVE DR.		INTERSECTION IMP.	70	100	20	80				80			

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCORE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/01
1223	DUNCANVILLE	DUNCANVILLE	SANTA FE TR.	@ WHEATLAND		INTERSECTION IMP	70	20	4	16		16					
1223	DUNCANVILLE	DUNCANVILLE	SANTA FE TR.	@ WHEATLAND		INTERSECTION IMP	70	20	4	16		16					
2017	TXDOT	THE COLONY	SH 121	@ 6 INTERSECTIONS		SIGNAL IMPROVEMENTS	70	400	0	400	400						
2017	TXDOT	THE COLONY	SH 121	@ 6 INTERSECTIONS		SIGNAL IMPROVEMENTS	70	400	0	400	400						
1211	TXDOT	DALLAS	US 67 HOV LNS	IH 35E	IH 20	HOV LANES	70	6672	1112	5560				5560			
1211	TXDOT/DART	DALLAS	US 67 HOV LNS	IH 35E	IH 20	HOV LANES (W/WIDENING)	73	6672	1112	5560				5560			
1961	DENTON	DENTON	VARIOUS LOCATIONS			SIGNAL IMPROVEMENTS	70	76	16	60		60					
1961	DENTON	DENTON	VARIOUS LOCATIONS			SIGNAL IMPROVEMENTS	70	76	16	60			60				
1217	DUNCANVILLE	DUNCANVILLE	WHEATLAND	@ MAIN ST		INTERSECTION IMP	70	26	6	21		21					
1217	DUNCANVILLE	DUNCANVILLE	WHEATLAND	@ MAIN ST		INTERSECTION IMP (LOCAL FUND)	70	26	26	0		0					
1881	MESQUITE	MESQUITE	BRUTON RD.	@ PIONEER RD		SIGNAL IMPROVEMENTS	69	60	30	30			30				
1881	MESQUITE	MESQUITE	BRUTON RD.	@ PIONEER RD		SIGNAL IMPROVEMENTS	66	60	30	30			30				
2048	RICHARDSON	RICHARDSON	CUSTER RD	@ ARAPAHO RD		INTERSECTION IMP	64	450	225	225		60	165				
2048	RICHARDSON	RICHARDSON	CUSTER RD	@ ARAPAHO RD		INTERSECTION IMP (LOCAL FUND)	65	450	450	0		0		0			
1814	LEWISVILLE	LEWISVILLE	FM 1171	@ OLD ORCHARD		INTERSECTION IMP	66	550	450	100		100					
1814	LEWISVILLE	LEWISVILLE	FM 1171	@ OLD ORCHARD		INTERSECTION IMP	66	550	450	100		100					
302	CEDAR HILL	CEDAR HILL	FM 1382	@ CANNADY		SIGNAL IMPROVEMENTS	60	80	16	64	64						
302	CEDAR HILL	CEDAR HILL	FM 1382	@ CANNADY		SIGNAL IMPROVEMENTS	63	78	16	62	62						
301	CEDAR HILL	CEDAR HILL	FM 1382	@ OLD CLARK RD		SIGNAL IMPROVEMENTS	60	80	16	64			64				
301	CEDAR HILL	CEDAR HILL	FM 1382	@ OLD CLARK RD		SIGNAL IMPROVEMENTS	66	80	16	64			64				
2068	TXDOT	DESOTO	FM 1382	@ WESTMORELAND RD		SIGNAL IMPROVEMENTS	62	64	0	64						64	
2068	TXDOT	DESOTO	FM 1382	@ WESTMORELAND RD		SIGNAL IMPROVEMENTS (CANCELLED)	63	0	0	0							
2014	TXDOT	LEWISVILLE	FM 3040	@ MEADOWGLEN		SIGNAL IMPROVEMENTS	63	63	0	63	63						
2014	TXDOT	LEWISVILLE	FM 3040	@ MEADOWGLEN		SIGNAL IMPROVEMENTS	66	73	0	73	73						
3063	TXDOT	GARLAND	FOREST LN	PLANO RD	GARLAND RD	CORRIDOR IMP (METRO PASS)	68	700	350	350		350					
3063	TXDOT/DART	GARLAND	FOREST LN (M H)	PLANO RD	GARLAND RD	CORRIDOR IMP (TRANSIT PASS)	69	700	350	350				350			
625	DALLAS	DALLAS	HAMPTON RD.	FORT WORTH AVE.	US 67	INTER. IMP. (METRO PASS)	68	1200	600	600			600				
625	TXDOT/DART	DALLAS	HAMPTON RD.	FORT WORTH AVE.	US 67	INTER. IMP. (TRANSIT PASS)	69	1200	600	600				600			
626	DALLAS	DALLAS	MOCKINGBIRD LN	@ INWOOD RD		INTERSECTION IMP (METRO PASS)	63	1125	625	500			500				
626	TXDOT/DART	DALLAS	MOCKINGBIRD LN	@ INWOOD RD		INTERSECTION IMP (TRANSIT PASS)	63	1125	625	500				500			
637	DALLAS	DALLAS	PLANO RD.	@ NORTHWEST HWY.		INTER. IMP. (METRO PASS)	68	1250	625	625			625				
637	TXDOT/DART	DALLAS	PLANO RD.	@ NORTHWEST HWY.		INTER. IMP. (TRANSIT PASS)	66	1250	625	625				625			
10	ALLEN	ALLEN	SH 5	@ MCDERMOTT/FM 2170		INTERSECTION IMP	69	200	0	200		100	100				
10	ALLEN	ALLEN	SH 5	@ MCDERMOTT/FM 2170		INTERSECTION IMP (SEE 29)	63	200	0	200			200				
2031	TXDOT	IRVING	SH 114 FRTG RDS.	@ WHITTEN, ROCHELLE	& HIDDEN RIDGE	SIGNAL IMPROVEMENTS	63	164	0	164	164						
2031	TXDOT	IRVING	SH 114 FRTG RDS	@ WHITTEN, ROCHELLE	& HIDDEN RIDGE	SIGNAL IMPROVEMENTS (CONSTRUCTED)	60	0	0	0	x						
1002	MESQUITE	MESQUITE	TOWN EAST BLVD	@ SKYLINE DR		SIGNAL IMPROVEMENTS	60	56	30	26		26					
1002	MESQUITE	MESQUITE	TOWN EAST BLVD	@ SKYLINE DR		SIGNAL IMPROVEMENTS	60	56	30	26			26				
1001	MESQUITE	MESQUITE	TOWN EAST BLVD.	@ FORNEY RD		SIGNAL IMPROVEMENTS	60	57	30	27		27					
1001	MESQUITE	MESQUITE	TOWN EAST BLVD	@ FORNEY RD.		SIGNAL IMPROVEMENTS	60	57	30	27			27				
1030	LEWISVILLE	LEWISVILLE	SH 121	@ VALLEY VIEW DRIVE		SIGNAL IMPROVEMENTS	60	100	20	80		50	30				
1030	LEWISVILLE	LEWISVILLE	SH 121	@ VALLEY VIEW DRIVE		SIGNAL IMPROVEMENTS	60	100	20	80			80				
3066	DALLAS CO.	BALCH SPRINGS	VARIOUS LOCATIONS			4 SIGNAL IMPROVEMENTS	60	93	19	74		74					
3066	DALLAS CO.	BALCH SPRINGS	VARIOUS LOCATIONS			4 SIGNAL IMPROVEMENTS	60	93	19	74		20		54			

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2470	DART	DALLAS	REUNION AREA			PARK AND RIDE [illegible]	6?	7?	16	??	60						
2470	DART	DALLAS	REUNION AREA			PARK AND RIDE [illegible]	65	148	30	112	60		80				
305	CEDAR HILL	CEDAR HILL	CLARK RD.	CLARK RD	BELT LINE RD	SIGNAL IMPROVEMENTS	6?	25	?	20		20					
305	CEDAR HILL	CEDAR HILL	CLARK RD	CLARK RD	BELT LINE RD	SIGNAL IMPROVEMENTS	65	25	?	20			20				
1944	DENTON	DENTON	CORRIDOR IMPROVEMENT	CITYWIDE		CORRIDOR [illegible]	?	4??	??	3??		17?	8?			1??	
1944	DENTON	DENTON	CORRIDOR IMPROVEMENT	CITYWIDE		CORRIDOR [illegible]	6?	4??	87	34?		170		8?		1??	
1815	LEWISVILLE	LEWISVILLE	EDMONDS LN	@ FOX AVE		INTERSECTION IMP.	65	70	14	56		56					
1815	LEWISVILLE	LEWISVILLE	EDMONDS LN	@ FOX AVE		INTERSECTION IMP.	65	7?	14	56		56					
1526A	GRAND PRAIRIE	GRAND PRAIRIE	INTERSECTION CAPACITY IMP	VARIOUS LOCATIONS		INTERSECTION [illegible]	6?	???	270	6??		4??	2??				
1526?	GRAND PRAIRIE	GRAND PRAIRIE	INTERSECTION CAPACITY IMP	VARIOUS LOCATIONS		INTERSECTION [illegible]	6?	???	272	???		400		2??			
5332	DALLAS CO	VARIOUS	INTERSECTION IMP.	VARIOUS LOCATIONS		6 INTERSECTION IMP.	6?	2???	610	2040			10??	10??			
2298	DALLAS CO	VARIOUS	INTERSECTION IMP	VARIOUS LOCATIONS		6 INTERSECTION IMP.	6?	2???	610	2044			???	10??	4??		
2441	DENTON CO	DALLAS	MARSH LN	@ [illegible]		INTERSECTION IMP	66	300	6?	240					24?		
2441	DENTON CO	DALLAS	MARSH LN	@ [illegible]		INTERSECTION IMP	65	80	80	6						6	
1660	IRVING	IRVING	SH 161	VARIOUS LOCATIONS		ART./INTG. SIGNALS	65	39?	80	316	316						
1660	IRVING	IRVING	SH 161	VARIOUS LOCATIONS		ART./INTG. SIGNALS	65	450	90	360	340						
1564	GRAND PRAIRIE	GRAND PRAIRIE	SPUR 303	?? ??	FUTURE [illegible]	SIGNAL IMPROVEMENT	6?	363	200	163			163				
1564	GRAND PRAIRIE	GRAND PRAIRIE	SPUR 303	?? ??	FUTURE [illegible]	SIGNAL IMPROVEMENT	6?	363	200	163			163				
2154	RICHARDSON	RICHARDSON	SIGNALIZATION	CITYWIDE		SIGNAL IMPROVEMENTS	65	1000	200	800		400	400				
2154	RICHARDSON	RICHARDSON	SIGNALIZATION	CITYWIDE		SIGNAL IMPROVEMENTS	65	1000	200	800		400		400			
15??	GRAND PRAIRIE	GRAND PRAIRIE	TRAFFIC SIGNALS	CITYWIDE		SIGNAL IMPROVEMENT	6?	74?	???	61?	100	100	100	210			
15??	GRAND PRAIRIE	GRAND PRAIRIE	TRAFFIC SIGNALS	CITYWIDE		SIGNAL IMPROVEMENT	6?	74?	???	61?	100	100		310			
1215	DUNCANVILLE	DUNCANVILLE	VARIOUS LOCATIONS			5 INTERSECTION IMP.	65	3??	8?	315		110	6?	114			
1215	DUNCANVILLE	DUNCANVILLE	VARIOUS LOCATIONS			5 INTERSECTION IMP.	6?	3??	8?	318		110		208			
344	CARROLLTON	CARROLLTON	CENTRAL COMPUTER SYST.			SIGNAL IMPROVEMENT	6?	1602	3??	12??		6??	6??				
344	CARROLLTON	CARROLLTON	CENTRAL COMPUTER SYST.			7? SIGNAL IMPROVEMENTS	6?	1?02	320	12??			1202				
715	DALLAS	DALLAS	VARIOUS LOCATIONS	CITYWIDE		135 INTERSECTION IMP.	6?	16353	3271	13082		4400	????	2???	4???		
715	DALLAS	DALLAS	VARIOUS LOCATIONS	CITYWIDE		135 INTERSECTION IMP.	6?	16353	3271	13?42		3000		3000	14??	6491	
1242	FARMERS BRANCH	FARMERS BRANCH	VARIOUS LOCATIONS			2 INTERSECTION IMP.	6?	500	100	400		200	200				
1242	FARMERS BRANCH	FARMERS BRANCH	VARIOUS LOCATIONS			2 INTERSECTION IMP.	6?	500	100	400		200		200			
2218	DALLAS CO.	DALLAS	IRVING BLVD	@ MOCKINGBIRD LN		INTERSECTION IMP.	64	800	160	640				640			
2218	DALLAS CO	DALLAS	IRVING BLVD.	@ MOCKINGBIRD LN		INTERSECTION IMP.	64	800	160	640				640			
636	DALLAS	DALLAS	JUPITER RD	@ NORTHWEST HWY		INTER. IMP. (METRO PASS)	64	1250	626	626			626				
636	TXDOT/DART	DALLAS	JUPITER RD	@ NORTHWEST HWY		INTER. IMP. (TRANSIT PASS)	64	1250	625	625				626			
1887	MESQUITE	MESQUITE	MOTLEY DR.	@ EASTFIELD COLLEGE		SIGNAL IMPROVEMENTS	64	60	30	30		30					
1887	MESQUITE	MESQUITE	MOTLEY DR.	@ EASTFIELD COLLEGE		SIGNAL IMPROVEMENTS	64	60	30	30			30				
2447	TXDOT	DALLAS	SH 2??	@ CAMPBELL RD		GRADE SEPARATION	64	3100	0	3100				3100			
2447	TXDOT	DALLAS	SH 2??	@ CAMPBELL RD		INTERSECTION IMPROVEMENTS	64	2000	0	2000						2000	
2179	COLLIN CO.	MURPHY	FM 2551	@ FM 544		INTERSECTION IMP	63	1800	360	1440	1440						
2179	COLLIN CO.	MURPHY	FM 2551	@ FM 544		INTERSECTION IMP	63	1800	360	1440	1440						
842	DALLAS	DALLAS	FIVE-MILE CREEK BIKEWAY	IH 35E	COOMBS CR.	BIKEWAY	62	285	57	228		228					
842	DALLAS	DALLAS	FIVE-MILE CREEK BIKEWAY	IH 35E	COOMBS CR.	BIKEWAY	62	285	57	228				228			
2208	DALLAS CO.	CARROLLTON	BELT LINE RD	@ IH 35E		INTERSECTION IMP. (PASS)	58	600	120	480			480				
2208	DALLAS CO./DART	CARROLLTON	BELT LINE RD.	@ IH 35E		INTERSECTION IMP. (TRANSIT PASS)	56	600	120	480				480			

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CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
EASTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 CA	1995	1996	1997	[illegible]	[illegible]
1312	DUNCANVILLE	DUNCANVILLE	INTERSECTION IMP.	VARIOUS LOCATIONS		2 INTERSECTION IMP.	66	136	27	109		11	97				
1312	DUNCANVILLE	DUNCANVILLE	INTERSECTION IMP.	VARIOUS LOCATIONS		2 INTERSECTION IMP.	56	135	27	108		11	97				
2446	DENTON CO.	DALLAS	INTERSECTION IMP.	VARIOUS LOCATIONS		3 INTERSECTION IMP.	56	900	180	720			300	300			
2446	DENTON CO.	DALLAS	INTERSECTION IMP.	VARIOUS LOCATIONS		3 INTERSECTION IMP.	56	900	180	720						120	
780	DALLAS	DALLAS	INTERSECTION IMP.	VARIOUS LOCATIONS		16 INTERSECTION IMP.	58	6416	1083	4332		60	964	1044		2220	
780	DALLAS	DALLAS	INTERSECTION IMP.	VARIOUS LOCATIONS		15 INTERSECTION IMP.	58	6416	1083	4332		60	694	646	620	2500	
1010	LEWISVILLE	LEWISVILLE	INTERSECTION IMP.	VARIOUS LOCATIONS		2 INTERSECTION IMP./SIGNALS	68	160	32	128		128					
1010	LEWISVILLE	LEWISVILLE	INTERSECTION IMP.	VARIOUS LOCATIONS		2 INTERSECTION IMP./SIGNALS	56	160	32	128		128					
11	ALLEN	ALLEN	INTERSECTION IMP.	SH 5	SH 121	INTERSECTION IMP.	58	250	0	250				250			
11	ALLEN	ALLEN	INTERSECTION IMP.	SH 5	SH 121	INTERSECTION IMP. (SH 5)	68	250	0	250					250		
1052	DENTON	DENTON	INTERSECTION IMP.	VARIOUS LOCATIONS		2 INTERSECTION IMP.	76	316	64	252		127	125				
1052	DENTON	DENTON	INTERSECTION IMP.	VARIOUS LOCATIONS		INTERSECTION IMP.	74	125	25	100		100			6		
2087	RICHARDSON	RICHARDSON	JUPITER RD	@ BUCKINGHAM		INTERSECTION IMP.	68	740	148	592			20	100	472		
2087	RICHARDSON	RICHARDSON	JUPITER RD	@ BUCKINGHAM		INTERSECTION IMP.	88	740	148	592			20	150		422	
426	THE COLONY	THE COLONY	N. COLONY	@ FM 423		INTERSECTION IMP.	66	76	16	60		60					
426	THE COLONY	THE COLONY	N. COLONY	@ FM 423		INTERSECTION IMP.	66	126	66	60		60					
2903A	DART	VARIOUS	ALTERNATIVE FUEL VEHICLES			TRANSIT VEHICLES (DTA)	52	31780	6356	25424	6900		346	240	17006		644
2903A	DART	VARIOUS	ALTERNATIVE FUEL VEHICLES			TRANSIT VEHICLES (DTA)	82	31780	6356	25424	6900		2460	240		14917	644
2903B	VARIOUS	VARIOUS	ALTERNATIVE FUEL VEHICLES			PUBLIC FLEET	52	7811	1562	6248	2083		2083	2083			
2903B	VARIOUS	VARIOUS	ALTERNATIVE FUEL VEHICLES			PUBLIC FLEET	62	7831	1562	6200	1606		1360	636		2377	
4100	DALLAS	VARIOUS	RAILTRAN			COMMUTER RAIL PHASE		30466	20466	10000	10000						
4100	DALLAS	VARIOUS	RAILTRAN			COMMUTER RAIL PHASE		30466	20466	10000	10000						
4000	DART	VARIOUS	OZONE ALERT PROGRAM					1968	1328	640	640						
4000	DART	VARIOUS	OZONE ALERT PROGRAM					1968	1328	640	640						
4087	DENTON	DENTON	SPAN OZONE ALERT PROGRAM					10	5	5	5						
4087	DENTON	DENTON	SPAN OZONE ALERT PROGRAM					10	5	5	5						
4671	DALLAS	DALLAS	CBD BIKE PARKING			BIKEWAY		0		0							
4671	DALLAS	DALLAS	CBD BIKE PARKING			BIKEWAY	87	18	7	11			11				
4283	TEXAS INSTRUME	VARIOUS	BIKE STORAGE			BIKEWAY		0		0							
4283	TEXAS INSTRUME	VARIOUS	BIKE STORAGE			BIKEWAY	85	40	20	20			20				
4000	DENTON COUNTY	VARIOUS	IH 35E	PROP SH 121 BYPASS	FM 3040	HOV		0		0							
4000	DENTON COUNTY	VARIOUS	IH 35E	PROP SH 121 BYPASS	FM 3040	HOV	83	800	168	632						632	
4100	PLANO	PLANO	COLLIN CREEK MALL			INTERSECTION IMPROVEMENT		0		0							
4100	PLANO	PLANO	COLLIN CREEK MALL			INTERSECTION IMPROVEMENT	83	150	54	96					96		
4068	DENTON	DENTON	US 377 @ IH 35E			INTERSECTION IMPROVEMENT		0		0							
4068	DENTON	DENTON	US 377 @ IH 35E			INTERSECTION IMPROVEMENT	80	56	26	30				30			
4103	DE SOTO	DE SOTO	BELT LINE RD @ POLK ST			INTERSECTION IMPROVEMENT		0		0							
4103	DE SOTO	DE SOTO	BELT LINE RD @ POLK ST			INTERSECTION IMPROVEMENT	80	140	57	83				83			
4297	DART	VARIOUS	TRANSIT FARE PROGRAM - 1996			OZONE ALERT		0		0							
4297	DART	VARIOUS	TRANSIT FARE PROGRAM - 1996			OZONE ALERT	80	1968	1328	640			640				
4113	FARMERS BRANCH	FARMERS BRANCH	WEBB CHAPEL RD @ IH 635/MEDICAL CTR DR			INTERSECTION IMPROVEMENT		0		0							
4113	FARMERS BRANCH	FARMERS BRANCH	WEBB CHAPEL RD @ IH 635/MEDICAL CTR DR			INTERSECTION IMPROVEMENT	88	250	84	166				166			
4090	TRANSP STRATEGI	VARIOUS	TRAVEL REDUCTION IMPLEMENTATION PLAN			TDM		0		0							
4090	TRANSP STRATEGI	VARIOUS	TRAVEL REDUCTION IMPLEMENTATION PLAN			TDM	80	300	0	0			0	0			

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	CODE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	[illegible]	[illegible]
4186	RICHARDSON	RICHARDSON	BELTLINE @ PLANO			INTERSECTION IMPROVEMENT		0		0							
4186	RICHARDSON	RICHARDSON	BELTLINE @ PLANO			INTERSECTION IMPROVEMENT	45	410	189	221				71	[illegible]		
4151	GARLAND	GARLAND	IH 635 SB ENTRANCE RAMP @ CENTERVILLE			INTERSECTION IMPROVEMENT		0		0							
4151	GARLAND	GARLAND	IH 635 SB ENTRANCE RAMP @ CENTERVILLE			INTERSECTION IMPROVEMENT	7?	160	42	118				118			
4152	DESOTO	DESOTO	WINTERGREEN RD @ POLK			INTERSECTION IMPROVEMENT		0		0							
4152	DESOTO	DESOTO	WINTERGREEN RD @ POLK			INTERSECTION IMPROVEMENT	7?	115	47	[illegible]				[illegible]			
4378	DENTON	DENTON	US 380—MALONE-2/BONNIE BRAE-2/CARROLL			INTERSECTION IMPROVEMENT		0		0							
4348	DENTON	DENTON	US 380—MALONE-2/BONNIE BRAE-2/CARROLL			INTERSECTION IMPROVEMENT	72	170	44	126				126			
4150	GARLAND	GARLAND	FIRST ST @ LAVON DR			INTERSECTION IMPROVEMENT		0		0							
4150	GARLAND	GARLAND	FIRST ST @ LAVON DR			INTERSECTION IMPROVEMENT	7?	55	14	41				41			
4181	DESOTO	DESOTO	PLEASANT RUN RD @ CHATTEY RD			INTERSECTION IMPROVEMENT		0		0							
4181	DESOTO	DESOTO	PLEASANT RUN RD @ CHATTEY RD			INTERSECTION IMPROVEMENT	77	120	46	71					71		
4164	PLANO	PLANO	US 75 @ PLANO PKWY—TEXAS U-TURN			INTERSECTION IMPROVEMENT		0		0							
4164	PLANO	PLANO	US 75 @ PLANO PKWY—TEXAS U-TURN			INTERSECTION IMPROVEMENT	76	500	250	250			250				
4030	BAXTER HEALTHC	VARIOUS	CARPOOL INCENTIVE PROGRAM			TDM		0		0							
4030	BAXTER HEALTHC	VARIOUS	CARPOOL INCENTIVE PROGRAM			TDM	76	2	0	2				2			
4187	RICHARDSON	RICHARDSON	ARAPAHO @ PLANO			INTERSECTION IMPROVEMENT		0		0							
4187	RICHARDSON	RICHARDSON	ARAPAHO @ PLANO			INTERSECTION IMPROVEMENT	76	610	[illegible]	351					351		
4077	DALLAS	DALLAS	PRESTON @ LBJ FRWY			INTERSECTION IMPROVEMENT		0		0							
4077	DALLAS	DALLAS	PRESTON @ LBJ FRWY			INTERSECTION IMPROVEMENT	73	250	50	200					200		
4105	CARROLLTON	CARROLLTON	CROSBY RD @ IH 35E			INTERSECTION IMPROVEMENT		0		[illegible]							
4105	CARROLLTON	CARROLLTON	CROSBY RD @ IH 35E			INTERSECTION IMPROVEMENT	73	84	12	72					72		
4156	IRVING	IRVING	BELT LINE RD	SH 183	STRAIGHT ST	SIGNAL IMPROVEMENTS		0		0							
4156	IRVING	IRVING	BELT LINE RD	SH 183	STRAIGHT ST	SIGNAL IMPROVEMENTS	7?	140	30	110					110		
4296	TXDOT - DALLAS	VARIOUS	MULTIJURISDICTIONAL [illegible] NETWORK			[illegible]		0		0							
4296	TXDOT - DALLAS	VARIOUS	MULTIJURISDICTIONAL [illegible] NETWORK			[illegible]	73	400	84	316					316		
4307	CARROLLTON	CARROLLTON	BELT LINE RD @ IH 35E			INTERSECTION IMPROVEMENT		0		0							
4307	CARROLLTON	CARROLLTON	BELT LINE RD @ IH 35E			INTERSECTION IMPROVEMENT	73	60	12	48					48		
4194	DESOTO	DESOTO	HAMPTON RD @ CENTRE PARK BLVD			SIGNAL IMPROVEMENTS		0		0							
4194	DESOTO	DESOTO	HAMPTON RD @ CENTRE PARK BLVD			SIGNAL IMPROVEMENTS	72	80	33	47						47	
4388	DENTON	DENTON	3 @ OAK; 3 @ HICKORY; 1 @ FM2164			SIGNAL IMPROVEMENTS		0		0							
4388	DENTON	DENTON	3 @ OAK; 3 @ HICKORY; 1 @ FM2164			SIGNAL IMPROVEMENTS	72	126	33	93							93
4200	DART	VARIOUS	TDM (3 PROJECTS)			TDM		0		0							
4200	DART	VARIOUS	TDM (3 PROJECTS)			TDM	71	0		0							
4188	RICHARDSON	RICHARDSON	ARAPAHO @ GREENVILLE			INTERSECTION IMPROVEMENT		0		0							
4188	RICHARDSON	RICHARDSON	ARAPAHO @ GREENVILLE			INTERSECTION IMPROVEMENT	76	[illegible]	451	629					629		
4114	FARMERS BRANCH	FARMERS BRANCH	INCIDENT DETECTION AND RESPONSE			IDRS		0		0							
4114	FARMERS BRANCH	FARMERS BRANCH	INCIDENT DETECTION AND RESPONSE			IDRS	70	320	100	220				220			
4097	DENTON	DENTON	TRANSIT FARE PROGRAM			OZONE ALERT		0		0							
4097	DENTON	DENTON	TRANSIT FARE PROGRAM			OZONE ALERT	70	10	4	6			6				
4194	RICHARDSON	RICHARDSON	BELTLINE @ JUPITER			INTERSECTION IMPROVEMENT		0		0							
4194	RICHARDSON	RICHARDSON	BELTLINE @ JUPITER			INTERSECTION IMPROVEMENT	70	1300	598	702						702	
4191	RICHARDSON	RICHARDSON	CENTENNIAL @ GREENVILLE & ABRAMS (SEE 3041)			INTERSECTION IMPROVEMENT		0		0							
4191	RICHARDSON/DART	RICHARDSON	CENTENNIAL @ GREENVILLE & ABRAMS (SEE 3041) (TRANSIT PASS)			INTERSECTION IMPROVEMENT	70	1875	1031	844				844			

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	RANK	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CURRENT	1994 CAO	1995	1996	1997	98/99	2000/03
4188	RICHARDSON	RICHARDSON	ARAPAHO @ JUPITER			INTERSECTION IMPROVEMENT		0		0							
4188	RICHARDSON	RICHARDSON	ARAPAHO @ JUPITER			INTERSECTION IMPROVEMENT	70	870	446	624						624	
4189	RICHARDSON	RICHARDSON	SIGNAL SYSTEM ENHANCEMENTS			SIGNAL IMPROVEMENTS		0		0							
4189	RICHARDSON	RICHARDSON	SIGNAL SYSTEM ENHANCEMENTS			SIGNAL IMPROVEMENTS	68	275	58	217				217			
4070	DALLAS	DALLAS	MOCKINGBIRD LN	SH 183	STEMMONS	INTERSECTION IMPROVEMENT		0		0							
4070	DALLAS	DALLAS	MOCKINGBIRD LN	SH 183	STEMMONS	INTERSECTION IMPROVEMENT	64	605	121	484					484		
4300	CARROLLTON	CARROLLTON	TRINITY MILLS RD @ SH 35E			INTERSECTION IMPROVEMENT		0		0							
4300	CARROLLTON	CARROLLTON	TRINITY MILLS RD @ SH 35E			INTERSECTION IMPROVEMENT	66	248	60	160					160		
4304	CARROLLTON	CARROLLTON	HEBRON PKWY SIGNAL PROGRESSION			SIGNAL IMPROVEMENTS		0		0							
4304	CARROLLTON	CARROLLTON	HEBRON PKWY SIGNAL PROGRESSION			SIGNAL IMPROVEMENTS	65	30	6	24					24		
4181	GRAND PRAIRIE	GRAND PRAIRIE	LONE STAR PARK TRAFFIC MANAGEMENT PROGRAM			TRAFFIC MANAGEMENT		0		0							
4181	GRAND PRAIRIE	GRAND PRAIRIE	LONE STAR PARK TRAFFIC MANAGEMENT PROGRAM			TRAFFIC MANAGEMENT	75	1600	300	1200				600	600		
4182	GARLAND	GARLAND	PLANO RD @ BUCKINGHAM RD WESTBOUND			INTERSECTION IMPROVEMENT		0		0							
4182	GARLAND	GARLAND	PLANO RD @ BUCKINGHAM RD WESTBOUND			INTERSECTION IMPROVEMENT	67	147	36	106					106		
4186	DE SOTO	DE SOTO	PLEASANT RUN RD @ COCKRELL HILL RD			SIGNAL IMPROVEMENTS		0		0							
4186	DE SOTO	DE SOTO	PLEASANT RUN RD @ COCKRELL HILL RD			SIGNAL IMPROVEMENTS	67	80	33	47						47	
4036	CEDAR HILL	CEDAR HILL	JOE WILSON RD @ FM 1382			INTERSECTION IMPROVEMENT		0		0							
4036	CEDAR HILL	CEDAR HILL	JOE WILSON RD @ FM 1382			INTERSECTION IMPROVEMENT	67	46	5	41					41		
4037	CEDAR HILL	CEDAR HILL	FM 1382 @ DUNCANVILLE RD			INTERSECTION IMPROVEMENT		0		0							
4037	CEDAR HILL	CEDAR HILL	FM 1382 @ DUNCANVILLE RD			INTERSECTION IMPROVEMENT	67	46	5	41					41		
4180	GRAND PRAIRIE	GRAND PRAIRIE	CITYWIDE INCIDENT DETECTION PROGRAM			IDRS		0		0							
4180	GRAND PRAIRIE	GRAND PRAIRIE	CITYWIDE INCIDENT DETECTION PROGRAM			IDRS	65	300	75	225				225			
4026	BOWMAN-MELTO	VARIOUS	REGIONAL ETR COORDINATION			TDM		0		0							
4026	BOWMAN-MELTO	VARIOUS	REGIONAL ETR COORDINATION			TDM	66	946		0			0	0			
4330	DART/CDA	VARIOUS	TRANSPORTATION MANAGEMENT ASSOC			TDM		0		0							
4330	DART/CDA	VARIOUS	TRANSPORTATION MANAGEMENT ASSOC			TDM	64	448	45	406			202	202			
4066	DENTON	DENTON	FM 428 @ MAYHILL			SIGNAL IMPROVEMENTS		0		0							
4066	DENTON	DENTON	FM 428 @ MAYHILL			SIGNAL IMPROVEMENTS	66	75	34	41			41				
4067	DENTON	DENTON	SH 35E @ MCCORMICK			SIGNAL IMPROVEMENTS		0		0							
4067	DENTON	DENTON	SH 35E @ MCCORMICK			SIGNAL IMPROVEMENTS	65	120	54	66				66			
4074	DALLAS	DALLAS	REGAL ROW @ STEMMONS FRWY (SEE 998)			INTERSECTION IMPROVEMENT		0		0							
4074	DALLAS	DALLAS	REGAL ROW @ STEMMONS FRWY (SEE 998)			INTERSECTION IMPROVEMENT	63	500	100	400			400				
4075	DALLAS	DALLAS	REGAL ROW @ SH 183 (SEE 998)			INTERSECTION IMPROVEMENT		0		0							
4075	DALLAS	DALLAS	REGAL ROW @ SH 183 (SEE 998)			INTERSECTION IMPROVEMENT	63	507	101	406			406				
4080	DENTON	DENTON	LOOP 288 @ KINGS ROW			INTERSECTION IMPROVEMENT		0		0							
4080	DENTON	DENTON	LOOP 288 @ KINGS ROW			INTERSECTION IMPROVEMENT	63	210	42	168					168		
4185	PLANO	PLANO	COMPUTERIZED TRAFFIC SIGNAL SYSTEM			SURVEILLANCE		0		0							
4185	PLANO	PLANO	COMPUTERIZED TRAFFIC SIGNAL SYSTEM			SURVEILLANCE	63	453	163	290			290				
4084	THE COLONY	THE COLONY	FM423 @ COUGAR ALLEY			SIGNAL IMPROVEMENTS		0		0							
4084	THE COLONY	THE COLONY	FM423 @ COUGAR ALLEY			SIGNAL IMPROVEMENTS	63	80	16	64					64		
4286	TXDOT - DALLAS	VARIOUS	SH 5 @ BETHANY			SIGNAL IMPROVEMENTS		0		0							
4286	TXDOT - DALLAS	VARIOUS	SH 5 @ BETHANY			SIGNAL IMPROVEMENTS	60	12		12					12		
4089	COPPELL	COPPELL	SANDY LAKE RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT		0		0							
4089	COPPELL	COPPELL	SANDY LAKE RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT	60	65	13	52					52		

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PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCORE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 COMMITTED	1994 [illegible]	1995	1996	1997	[illegible]	[illegible]
4044	COPPELL	COPPELL	BELT LINE RD @ MOCKINGBIRD LN			INTERSECTION IMPROVEMENT		0		0							
4364	COPPELL	COPPELL	BELT LINE RD @ MOCKINGBIRD LN			INTERSECTION IMPROVEMENT	60	50	10	40					40		
4300	CARROLLTON	CARROLLTON	MARSH LN SIGNAL PROGRESSION			SIGNAL IMPROVEMENTS		0		0							
4370	CARROLLTON	CARROLLTON	MARSH LN SIGNAL PROGRESSION			SIGNAL IMPROVEMENTS	60	30	6	24					24		
4186	IRVING	IRVING	SH 183	DALLAS COUNTY LINE	[illegible]	MOBILITY ASSISTANCE		0		0							
4186	IRVING	IRVING	SH 183	DALLAS COUNTY LINE	[illegible]	MOBILITY ASSISTANCE	60	400	80	320				320			
4264	TXDOT - DALLAS	VARIOUS	US 67 @ COCKRELL HILL & DANIELDALE			SIGNAL IMPROVEMENTS		0		0							
4264	TXDOT - DALLAS	VARIOUS	US 67 @ COCKRELL HILL & DANIELDALE			SIGNAL IMPROVEMENTS	60	24		24					24		
4048	COPPELL	COPPELL	DENTON TAP RD @ WRANGLER			INTERSECTION IMPROVEMENT		0		0							
4348	COPPELL	COPPELL	DENTON TAP RD @ WRANGLER			INTERSECTION IMPROVEMENT	60	36	7	29						28	
4092	DENTON	DENTON	LOOP 288 @ US 380			SIGNAL IMPROVEMENTS		0		0							
4092	DENTON	DENTON	LOOP 288 @ US 380			SIGNAL IMPROVEMENTS	60	55	11	44						44	
4282	TXDOT - DALLAS	VARIOUS	IH 35E @ PLEASANT RUN			SIGNAL IMPROVEMENTS		0		0							
4282	TXDOT - DALLAS	VARIOUS	IH 35E @ PLEASANT RUN			SIGNAL IMPROVEMENTS	60	12		12					12		
4372	DALLAS	DALLAS	ROUTE SIGNS			BIKEWAY		0		0							
4372	DALLAS	DALLAS	ROUTE SIGNS			BIKEWAY	60	26	12	14					14		
4046	COPPELL	COPPELL	BELT LINE RD @ MACARTHUR			INTERSECTION IMPROVEMENT		0		0							
4046	COPPELL	COPPELL	BELT LINE RD @ MACARTHUR			INTERSECTION IMPROVEMENT	60	90	18	72					72		
4294	TXDOT - DALLAS	VARIOUS	INCIDENT MGMT ON US 75 & IH635			IMS		0		0							
4294	TXDOT - DALLAS	VARIOUS	INCIDENT MGMT ON US 75 & IH635			IMS	60	1200		1200				1200			
4091	DENTON	DENTON	IH 35 @ US 380			INTERSECTION IMPROVEMENT		0		0							
4091	DENTON	DENTON	IH 35 @ US 380			INTERSECTION IMPROVEMENT	60	100	20	80						80	
4283	TXDOT - DALLAS	VARIOUS	IH 20 @ CEDAR RIDGE RD			SIGNAL IMPROVEMENTS		0		0							
4283	TXDOT - DALLAS	VARIOUS	IH 20 @ CEDAR RIDGE RD			SIGNAL IMPROVEMENTS	60	12		12					12		
4180	RICHARDSON	RICHARDSON	CAMPBELL	E OF GREENVILLE	W OF US 75	GRADE SEPARATION		0		0							
4180	RICHARDSON	RICHARDSON	CAMPBELL	E OF GREENVILLE	W OF US 75	GRADE SEPARATION	60	15000	6900	8100							8100
4081	COPPELL	COPPELL	BETHEL RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT		0		0							
4081	COPPELL	COPPELL	BETHEL RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT	60	30	6	24					24		
4082	COPPELL	COPPELL	BETHEL SCHOOL RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT		0		0							
4082	COPPELL	COPPELL	BETHEL SCHOOL RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT	60	80	16	64						64	
4038	CEDAR HILL	CEDAR HILL	BELT LINE RD @ MAIN ST			INTERSECTION IMPROVEMENT		0		0							
4038	CEDAR HILL	CEDAR HILL	BELT LINE RD @ MAIN ST			INTERSECTION IMPROVEMENT	60	45	9	36					36		
4087	COPPELL	COPPELL	DENTON TAP RD @ PARKWAY			INTERSECTION IMPROVEMENT		0		0							
4087	COPPELL	COPPELL	DENTON TAP RD @ PARKWAY			INTERSECTION IMPROVEMENT	60	30	6	24					24		
4036	CEDAR HILL	CEDAR HILL	BELT LINE TRAIL	ANDERSON RD	MAIN	BIKEWAY		0		0							
4036	CEDAR HILL	CEDAR HILL	BELT LINE TRAIL	ANDERSON RD	MAIN	BIKEWAY	60	65	13	52					52		
4383	COPPELL	COPPELL	BELT LINE RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT		0		0							
4383	COPPELL	COPPELL	BELT LINE RD @ DENTON TAP RD			INTERSECTION IMPROVEMENT	60	60	12	48						48	
4278	TXDOT - DALLAS	VARIOUS	HARRY HINES	LOOP 12	WALNUT HILL	SIGNAL IMPROVEMENTS		0		0							
4278	TXDOT - DALLAS	VARIOUS	HARRY HINES	LOOP 12	WALNUT HILL	SIGNAL IMPROVEMENTS	60	440		440					440		
4188	JOANNE H PRATT	VARIOUS	IMPLEMENTATION OF TELECOMMUTING			TDM		0		0							
4188	JOANNE H PRATT	VARIOUS	IMPLEMENTATION OF TELECOMMUTING			TDM	44	133		0			0	0			
4334	NCTCOG	VARIOUS	REGIONAL CORRIDOR MANAGEMENT PROGRAM			CMS		0		0							
4334	NCTCOG	VARIOUS	REGIONAL CORRIDOR MANAGEMENT PROGRAM			CMS		2000		2000			1000	1000			

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
EASTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCOPE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/03
4336	DART	VARIOUS	REGIONAL TDM PROGRAM/TECHNICAL RESPONSE TO MOBILITY INITIATIVES			TDM		0		0							
4336	DART	VARIOUS	REGIONAL TDM PROGRAM/TECHNICAL RESPONSE TO MOBILITY INITIATIVES			TDM		1018		1018			609	609			
	N TX CLEAN AIR C	VARIOUS	REGIONAL TDM PROGRAM/MARKETING PROGRAM			TDM		0		0							
	N TX CLEAN AIR C	VARIOUS	REGIONAL TDM PROGRAM/MARKETING PROGRAM			TDM		678		678			339	339			

SUBTOTALS		TOTAL	LOCAL	FEDERAL AND STATE	1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/03
	1994 TIP	305306	82544	222747	36606	19667	44281	44260	27464	30243	7486
	1995 TIP	346462	121164	223067	32147	18100	44718	62236	12300	64721	14749

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 COMMIT	1994 C/O	1995	1996	1997	98/99	2000/03
2074A	FWTA	VARIOUS	ALTERNATIVE FUEL VEHICLES			TRANSIT FLEET (FTA)	90	22363	4473	17890	3180				8000		6710
2074A	FWTA	VARIOUS	ALTERNATIVE FUEL VEHICLES			TRANSIT FLEET (FTA)	90	22363	4473	17890	3180				8000		6710
2074B	VARIOUS	VARIOUS	ALTERNATIVE FUEL VEHICLES			PUBLIC FLEET	90	2541	428	2113		365	[illegible]	734			
2074B	VARIOUS	VARIOUS	ALTERNATIVE FUEL VEHICLES			PUBLIC FLEET	90	2756	456	2200		371	1033	796			
1854	HURST	HURST	BEDFORD-EULESS RD	@ 5 LOCATIONS (TxDOT COMBINED 1853)		5 SIGNAL IMP.	85	56	16	40		40					
1854	HURST	HURST	BEDFORD-EULESS RD	@ 5 LOCATIONS (TxDOT COMBINED 1853)		5 SIGNAL IMP.	85	55	15	40		5	35				
1853	HURST	HURST	HARWOOD DR.	@ 4 LOCATIONS (TxDOT COMBINED 1854)		4 SIGNAL IMP.	85	44	10	34		34					
1853	HURST	HURST	HARWOOD DR.	@ 4 LOCATIONS (TxDOT COMBINED 1854)		4 SIGNAL IMP.	85	44	10	34		4	30				
2774	TXDOT	FORT WORTH	IH 35W	HATTIE ST	FELIX ST	SURVEILLANCE	83	297	0	297		247					
2774	TXDOT	FORT WORTH	IH 35W	HATTIE ST	FELIX ST	SURVEILLANCE	83	297	0	297		297					
2658	FWTA	VARIOUS	EXPAND BUSES			15 CNG BUSES (FTA)	72	1000	[illegible]	1000	1000						
2658	FWTA	VARIOUS	EXPAND BUSES			15 CNG BUSES (FTA)	70	1000	[illegible]	1000	1000						
184	ARLINGTON	ARLINGTON	COOPER ST/FM 157	@ SPUR 303	@ ARKANSAS	INTERSECT. IMP. (INTERCHANGE)	76	146	72	73	73						
184	TXDOT/ARLINGTON	ARLINGTON	COOPER ST/FM 157	@ SPUR 303	@ ARKANSAS	INTERSECT. IMP. (INTERCHANGE)	71	[illegible]	186	213	113			100			
1862	HURST	HURST	MELBOURNE	@ PIPELINE RD.		INTERSECT. IMP.	75	28	6	22		6	16				
1862	HURST	HURST	MELBOURNE	@ PIPELINE RD		INTERSECT. IMP.	75	28	6	22		6	16				
1864	HURST	HURST	PRECINCT LINE RD (FM 3029)	@ CANNON		SIGNAL IMP.	74	40	10	30	30						
1864	TXDOT/HURST	HURST	PRECINCT LINE RD (FM 3029)	@ CANNON		SIGNAL IMP.	71	51	13	38	38						
1866	HURST	HURST	PRECINCT LINE RD	@ REDBUD		SIGNAL IMP.	76	44	10	34		34					
1866	HURST	HURST	PRECINCT LINE RD.	@ REDBUD		SIGNAL IMP.	76	46	10	36		6		30			
1865	HURST	HURST	AIRPORT FRWY	@ PRECINCT LINE RD (TxDOT COMBINED 1864)		SURVEILLANCE	83	16	4	12		12					
1865	HURST	HURST	AIRPORT FRWY	@ PRECINCT LINE RD (TxDOT COMBINED 1864)		SURVEILLANCE	69	16	4	12		12					
1864	HURST	HURST	AIRPORT FRWY	@ BEDFORD-EULESS RD (TxDOT COMBINED 1865)		SURVEILLANCE	68	16	4	12		12					
1864	HURST	HURST	AIRPORT FRWY	@ BEDFORD-EULESS RD (TxDOT COMBINED 1865)		SURVEILLANCE	69	15	4	12		12					
2772	TXDOT	VARIOUS	3 SIGNAL IMPROVEMENTS			3 SIGNAL IMP.	65	317	0	317		317					
2772	TXDOT	VARIOUS	3 SIGNAL IMPROVEMENTS			3 SIGNAL IMP.	65	248	0	248	74		60		86		
122	ARLINGTON	ARLINGTON	BOWEN RD	@ PLEASANT RIDGE RD.		SIGNAL IMP.	68	53	11	42		42					
122	ARLINGTON	ARLINGTON	BOWEN RD	@ PLEASANT RIDGE RD		SIGNAL IMP. (LOCAL FUNDS)	68	53	53	0			0				
149	ARLINGTON	ARLINGTON	COLLINS (FM 157)	@ US 180		INTERSECTION IMP.	66	1870	394	1676		1676					
149	TXDOT/ARLINGTON	ARLINGTON	COLLINS (FM 157)	@ US 180		INTERSECTION IMP.	65	1870	394	1676		876		800			
1806	GRAPEVINE	GRAPEVINE	MAIN ST	@ WALL, WORTH, & COLLEGE		SIGNAL IMP.	65	274	56	219		219					
1806	GRAPEVINE	GRAPEVINE	MAIN ST	@ WALL, WORTH, & COLLEGE		SIGNAL IMP.	66	274	56	219		15	204				
1860	HURST	HURST	PRECINCT LINE RD	@ PIPELINE RD (TxDOT COMBINED 1860)		INTERSECTION IMP.	64	66	13	53		53					
1860	HURST	HURST	PRECINCT LINE RD	@ PIPELINE RD (TxDOT COMBINED 1860)		INTERSECTION IMP.	64	60	12	48		5	43				
1860	HURST	HURST	PRECINCT LINE RD.	@ BEDFORD RD. (TxDOT COMBINED 1858)		INTERSECTION IMP.	66	66	13	52		52					
1860	HURST	HURST	PRECINCT LINE RD.	@ BEDFORD RD. (TxDOT COMBINED 1858)		INTERSECTION IMP.	66	60	12	48		4	44				
278	ARLINGTON	ARLINGTON	SPUR 303	BUSAN DR.	FIELDER RD	SIGNAL IMP.	66	23	5	18		18					
278	TXDOT/ARLINGTON	ARLINGTON	SPUR 303	BUSAN DR.	FIELDER RD	SIGNAL IMP.	65	23	5	18			18				
286	ARLINGTON	ARLINGTON	TRAFFIC SIGNAL UPGRADE	CITYWIDE		SIGNAL IMP.	64	844	169	676		36	640				
286	ARLINGTON	ARLINGTON	TRAFFIC SIGNAL UPGRADE	CITYWIDE		SIGNAL IMP.	66	844	169	676		36	640				
287	ARLINGTON	ARLINGTON	VARIOUS LOCATIONS	GREEN OAKS/DIVISION		SIGNAL IMP.	65	229	46	183		183					
287	ARLINGTON	ARLINGTON	VARIOUS LOCATIONS	GREEN OAKS/DIVISION		SIGNAL IMP.	65	229	46	183		16	166				
1377	FORT WORTH	FORT WORTH	VARIOUS LOCATIONS			SIGNAL IMP.	65	2160	432	1728		1728					
1377	FORT WORTH	FORT WORTH	VARIOUS LOCATIONS			SIGNAL IMP.	64	2160	432	1728			1728				

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCORE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 COMMIT	1994 CO	1995	1996	1997	98/99	2000+
1627	GRAND PRAIRIE	GRAND PRAIRIE	IH 30 FRONTAGE	[illegible]	[illegible]	INTERCHANGE SIGNALS	55	120	36	84			84				
1627	TXDOT/GRAND PR	GRAND PRAIRIE	IH 30 FRONTAGE	FOUNTAIN [illegible]	EAST & PADDOCK	INTERCHANGE SIGNALS	65	120	36	84		44	40				
1629	GRAND PRAIRIE	GRAND PRAIRIE	SH 360	@ GREAT SOUTHWEST		INTERSECTION IMP	65	354	76	277			277				
1629	TXDOT/GRAND PR	GRAND PRAIRIE	SH 360	@ GREAT SOUTHWEST		INTERSECTION IMP	66	354	76	277			277				
1641	GRAND PRAIRIE	GRAND PRAIRIE	TRAFFIC SIGNALS	CITYWIDE		SIGNAL IMP	44	850	426	426			200	226			
1641	GRAND PRAIRIE	GRAND PRAIRIE	TRAFFIC SIGNALS	CITYWIDE		SIGNAL IMP	65	850	426	425			200	226			
2116	RICHLAND HILLS	RICHLAND HILLS	GLENVIEW DR	@ BOOTH-CALLOWAY		INTERSECTION IMP	56	276	63	213		213					
2116	RICHLAND HILLS	RICHLAND HILLS	GLENVIEW DR	@ BOOTH-CALLOWAY		INTERSECTION IMP	54	276	63	213		13	200				
1667	HURST	HURST	HURST BLVD (SH 10)	@ PRECINCT LINE RD		INTERSECTION IMP	65	429	0	429	29			400			
1667	TXDOT/HURST	HURST	HURST BLVD (SH 10)	@ PRECINCT LINE RD		INTERSECTION IMP	60	429	0	429	29			400			
2770	TXDOT	EULESS	SH 10	@ [illegible]		SIGNAL IMP	50	44	0	44	44						
2770	TXDOT	EULESS	SH 10	@ [illegible]		SIGNAL IMP	46	48	0	48	48						
2666	FWTA	VARIOUS	RAILTRAN COMMUTER RAIL			RAIL	67	10000		10000		10000					
2666	FWTA	VARIOUS	RAILTRAN COMMUTER RAIL			RAIL	67	10000		10000		10000					
2004	FWTA	VARIOUS	RIDESHARE PROGRAM			OPERATIONS (FTA)	60	312	156	156	156						
2004	FWTA	VARIOUS	RIDESHARE PROGRAM			OPERATIONS (FTA)	60	312	156	156	156						
2779	TXDOT	BEDFORD	SH 121	@ CENTRAL DR		INTERSECTION IMP	46	261	0	261		261					
2779	TXDOT	BEDFORD	SH 121	@ CENTRAL DR		INTERSECTION IMP	43	343	0	343			343				
306	ARLINGTON	ARLINGTON	PARK-N-RIDE	IH 30 AREA		CAPITAL ASSIST	47	550	110	440		440					
306	ARLINGTON	ARLINGTON	PARK-N-RIDE	IH 30 AREA		CAPITAL ASSIST	47	550	110	440		440					
1614	GRAPEVINE	GRAPEVINE	GRAPEVINE/SOUTHLAKE BIKE TRAIL			BIKE TRAILS	47	509	102	407		407					
1614	GRAPEVINE	GRAPEVINE	GRAPEVINE/SOUTHLAKE BIKE TRAIL			BIKE TRAILS	47	509	102	407		46	362				
2776	TXDOT	FORT WORTH	IH 35W/LOOP 820	IH 35W TO US 287 &	IH 35W @ IH 20	SURVEILLANCE	46	2630	0	2630	2630						
2776	TXDOT	FORT WORTH	IH 35W/LOOP 820	IH 35W TO US 287 &	IH 35W @ IH 20	SURVEILLANCE	46	2120	0	2120	2120						
2771	TXDOT	FORT WORTH	IH 30	@ UNIVERSITY DR		SURVEILLANCE	48	60	0	60		60					
2771	TXDOT	FORT WORTH	IH 30	@ UNIVERSITY DR		SURVEILLANCE	48	60	0	60			60				
2768	TXDOT	GRAPEVINE	SH 121	@ GLADE RD.		INTERSECTION IMP	46	121	0	121	121						
2763	TXDOT	GRAPEVINE	SH 121	@ GLADE RD		INTERSECTION IMP	46	88	0	88	88						
172	ARLINGTON	ARLINGTON	GREEN OAKS BLVD	@ RANDOL MILL RD		SIGNAL IMP	43	74	16	58		58					
172	ARLINGTON	ARLINGTON	GREEN OAKS BLVD	@ RANDOL MILL RD		SIGNAL IMP	43	74	16	58			58				
8120	TXDOT	RICHLAND HILLS	RUFE SNOW DR. (SPUR 474)	@ BAKER BLVD. (SH 183)		INTERSECTION IMP	43	280	0	280		280					
8120	TXDOT	RICHLAND HILLS	RUFE SNOW DR. (SPUR 474)	@ BAKER BLVD. (SH 183)		INTERSECTION IMP.	43	280	0	280			280				
1067	HURST	HURST	LONG BOONE RD	@ HURSTVIEW DR		SIGNAL IMP	42	47	10	37		37					
1067	HURST	HURST	LONG BOONE RD	@ HURSTVIEW DR		SIGNAL IMP	42	47	10	37		5	32				
1762	LAKE WORTH	LAKE WORTH	PARK-N-RIDE			PARK-N-RIDE (FTA)	37	440	88	352	352						
1762	LAKE WORTH	LAKE WORTH	PARK-N-RIDE			PARK-N-RIDE (FTA)	37	440	88	352	352						
1297	FORT WORTH	FORT WORTH	CLEARFORK/BENBROOK BIKE TRAIL	SOUTHWEST BLVD	LAKE BENBROOK	BIKE TRAIL	36	688	138	550		550					
1297	FORT WORTH	FORT WORTH	CLEARFORK/BENBROOK BIKE TRAIL	SOUTHWEST BLVD	LAKE BENBROOK	BIKE TRAIL	35	688	138	550		50	500				
	REGIONAL	VARIOUS	TRAVEL DEMAND MANAGEMENT			SHARE OF REG COST (FTA)		126	26	100	100						
	REGIONAL	VARIOUS	INSPECTION SITE AND SUBSIDIZED VANPOOL			SHARE OF REG COST (FTA)		126	26	100	100						
4144	FWTA	VARIOUS	OZONE ALERT PROGRAM					152	47	105	105						
4144	FWTA	VARIOUS	OZONE ALERT PROGRAM					152	47	105	105						
4147	FWTA	VARIOUS	EAST FORT WORTH PARK-AND-RIDE PROJECT			PARK-AND-RIDE		0		0							
4147	FWTA	VARIOUS	EAST FORT WORTH PARK-AND-RIDE PROJECT			PARK-AND-RIDE	94	200	92	108			108				

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCORE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	[illegible]	[illegible]
4148	FWTA	VARIOUS	SUBSIDIZED VANPOOL PROGRAM			TDM		0		0							
4148	FWTA	VARIOUS	SUBSIDIZED VANPOOL PROGRAM			TDM	85	358	107	251			251				
4149	FWTA	VARIOUS	EDUCATION PROGRAM AT BIRD CTR SCHOOLS			TDM		0		0							
4149	FWTA	VARIOUS	EDUCATION PROGRAM AT BIRD CTR SCHOOLS			TDM	75	46	21	24			24				
4003	ARLINGTON	ARLINGTON	COOPER ST (FM 157)	IH 20	PLEASANT RIDGE	INTERSECTION IMPROVEMENT		0		0							
4003	ARLINGTON	ARLINGTON	COOPER ST (FM 157)	IH 20	PLEASANT RIDGE	INTERSECTION IMPROVEMENT	83	76	27	49			49				
4006	ARLINGTON	ARLINGTON	FIELDER RD @ PARK ROW DR			INTERSECTION IMPROVEMENT		0		0							
4006	ARLINGTON	ARLINGTON	FIELDER RD @ PARK ROW DR			INTERSECTION IMPROVEMENT	85	91	42	49				49			
4214	ARLINGTON	ARLINGTON	PIONEER PKWY @ PARK SPRINGS BLVD			INTERSECTION IMPROVEMENT		0		0							
4214	ARLINGTON	ARLINGTON	PIONEER PKWY @ PARK SPRINGS BLVD			INTERSECTION IMPROVEMENT	83	62	26	27				27			
4318	HURST	HURST	PRECINCT LINE RD @ THOUSAND OAKS DR			SIGNAL IMPROVEMENTS		0		0							
4318	HURST	HURST	PRECINCT LINE RD @ THOUSAND OAKS DR			SIGNAL IMPROVEMENTS	80	6	2	3			3				
4200	TRANSP STRATEGI	VARIOUS	TRAVEL REDUCTION IMPLEMENTATION PLAN			TDM		0		0							
4200	TRANSP STRATEGI	VARIOUS	TRAVEL REDUCTION IMPLEMENTATION PLAN			TDM	83	153		0			0	0			
4111	EULESS	EULESS	N MAIN ST @ SH 183			INTERSECTION IMPROVEMENT		0		0							
4111	EULESS	EULESS	N MAIN ST @ SH 183			INTERSECTION IMPROVEMENT	95	89	30	59				59			
4002	ARLINGTON	ARLINGTON	COPELAND RD @ COLLINS ST			INTERSECTION IMPROVEMENT		0		0							
4002	ARLINGTON	ARLINGTON	COPELAND RD @ FM 157 (COLLINS ST)			INTERSECTION IMPROVEMENT	83	85	42	46			46				
4146	FWTA	VARIOUS	COMMUTE ALLOWANCE PROGRAM			TDM		0		0							
4146	FWTA	VARIOUS	COMMUTE ALLOWANCE PROGRAM			TDM	76	90	41	48			24	24			
4008	ARLINGTON	ARLINGTON	MATLOCK RD @ IH 20			INTERSECTION IMPROVEMENT		0		0							
4008	ARLINGTON	ARLINGTON	MATLOCK RD @ IH 20			INTERSECTION IMPROVEMENT	77	83	26	57				57			
4009	ARLINGTON	ARLINGTON	DIVISION ST @ COOPER ST			INTERSECTION IMPROVEMENT		0		0							
4009	ARLINGTON	ARLINGTON	SH 180 (DIVISION ST) @ COOPER ST			INTERSECTION IMPROVEMENT	77	232	70	162				162			
4120	FORT WORTH	FORT WORTH	MONTGOMERY @ IH 30			INTERSECTION IMPROVEMENT		0		0							
4120	FORT WORTH	FORT WORTH	MONTGOMERY @ IH 30			INTERSECTION IMPROVEMENT	77	120	38	82						82	
4122	FORT WORTH	FORT WORTH	8TH AVE @ PENNSYLVANIA			INTERSECTION IMPROVEMENT		0		0							
4122	FORT WORTH	FORT WORTH	8TH AVE @ PENNSYLVANIA			INTERSECTION IMPROVEMENT	77	126	52	73			73				
4314	HURST	HURST	PIPELINE RD @ MELBOURNE RD			INTERSECTION IMPROVEMENT		0		0							
4314	HURST	HURST	PIPELINE RD @ MELBOURNE RD			INTERSECTION IMPROVEMENT	76	240	110	130					130		
4010	ARLINGTON	ARLINGTON	PARK ROW DR	COOPER ST	PECAN DR	CORRIDOR IMPROVEMENTS		0		0							
4010	ARLINGTON	ARLINGTON	PARK ROW DR	COOPER ST	PECAN DR	CORRIDOR IMPROVEMENTS	76	1250	676	676			676				
4004	ARLINGTON	ARLINGTON	PARK ROW DR @ SH 360			INTERSECTION IMPROVEMENT		0		0							
4004	ARLINGTON	ARLINGTON	PARK ROW DR @ SH 360			INTERSECTION IMPROVEMENT	75	416	192	223			223				
4313	HURST	HURST	NORWOOD DR @ SH 10			INTERSECTION IMPROVEMENT		0		0							
4313	HURST	HURST	NORWOOD DR @ SH 10			INTERSECTION IMPROVEMENT	76	290	134	167			167				
4134	FORT WORTH	FORT WORTH	SPUR 348 @ LAS VEGAS			INTERSECTION IMPROVEMENT		0		0							
4134	FORT WORTH	FORT WORTH	SPUR 348 @ LAS VEGAS			INTERSECTION IMPROVEMENT	73	60	15	45					45		
4172	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ GLENVIEW			INTERSECTION IMPROVEMENT		0		0							
4172	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ GLENVIEW			INTERSECTION IMPROVEMENT	70	500	250	250					250		
4007	ARLINGTON	ARLINGTON	ARKANSAS LN @ MATLOCK RD			INTERSECTION IMPROVEMENT		0		0							
4007	ARLINGTON	ARLINGTON	ARKANSAS LN @ MATLOCK RD			INTERSECTION IMPROVEMENT	70	230	72	164				164			
4112	EULESS	EULESS	WESTPARK WAY	SH 183	PARKVIEW	CORRIDOR IMPROVEMENTS		0		0							
4112	EULESS	EULESS	WESTPARK WAY	SH 183	PARKVIEW	CORRIDOR IMPROVEMENTS	70	82	28	54			54				

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/03
4009	ARLINGTON	ARLINGTON	LAMAR BLVD @ RANDY SNOW LN			INTERSECTION IMPROVEMENT		0		0							
4009	ARLINGTON	ARLINGTON	LAMAR BLVD @ RANDY SNOW LN			INTERSECTION IMPROVEMENT	75	120	40	80				80			
4013	ARLINGTON	ARLINGTON	FIELDER RD @ NORWOOD LN			INTERSECTION IMPROVEMENT		0		0							
4013	ARLINGTON	ARLINGTON	FIELDER RD @ NORWOOD LN			INTERSECTION IMPROVEMENT	74	176	56	120					120		
4150	EULESS	EULESS	GLADE RD @ BAZE DR			INTERSECTION IMPROVEMENT		0		0							
4150	EULESS	EULESS	GLADE RD @ BAZE DR			INTERSECTION IMPROVEMENT	73	18	6	11			11				
4148	FWTA	VARIOUS	RAILTRAN PROJECT			RAILTRAN — TARRANT COUNTY		0		0							
4148	FWTA	VARIOUS	RAILTRAN PROJECT			RAILTRAN — TARRANT COUNTY	73	14486	4486	10000			10000				
4144	FWTA	VARIOUS	TRANSIT FARE PROGRAM			OZONE ALERT		0		0							
4144	FWTA	VARIOUS	TRANSIT FARE PROGRAM			OZONE ALERT	73	152	47	106			106				
4064	COLLEYVILLE	COLLEYVILLE	SH 26 @ GLADE			INTERSECTION IMPROVEMENT		0		0							
4064	COLLEYVILLE	COLLEYVILLE	SH 26 @ GLADE			INTERSECTION IMPROVEMENT	64	350	63	287					287		
4126	FORT WORTH	FORT WORTH	HULEN ST/IH 20 @ BAYWAY			INTERSECTION IMPROVEMENT		0		0							
4126	FORT WORTH	FORT WORTH	HULEN ST/IH 20 @ BAYWAY			INTERSECTION IMPROVEMENT	64	240	60	180						180	
4066	COLLEYVILLE	COLLEYVILLE	SH 26 @ PLEASANT RUN			INTERSECTION IMPROVEMENT/SIGNAL		0		0							
4058	COLLEYVILLE	COLLEYVILLE	SH 26 @ PLEASANT RUN			INTERSECTION IMPROVEMENT/SIGNAL	66	310	62	248					248		
4276	TXDOT - FT WORT	FORT WORTH	IH 820 @ BEACH ST			SIGNAL IMPROVEMENTS		0		0							
4276	TXDOT - FT WORT	FORT WORTH	IH 820 @ BEACH ST			SIGNAL IMPROVEMENTS	67	80	17	63			63				
4173	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW	[illegible]	[illegible]	INTERSECTION IMPROVEMENT		0		0							
4173	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW	[illegible]	[illegible]	INTERSECTION IMPROVEMENT	64	537	[illegible]	288					288		
4016	ARLINGTON	ARLINGTON	ABRAM ST @ NEW YORK AVE			INTERSECTION IMPROVEMENT		0		0							
4016	ARLINGTON	ARLINGTON	ABRAM ST @ NEW YORK AVE			INTERSECTION IMPROVEMENT	65	190	60	130				130			
4294	BOWMAN-MELTO	VARIOUS	REGIONAL ETR COORDINATION			TDM		0		0							
4294	BOWMAN-MELTO	VARIOUS	REGIONAL ETR COORDINATION			TDM	66	446		0			0	0			
4121	FORT WORTH	FORT WORTH	7TH ST/COMMERCE @ CALHOUN			INTERSECTION IMPROVEMENT		0		0							
4121	FORT WORTH	FORT WORTH	7TH ST/COMMERCE @ CALHOUN			INTERSECTION IMPROVEMENT	61	100	31	69			69				
4332	GRAPEVINE	GRAPEVINE	NORTHWEST HWY BIKE & BIKE TRAIL			BIKEWAY		0		0							
4332	GRAPEVINE	GRAPEVINE	NORTHWEST HWY BIKE & BIKE TRAIL			BIKEWAY	64	125	25	100					100		
4015	ARLINGTON	ARLINGTON	PARK ROW DR @ NORWOOD LN			INTERSECTION IMPROVEMENT		0		0							
4015	ARLINGTON	ARLINGTON	PARK ROW DR @ NORWOOD LN			INTERSECTION IMPROVEMENT	65	175	55	120					120		
4181	NORTH RICHLAND	NORTH RICHLAND	COTTONBELT TRAIL			BIKEWAY		0		0							
4181	NORTH RICHLAND	NORTH RICHLAND	COTTONBELT TRAIL			BIKEWAY	63	1725	362	1363						1363	
4179	NORTH RICHLAND	NORTH RICHLAND	SOUTH ELECTRIC TRAIL			BIKEWAY		0		0							
4179	NORTH RICHLAND	NORTH RICHLAND	SOUTH ELECTRIC TRAIL			BIKEWAY	63	750	157	593					593		
4012	ARLINGTON	ARLINGTON	RANDOL MILL RD	OAKWOOD LN	RANDOL MILL PARK	CORRIDOR IMPROVEMENTS		0		0							
4012	ARLINGTON	ARLINGTON	RANDOL MILL RD	OAKWOOD LN	RANDOL MILL PARK	CORRIDOR IMPROVEMENTS	63	450	96	354					354		
4234	TXDOT - FT WORT	GRAPEVINE	SH 114 @ DALLAS RD			SIGNAL IMPROVEMENTS		0		0							
4234	TXDOT - FT WORT	GRAPEVINE	SH 114 @ DALLAS RD			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4271	TXDOT - FT WORT	NORTH RICHLAND	SH 26 @ EMERALD HILLS WAY			SIGNAL IMPROVEMENTS		0		0							
4271	TXDOT - FT WORT	NORTH RICHLAND	SH 26 @ EMERALD HILLS WAY			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4279	TXDOT - FT WORT	NORTH RICHLAND	SH 26 @ STRUMMER DR			SIGNAL IMPROVEMENTS		0		0							
4279	TXDOT - FT WORT	NORTH RICHLAND	SH 26 @ STRUMMER DR			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4230	TXDOT - FT WORT	GRAPEVINE	SH 121 @ HALL-JOHNSON RD			SIGNAL IMPROVEMENTS		0		0							
4230	TXDOT - FT WORT	GRAPEVINE	SH 121 @ HALL-JOHNSON RD			SIGNAL IMPROVEMENTS	62	80	5	65			65				

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 [illegible]	1995	1996	1997	[illegible]	[illegible]
4273	TXDOT - FT WORT	GRAPEVINE	SH 121 @ BETHEL RD			SIGNAL IMPROVEMENTS		0		0							
4273	TXDOT - FT WORT	GRAPEVINE	SH 121 @ BETHEL RD			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4303	TXDOT - FT WORT	WATAUGA	US 377 @ CHAPMAN RD			SIGNAL IMPROVEMENTS		0		0							
4303	TXDOT - FT WORT	WATAUGA	US 377 @ CHAPMAN RD			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4223	TXDOT - FT WORT	EULESS	SH 10 @ PIPELINE RD			SIGNAL IMPROVEMENTS		0		0							
4223	TXDOT - FT WORT	EULESS	SH 10 @ PIPELINE RD			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4232	TXDOT - FT WORT	GRAPEVINE	SH 121 @ MUSTANG DR			SIGNAL IMPROVEMENTS		0		0							
4232	TXDOT - FT WORT	GRAPEVINE	SH 121 @ MUSTANG DR			SIGNAL IMPROVEMENTS	62	55	8	43			40				
4272	TXDOT - FT WORT	WATAUGA	US 377 @ BUCKNER BLVD			SIGNAL IMPROVEMENTS		0		0							
4272	TXDOT - FT WORT	WATAUGA	US 377 @ BUCKNER BLVD			SIGNAL IMPROVEMENTS	62	50	3	47			47				
4164	GRAPEVINE	GRAPEVINE	NORTHWEST HIGHWAY (BS 114L)	SH 114	SH 26	CORRIDOR IMPROVEMENTS		0		0							
4164	GRAPEVINE	GRAPEVINE	NORTHWEST HIGHWAY (BS 114L)	SH 114	SH 26	CORRIDOR IMPROVEMENTS	62	4813	1318	3566					3567		
4171	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW BRIDGE @ IH 820			GRADE SEPARATION		0		0							
4171	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW BRIDGE @ IH 820			GRADE SEPARATION	62	2716	842	1874					1874		
4133	FORT WORTH	FORT WORTH	CITYWIDE INCIDENT DETECTION PROGRAM			IDMS		0		0							
4133	FORT WORTH	FORT WORTH	CITYWIDE INCIDENT DETECTION PROGRAM			IDMS	62	400	80	320				320			
4179	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ STARDUST			INTERSECTION IMPROVEMENT		0		0							
4179	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ STARDUST			INTERSECTION IMPROVEMENT	60	760	211	548					548		
4177	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ WATAUGA RD			INTERSECTION IMPROVEMENT		0		0							
4177	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ WATAUGA RD			INTERSECTION IMPROVEMENT	63	866	259	607					607		
4132	FORT WORTH	FORT WORTH	SYSTEM EXPANSION			SIGNAL IMPROVEMENTS		0		0							
4132	FORT WORTH	FORT WORTH	SYSTEM EXPANSION			SIGNAL IMPROVEMENTS	63	1000	200	800				800			
4175	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ IND PARK			INTERSECTION IMPROVEMENT		0		0							
4175	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ IND PARK			INTERSECTION IMPROVEMENT	62	477	148	329					329		
4174	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ LEWIS DR			INTERSECTION IMPROVEMENT		0		0							
4174	NORTH RICHLAND	NORTH RICHLAND	RUFE SNOW @ LEWIS DR			INTERSECTION IMPROVEMENT	52	[illegible]	172	344					344		
4236	TXDOT - FT WORT	FORT WORTH	US 287 @ BERRY ST			SIGNAL IMPROVEMENTS		0		0							
4236	TXDOT - FT WORT	FORT WORTH	US 287 @ BERRY ST			SIGNAL IMPROVEMENTS	63	30		30			30				
4227	TXDOT - FT WORT	BEDFORD	SH 121 @ MID-CITIES BLVD			SIGNAL IMPROVEMENTS		0		0							
4227	TXDOT - FT WORT	BEDFORD	SH 121 @ MID-CITIES BLVD			SIGNAL IMPROVEMENTS	63	85	6	78			78				
4258	TXDOT - FT WORT	FORT WORTH	IH 30 @ UNIVERSITY & VICKERY			SIGNAL IMPROVEMENTS		0		0							
4258	TXDOT - FT WORT	FORT WORTH	IH 30 @ UNIVERSITY & VICKERY			SIGNAL IMPROVEMENTS	60	13		13			13				
4226	TXDOT - FT WORT	NORTH RICHLAND	FM 3029 @ THOUSAND OAKS			SIGNAL IMPROVEMENTS		0		0							
4226	TXDOT - FT WORT	NORTH RICHLAND	FM 3029 @ THOUSAND OAKS			SIGNAL IMPROVEMENTS	60	3		3			3				
4266	TXDOT - FT WORT	FORT WORTH	IH 30 @ OAKLAND BLVD			SIGNAL IMPROVEMENTS		0		0							
4266	TXDOT - FT WORT	FORT WORTH	IH 30 @ OAKLAND BLVD			SIGNAL IMPROVEMENTS	60	4		4			4				
4264	TXDOT - FT WORT	FORT WORTH	IH 20 @ HULEN ST			SIGNAL IMPROVEMENTS		0		0							
4264	TXDOT - FT WORT	FORT WORTH	IH 20 @ HULEN ST			SIGNAL IMPROVEMENTS	60	8		8			8				
4262	TXDOT - FT WORT	FORT WORTH	IH 820 @ TRINITY BLVD			SIGNAL IMPROVEMENTS		0		0							
4262	TXDOT - FT WORT	FORT WORTH	IH 820 @ TRINITY BLVD			SIGNAL IMPROVEMENTS	60	4		4			4				
4260	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ BRANSFORD RD			SIGNAL IMPROVEMENTS		0		0							
4260	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ BRANSFORD RD			SIGNAL IMPROVEMENTS	60	60		60			60				
4270	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ TINKER ST			SIGNAL IMPROVEMENTS		0		0							
4270	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ TINKER ST			SIGNAL IMPROVEMENTS	60	10		10			10				

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	YEAR	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 CAQ	1995	1996	1997	1998	[illegible]
4229	TXDOT - FT WORT	EULESS	SH 10 @ ECTOR & SIMMONS			SIGNAL IMPROVEMENTS		0		0							
4229	TXDOT - FT WORT	EULESS	SH 10 @ ECTOR & SIMMONS			SIGNAL IMPROVEMENTS	95	10		10			10				
4260	TXDOT - FT WORT	FORT WORTH	IH 20 @ HEMPHILL ST			SIGNAL IMPROVEMENTS		0		0							
4260	TXDOT - FT WORT	FORT WORTH	IH 20 @ HEMPHILL ST			SIGNAL IMPROVEMENTS	95	8		8			8				
4287	TXDOT - FT WORT	HALTOM CITY	IH 820 @ US 377			SIGNAL IMPROVEMENTS		0		0							
4287	TXDOT - FT WORT	HALTOM CITY	IH 820 @ US 377			SIGNAL IMPROVEMENTS	95	85	8	76			76				
4281	TXDOT - FT WORT	FORT WORTH	IH 20 @ BRYANT-IRVIN RD			SIGNAL IMPROVEMENTS		0		0							
4281	TXDOT - FT WORT	FORT WORTH	IH 20 @ BRYANT-IRVIN RD			SIGNAL IMPROVEMENTS	95	8		8			8				
4119	EULESS	EULESS	ECTOR DR @ TROJAN TRL			INTERSECTION IMPROVEMENT		0		0							
4119	EULESS	EULESS	ECTOR DR @ TROJAN TRL			INTERSECTION IMPROVEMENT	95	75	15	60			60				
4283	TXDOT - FT WORT	FORT WORTH	SH 183 @ VICKERY BLVD			SIGNAL IMPROVEMENTS		0		0							
4283	TXDOT - FT WORT	FORT WORTH	SH 183 @ VICKERY BLVD			SIGNAL IMPROVEMENTS	95	4		4			4				
4208	TARRANT COUNTY	VARIOUS	TARRANT COUNTY MOTORIST ASSISTANCE PROGRAM			MOBILITY ASSISTANCE		0		0							
4208	TARRANT COUNTY	VARIOUS	TARRANT COUNTY MOTORIST ASSISTANCE PROGRAM			MOBILITY ASSISTANCE	95	2776	545	2230			2230				
4334	BEDFORD	BEDFORD	CENTRAL DR @ AIRPORT FRWY			INTERSECTION IMPROVEMENT		0		0							
4334	BEDFORD	BEDFORD	CENTRAL DR @ AIRPORT FRWY			INTERSECTION IMPROVEMENT	95	76		76			76				
4213	TXDOT - FT WORT	VARIOUS	IH 35W	IH 30	IH 20	SURVEILLANCE		0		0							
4213	TXDOT - FT WORT	VARIOUS	IH 35W	IH 30	IH 20	SURVEILLANCE	95	125		100				100			
4298	TXDOT - FT WORT	FORT WORTH	IH 820 @ SPUR 565			SIGNAL IMPROVEMENTS		0		0							
4298	TXDOT - FT WORT	FORT WORTH	IH 820 @ SPUR 565			SIGNAL IMPROVEMENTS	60	8		8			8				
4220	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ JOHN MCCAIN			SIGNAL IMPROVEMENTS		0		0							
4220	TXDOT - FT WORT	COLLEYVILLE	SH 26 @ JOHN MCCAIN			SIGNAL IMPROVEMENTS	60	10		10			10				
4287	TXDOT - FT WORT	FORT WORTH	IH 30 @ LAS VEGAS TRL			SIGNAL IMPROVEMENTS		0		0							
4287	TXDOT - FT WORT	FORT WORTH	IH 30 @ LAS VEGAS TRL			SIGNAL IMPROVEMENTS	66	13		13			13				
4230	TXDOT - FT WORT	NORTH RICHLAND	FM 1938 @ N TARRANT PKWY			SIGNAL IMPROVEMENTS		0		0							
4230	TXDOT - FT WORT	NORTH RICHLAND	FM 1938 @ N TARRANT PKWY			SIGNAL IMPROVEMENTS	60	53	8	45			45				
4258	TXDOT - FT WORT	FORT WORTH	US 287 @ MILLER & WILBARGER			SIGNAL IMPROVEMENTS		0		0							
4258	TXDOT - FT WORT	FORT WORTH	US 287 @ MILLER & WILBARGER			SIGNAL IMPROVEMENTS	60	10		10			10				
4264	TXDOT - FT WORT	FORT WORTH	IH 35 @ HORNE ST			SIGNAL IMPROVEMENTS		0		0							
4264	TXDOT - FT WORT	FORT WORTH	IH 35 @ HORNE ST			SIGNAL IMPROVEMENTS	60	8		8			8				
4188	NORTH RICHLAND	NORTH RICHLAND	LITTLE BEAR CREEK TRAIL			BIKEWAY		0		0							
4188	NORTH RICHLAND	NORTH RICHLAND	LITTLE BEAR CREEK TRAIL			BIKEWAY	66	2400	504	1896				1896			
4226	TXDOT - FT WORT	NORTH RICHLAND	FM 1938 @ WATAUGA RD			SIGNAL IMPROVEMENTS		0		0							
4226	TXDOT - FT WORT	NORTH RICHLAND	FM 1938 @ WATAUGA RD			SIGNAL IMPROVEMENTS	65	60		60			60				
4212	TXDOT - FT WORT	VARIOUS	IH 20	IH 820	SH 360	SURVEILLANCE		0		0							
4212	TXDOT - FT WORT	VARIOUS	IH 20	IH 820	SH 360	SURVEILLANCE	66	700		700			700				
4241	TXDOT - FT WORT	FORT WORTH	IH 30 @ CHERRY LN			SIGNAL IMPROVEMENTS		0		0							
4241	TXDOT - FT WORT	FORT WORTH	IH 30 @ CHERRY LN			SIGNAL IMPROVEMENTS	66	85		85			85				
4244	TXDOT - FT WORT	FORT WORTH	SH 121 @ BEACH ST			SIGNAL IMPROVEMENTS		0		0							
4244	TXDOT - FT WORT	FORT WORTH	SH 121 @ BEACH ST			SIGNAL IMPROVEMENTS	66	85		85			85				
4243	TXDOT - FT WORT	FORT WORTH	IH 35W @ SH 183			SIGNAL IMPROVEMENTS		0		0							
4243	TXDOT - FT WORT	FORT WORTH	IH 35W @ SH 183			SIGNAL IMPROVEMENTS	66	90		90			90				
4327	BEDFORD	BEDFORD	HARWOOD RD @ MCLAIN DR			INTERSECTION IMPROVEMENT		0		0							
4327	BEDFORD	BEDFORD	HARWOOD RD @ MCLAIN DR			INTERSECTION IMPROVEMENT	66	145	20	118						110	

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1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	[illegible]	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 QUARTER	1994 C/O	1995	1996	1997	[illegible]	[illegible]
4329	BEDFORD	BEDFORD	BEDFORD RD @ CENTRAL DR			INTERSECTION IMPROVEMENT		0		0							
4329	BEDFORD	BEDFORD	BEDFORD RD @ CENTRAL DR			INTERSECTION IMPROVEMENT	55	373	75	298			298				
4106	EULESS	EULESS	HARWOOD RD @ ARKANSAS			SIGNAL IMPROVEMENTS		0		0							
4106	EULESS	EULESS	HARWOOD RD @ ARKANSAS			SIGNAL IMPROVEMENTS	56	79	15	64			64				
4238	TXDOT - FT WORT	FORT WORTH	SH 30 @ GREEN OAKS RD			SIGNAL IMPROVEMENTS		0		6							
4238	TXDOT - FT WORT	FORT WORTH	SH 30 @ GREEN OAKS RD			SIGNAL IMPROVEMENTS	[illegible]	95		85			85				
4252	CLEAR TEXAS ASI	VARIOUS	BICYCLE PARKING FOR WESTERN SUBREGION			BIKEWAY		0		0							
4252	CLEAR TEXAS ASI	VARIOUS	BICYCLE PARKING FOR WESTERN SUBREGION			BIKEWAY	55	217	43	174			174				
4129	FORT WORTH	FORT WORTH	GRANBURY/WABASH	TRAIL LAKE	SEMINARY	INTERSECTION IMPROVEMENT		0		0							
4129	FORT WORTH	FORT WORTH	GRANBURY/WABASH	TRAIL LAKE	SEMINARY	INTERSECTION IMPROVEMENT	[illegible]	1400	280	1120				1120			
4326	BEDFORD	BEDFORD	MURPHY DR @ L DON DODSON/WAYSIDE DR			INTERSECTION IMPROVEMENT		0		0							
4326	BEDFORD	BEDFORD	MURPHY DR @ L DON DODSON/WAYSIDE DR			INTERSECTION IMPROVEMENT	55	145	27	118						118	
4107	EULESS	EULESS	WESTPARK WAY @ TIMBERS & SILVERCREST			SIGNAL IMPROVEMENTS		0		0							
4107	EULESS	EULESS	WESTPARK WAY @ TIMBERS & SILVERCREST			SIGNAL IMPROVEMENTS	[illegible]	120	37	83			83				
4231	TXDOT - FT WORT	KELLER	US 377 @ WALL-PRICE RD			SIGNAL IMPROVEMENTS		0		0							
4231	TXDOT - FT WORT	KELLER	US 377 @ WALL-PRICE RD			SIGNAL IMPROVEMENTS	62	50		40			40				
4131	FORT WORTH	FORT WORTH	N BEACH ST @ RAILTRAN			GRADE SEPARATION		0		0							
4131	FORT WORTH	FORT WORTH	N BEACH ST @ RAILTRAN			GRADE SEPARATION	63	2000	920	1080					1080		
4118	FOREST HILL	FOREST HILL	FOREST HILL DR			BIKEWAY		0		0							
4118	FOREST HILL	FOREST HILL	FOREST HILL DR			BIKEWAY	63	102	20	82			82				
4311	ARLINGTON	ARLINGTON	FIELDER RD	SYLVAN DR	RANDOL MILL	CORRIDOR IMPROVEMENTS		0		0							
4311	ARLINGTON	ARLINGTON	FIELDER RD	SYLVAN DR	RANDOL MILL	CORRIDOR IMPROVEMENTS	63	1810	655	1156					1156		
4318	HURST	HURST	CAMPUS DR @ THOUSAND OAKS DR			SIGNAL IMPROVEMENTS		0		0							
4318	HURST	HURST	CAMPUS DR @ THOUSAND OAKS DR			SIGNAL IMPROVEMENTS	63	45	21	24						24	
4256	TXDOT - FT WORT	FORT WORTH	US 287 @ ERATH ST			SIGNAL IMPROVEMENTS		0		0							
4256	TXDOT - FT WORT	FORT WORTH	US 287 @ ERATH ST			SIGNAL IMPROVEMENTS	50	6		6			6				
4247	TXDOT - FT WORT	FORT WORTH	US 287 @ RIVERSIDE DR			SIGNAL IMPROVEMENTS		0		0							
4247	TXDOT - FT WORT	FORT WORTH	US 287 @ RIVERSIDE DR			SIGNAL IMPROVEMENTS	50	46		46			46				
4219	TXDOT - FT WORT	VARIOUS	IH 35W	ALTA MESA	SH 174	SURVEILLANCE		0		0							
4219	TXDOT - FT WORT	VARIOUS	IH 35W	ALTA MESA	SH 174	SURVEILLANCE	50	400	400	0							
4130	FORT WORTH	FORT WORTH	CAMP BOWIE/W 7TH @ UNIVERSITY			INTERSECTION IMPROVEMENT		0		0							
4130	FORT WORTH	FORT WORTH	CAMP BOWIE/W 7TH @ UNIVERSITY			INTERSECTION IMPROVEMENT	50	1250	250	1000					1000		
4117	FOREST HILL	FOREST HILL	15-PASSENGER VAN AND 1994 OPERATING COST			TRANSIT CAPITAL		0		0							
4117	FOREST HILL	FOREST HILL	15-PASSENGER VAN AND 1994 OPERATING COST			TRANSIT CAPITAL	50	68	23	46			46				
4001	ARLINGTON	ARLINGTON	ABRAM ST	BROWNING	STADIUM	INTERSECTION IMPROVEMENT		0		0							
4001	ARLINGTON	ARLINGTON	ABRAM ST	BROWNING	STADIUM	INTERSECTION IMPROVEMENT	50	2660	1250	1410					1410		
4206	TXDOT - FT WORT	FORT WORTH	IH 35W	SYCAMORE SCHOOL RD	ALTA MESA	INTERSECTION IMPROVEMENT		0		0							
4206	TXDOT - FT WORT	FORT WORTH	IH 35W	SYCAMORE SCHOOL RD	ALTA MESA	INTERSECTION IMPROVEMENT	50	378		378			378				
4342	TXDOT - FT WORT	FORT WORTH	IH 30 @ BEACH ST			SIGNAL IMPROVEMENTS		0		0							
4342	TXDOT - FT WORT	FORT WORTH	IH 30 @ BEACH ST			SIGNAL IMPROVEMENTS	50	90		90			90				
4211	TXDOT - FT WORT	VARIOUS	SH 360	SH 183	IH 20	SURVEILLANCE		0		0							
4211	TXDOT - FT WORT	VARIOUS	SH 360	SH 183	IH 20	SURVEILLANCE	50	1900		1900			1900				
4348	TXDOT - FT WORT	FORT WORTH	IH 30 @ RIDGMAR BLVD			SIGNAL IMPROVEMENTS		0		0							
4348	TXDOT - FT WORT	FORT WORTH	IH 30 @ RIDGMAR BLVD			SIGNAL IMPROVEMENTS	50	66		66			66				

Note: First row of each project denotes programming in 1994 TIP, second row is 1995 TIP proposal.
10/6/94

1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	ZONE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	[illegible]	[illegible]
4240	TXDOT - FT WORT	FORT WORTH	SH 121 @ SYLVANIA AVE			SIGNAL IMPROVEMENTS		0		0							
4240	TXDOT - FT WORT	FORT WORTH	SH 121 @ SYLVANIA AVE			SIGNAL IMPROVEMENTS	60	66		66			66				
4237	TXDOT - FT WORT	FORT WORTH	US 287 @ BERRY-VAUGHN			SIGNAL IMPROVEMENTS		0		0							
4237	TXDOT - FT WORT	FORT WORTH	US 287 @ BERRY-VAUGHN			SIGNAL IMPROVEMENTS	60	60		60			60				
4224	TXDOT - FT WORT	FORT WORTH	FM 1187 @ IH 35W			SIGNAL IMPROVEMENTS		0		0							
4224	TXDOT - FT WORT	FORT WORTH	FM 1187 @ IH 35W			SIGNAL IMPROVEMENTS	60	66		66			66				
4274	TXDOT - FT WORT	FORT WORTH	IH 30 @ ASHLAND AVE			SIGNAL IMPROVEMENTS		0		0							
4274	TXDOT - FT WORT	FORT WORTH	IH 30 @ ASHLAND AVE			SIGNAL IMPROVEMENTS	50	80		80			80				
4245	TXDOT - FT WORT	FORT WORTH	SH 121 @ RIVERSIDE DR			SIGNAL IMPROVEMENTS		0		0							
4245	TXDOT - FT WORT	FORT WORTH	SH 121 @ RIVERSIDE DR			SIGNAL IMPROVEMENTS	60	66		66			66				
4248	TXDOT - FT WORT	FORT WORTH	IH 30 @ FOREST PARK			SIGNAL IMPROVEMENTS		0		0							
4248	TXDOT - FT WORT	FORT WORTH	IH 30 @ FOREST PARK			SIGNAL IMPROVEMENTS	60	66		66			66				
4216	TXDOT - FT WORT	FORT WORTH	SH 183	IH 820	DALLAS COUNTY LINE	SURVEILLANCE		0		0							
4216	TXDOT - FT WORT	FORT WORTH	SH 183	IH 820	DALLAS COUNTY LINE	SURVEILLANCE	60	1200		1200			1200				
4230	TXDOT - FT WORT	FORT WORTH	US 287 @ VAUGHN BLVD			SIGNAL IMPROVEMENTS		0		0							
4230	TXDOT - FT WORT	FORT WORTH	US 287 @ VAUGHN BLVD			SIGNAL IMPROVEMENTS	60	30		30			30				
4240	TXDOT - FT WORT	FORT WORTH	IH 35W @ EVERMAN RD			SIGNAL IMPROVEMENTS		0		0							
4240	TXDOT - FT WORT	FORT WORTH	IH 35W @ EVERMAN RD			SIGNAL IMPROVEMENTS	60	66		66			66				
4251	TXDOT - FT WORT	FORT WORTH	IH 820 @ BRENTWOOD-STAIR			SIGNAL IMPROVEMENTS		0		0							
4251	TXDOT - FT WORT	FORT WORTH	IH 820 @ BRENTWOOD-STAIR			SIGNAL IMPROVEMENTS	60	66		66			66				
4200	TXDOT - FT WORT	ARLINGTON	IH 20 @ COLLINS ST			SIGNAL IMPROVEMENTS		0		0							
4200	TXDOT - FT WORT	ARLINGTON	IH 20 @ COLLINS ST			SIGNAL IMPROVEMENTS	60	66		66			66				
4168	JOANNE H PRATT	VARIOUS	IMPLEMENTATION OF TELECOMMUTING			TDM		0		0							
4168	JOANNE H PRATT	VARIOUS	IMPLEMENTATION OF TELECOMMUTING			TDM	48	67		0			0	0			
4125	FORT WORTH	FORT WORTH	8TH AVE @ ROSEDALE			INTERSECTION IMPROVEMENT		0		0							
4125	FORT WORTH	FORT WORTH	8TH AVE @ ROSEDALE			INTERSECTION IMPROVEMENT	48	800	200	600					600		
4126	FORT WORTH	FORT WORTH	DIRKS RD @ BRYANT-IRVIN			INTERSECTION IMPROVEMENT		0		0							
4126	FORT WORTH	FORT WORTH	DIRKS RD @ BRYANT-IRVIN			INTERSECTION IMPROVEMENT	47	180	50	130					130		
4262	TXDOT - FT WORT	FORT WORTH	IH 820 @ MEADOWBROOK DR			SIGNAL IMPROVEMENTS		0		0							
4262	TXDOT - FT WORT	FORT WORTH	IH 820 @ MEADOWBROOK DR			SIGNAL IMPROVEMENTS	46	66		66			66				
4214	TXDOT - FT WORT	FORT WORTH	IH 820 @ IH 30 E			SURVEILLANCE		0		0							
4214	TXDOT - FT WORT	FORT WORTH	IH 820 @ IH 30 E			SURVEILLANCE	46	800		800				800			
4263	TXDOT - FT WORT	FORT WORTH	IH 820 @ SPUR 303			SIGNAL IMPROVEMENTS		0		0							
4263	TXDOT - FT WORT	FORT WORTH	IH 820 @ SPUR 303			SIGNAL IMPROVEMENTS	46	66		66			66				
4266	TXDOT - FT WORT	FORT WORTH	IH 35W @ NORTHSIDE DR			SIGNAL IMPROVEMENTS		0		0							
4266	TXDOT - FT WORT	FORT WORTH	IH 35W @ NORTHSIDE DR			SIGNAL IMPROVEMENTS	46	66		66			66				
4218	TXDOT - FT WORT	FORT WORTH	IH 20 @ MCCART ST			SURVEILLANCE		0		0							
4218	TXDOT - FT WORT	FORT WORTH	IH 20 @ MCCART ST			SURVEILLANCE	45	4000		4000					4000		
4322	BEDFORD	BEDFORD	BEDFORD RD @ MURPHY DR			INTERSECTION IMPROVEMENT		0		0							
4322	BEDFORD	BEDFORD	BEDFORD RD @ MURPHY DR			INTERSECTION IMPROVEMENT	46	380	76	304						304	
4178	NORTH RICHLAND	NORTH RICHLAND	ROUTE MAP & SIGNS			BIKEWAY		0		0							
4178	NORTH RICHLAND	NORTH RICHLAND	ROUTE MAP & SIGNS			BIKEWAY	43	125	29	96			96				
4127	FORT WORTH	FORT WORTH	IH 820 @ N BEACH			INTERSECTION IMPROVEMENT		0		0							
4127	FORT WORTH	FORT WORTH	IH 820 @ N BEACH			INTERSECTION IMPROVEMENT	43	3200	1500	1700				1700			

Note: First row of each project denotes programming in 1994 TIP, second row is 1995 TIP proposal.
10/6/94

1995 TRANSPORTATION IMPROVEMENT PROGRAM
CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM (CMAQ)
WESTERN SUBREGION

PROJECT CODE	AGENCY	CITY	PROJECT NAME	FROM	TO	PROJECT DESCRIPTION	SCOPE	PROJECT COST (dollars in thousands) TOTAL	LOCAL	FEDERAL AND STATE	FEDERAL AND STATE FUNDING BY FISCAL YEAR (dollars in thousands) 1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/03
4337	NCTCOG	VARIOUS	REGIONAL CORRIDOR MANAGEMENT PROGRAM			IDRS		0		0							
4337	NCTCOG	VARIOUS	REGIONAL CORRIDOR MANAGEMENT PROGRAM			IDRS		1000		1000			600	600			
4334	FWTA	VARIOUS	REGIONAL TRAVEL DEMAND PROGRAM			TDM		0		0							
4334	FWTA	VARIOUS	REGIONAL TDM PROGRAM/TECHNICAL RESPONSE TO MOBILITY INITIATIVE			TDM		1018		1018			509	509			
	N TX CLEAN AIR C	VARIOUS	REGIONAL TDM PROGRAM/MARKETING PROGRAM			TDM		0		0							
	N TX CLEAN AIR C	VARIOUS	REGIONAL TDM PROGRAM/MARKETING PROGRAM			TDM		340		340			170	170			

SUBTOTALS		TOTAL	LOCAL	FEDERAL AND STATE	1994 CONSTR	1994 C/O	1995	1996	1997	98/99	2000/03
	1994 TIP	61442	8084	43398	7717	17301	7207	1383	8490	0	6760
	1995 TIP	173121	28444	86081	7262	12378	30828	24872	28131	2106	8760

Note: First row of each project denotes programming in 1994 TIP, second row is 1995 TIP proposal.
10/6/94

APPENDIX E

Examples of Assumptions/Calculations Made to Analyze CMAQ Projects During Dallas-Fort Worth's 1995 TIP Process

(bikeways, bike storage projects, and intersection improvements)

Source: Texas No. 2.

CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM

ASSUMPTIONS AND CALCULATIONS FOR BICYCLE FACILITIES AND RELATED PROJECTS

PROJECT EVALUATION ASSUMPTIONS

- Assumed cold starts in calculation of emission benefits
- Assumed round trip length of the minimum of 10 miles or twice the project length
- Assumed speed of travelers being removed from roadway is 30 mph
- Assumed value of time of $9/hour
- Assumed design life of bikeway is 20 years
- Assumed design life of bike storage or parking facilities is 10 years
- Assumed exposure area of bikeway equal to (length of project x 2 miles), which represents a one-mile radius on either side of bikeway
- Assumed population exposed to bikeway varies by area type of project location:

Area Type	Land Use	Population Density (persons/sq. mile)
1	CBD	838
2	CBD Fringe	1809
3	Urban	3753
4	Suburban	1897
5	Rural	241

- Assumed 25 percent occupancy rate for bike parking/storage facilities
- Assumed one percent bike mode share for calculating work trip bikeway users induced by new bikeway; this was applied to population exposed to bikeway

PROJECT CALCULATIONS

I. BIKEWAYS

A. Criteria 1: Current Cost Effectiveness

1. Bikeway VHT Saved:

$$\frac{((\text{pop. density}) \times (\text{proj. length}) \times (2\ \text{mi.}) \times (\text{minimum of } (10\ \text{mi. or } (2 \times \text{proj. length}))) \times (0.01\ \text{mode share})}{30\ \text{mph}}$$

2. Annual Bikeway Benefit ($) Saved:

(VHT saved) x ($9/hour) x (280 days/year)

- Annual benefit divided by annual cost (based on design life) gives B/C ratio used to score cost-effectiveness criteria.

B. **Criteria 2: Air Quality/Energy Conservation Rating**

1. **Bikeway Vehicle Miles of Travel (VMT) Saved:**

((pop. density) x (proj. length) x (2 mi.) x (minimum of (10 mi. or (2 x proj. length))) x (0.01 mode share)

2. **Emission Factor Accounting for Cold Starts:**

30 mph factor = (original emission factor) x 1.46 = 2.541 x 1.46 = 3.710 grams/mile

- Cold start factor based on EPA MOBILE5a model using 100 percent cold starts.
- VOC reductions calculated as VMT x Emission Factor.
- Annual cost divided by the VOC reduction provides input to determine Criteria 2.

C. **Criteria 3: Project Commitment/Local Cost Participation**

- A 20 percent minimum commitment is required of all projects
- Additional commitment earns additional points

D. **Criteria 4: Intermodal/Multimodal/Social Mobility Rating**

- Actions promoting single occupant vehicle modes score no points
- 20 points is awarded for activities promoting multimodalism (including bikeways)

E. **Criteria 5: Congestion Management Strategies (CMS)/Transportation Control Measures (TCM)**

- Projects score 20 points if they are in the CMS or State Implementation Plan TCMs (including bikeways and related projects)

II. BIKE STORAGE PROJECTS

- Calculations to determine scores for bike storage projects are similar to those used for bikeways.

A. **Bike Storage VHT Saved:**

$$\frac{\text{(long term or work trip related parking spots)} \times \text{(0.25 occupancy)} \times \text{(10 mile round trip length)}}{\text{30 mph}}$$

B. **Bike Storage Annual Benefit:**

(Bike Storage VHT) x ($9/hour) x (260 days/year)

C. **Bike Storage VMT Saved:**

(long term or work related parking spots) x (0.25 occupancy) x (10 mile round trip length)

AIR QUALITY/ENERGY CONSERVATION RATING
INTERSECTION IMPROVEMENTS[1]

I. Calculate Existing Daily Hydrocarbon (HC) Emissions

$$E_b = EF_b * VOL_{app} * DIST_{app}$$

Where: E_b = Emissions before improvement (grams)

EF_b = Emission factor (grams per mile) based on assumed speed before improvement (see Figure 1)

VOL_{app} = Peak-period approach volume

$DIST_{app}$ = Approach distance in miles, varies by project type

II. Determine Average Speed after improvement

Increased Capacity–Improved Level of Service–Higher Speed

III. Calculate Daily HC Emissions after improvement

$$E_a = EF_a * VOL_{app} * DIST_{app}$$

Where: E_a = Emissions after improvement (grams)

EF_a = Emission factor (grams per mile) based on new average speed and improved level of service (see Figure 1)

IV. Find Annual HC Emission Reductions (E_r)

$$E_r = (E_b - E_a) * 300 \text{ days/year}$$

V. Determine Cost per Pound of HC Reductions

$$\text{Cost/Pound} = \frac{\text{Annual Project Cost } (C_t)}{E_r}$$

Where: C_t = 454 grams/pound

VI. Apply Score from Table 1

[1] Includes intersection improvements, grade separations, and signal retiming and progression projects.

APPENDIX G

Federal and State Transportation Control Measures Included in the San Francisco Bay Area's 1994 Regional Transportation Plan

Source: San Francisco No. 3, pages C-1 to C-5.

Attachment C: Federal and State Transportation Control Measures

Table C-1: Transportation Control Measures From the 1982 Federal Air Quality Plan for the Bay Area

	FEDERAL TCMs	DESCRIPTION
TCM 1	Reaffirm commitment to 28% transit ridership increase between 1978 and 1983.	Increase transit ridership according to the transit operator's five-year plans.
TCM 2	Support post-1983 improvements identified in the operator's five-year plans, and, after consultation with the operators, adopt ridership increase target for the period 1983 through 1987.	The goal for this TCM is to increase ridership by 15% between 1982/83 and 1987/88.
TCM 3	Seek to expand and improve public transit beyond committed levels.	This TCM is to upgrade and expand transit service between the years 1982/83 and 1987/88. The goal was to increase the combined fleet size of the nine major operators by 15% during this period.
TCM 4	Continue to support development of High Occupancy Vehicle (HOV) lanes.	Implement HOV lanes where justified on a case-by-case basis; also includes highway ramp meters with HOV bypass lanes.
TCM 5	Continues to support RIDES efforts.	Support for RIDES efforts in regionwide commuter matching services, vanpooling and employer services designed to encourage employees to participate in ridesharing activities.
TCM 6	Continue efforts to obtain funding to support long-range transit improvements.	Covers the funding and implementation of the Guadalupe light-rail transit in Santa Clara County and BART extensions to North Concord and Warm Springs (in Fremont).
TCM 7	Reaffirm commitment to preferential parking program.	Support the development of park-and-ride lots, where commuters can leave their cars and complete trips by other modes.
TCM 8	Encourage transit operators to work with Caltrans to identify underutilized lots along major transit lines that could be used as park-and-ride lots.	Applies to Caltrans' joint use park-and-ride program to establish lots in existing private parking areas; includes the goal of 14 new lots per year.
TCM 9	Expand Commute Alternatives Program.	Encourages employers to promote alternatives to commuting in the single-occupant vehicle. Includes funding to conduct employer transportation coordinator training classes, market ridesharing to the media and employers, and outreach programs to employers.

continued ...

(Cont'd.)
Table C-1: Transportation Control Measures From the 1982 Federal Air Quality Plan for the Bay Area

TCM 10	Develop Information Program for Local Governments	This TCM consists of providing information to local governments and developers detailing the role of local governments in addressing commute transportation and providing technical assistance.
TCM 11	Gasoline Conservation and Awareness Program (GasCap)	The GasCap program was funded by the California Energy Commission, sponsored by Caltrans and administered by the West Valley College. It entailed a training program oriented towards large vehicle fleets to teach proper driving techniques, vehicle maintenance and trip planning. It was discontinued in 1984.
TCM 12	Santa Clara Commuter Transportation Program	This TCM consists of the commuter program adopted by Santa Clara County in 1982. Is consists of a ridesharing program, express bus service, park-and-ride lots, upgrading Southern Pacific (CalTrain) service and HOV lanes

Federal Air Quality Contingency Transportation Control Measures

TCM 13	Increase bridge tolls to $1.00 on all bridges.	Would raise tolls to $1.00 on the Antioch, Bay, Benicia and Carquinez bridges.
TCM 14	Bay Bridge surcharge of $1.00	Increase Bay Bridge toll to $2.00 to discourage single occupant automobile use and improve transit.
TCM 15	Increase state gas tax by 9 cents	Raise State gasoline taxes from 9 cents to 18 cents per gallon. This measure takes credit for emission reductions due to a full 9 cent increase, phased in by 1995.
TCM 16	Implement MTC Resolution No. 1876, Revised—New Rail Starts Agreement	Complete the $3.5 billion, 6 rail extension program by securing State and Federal funds for program. Only takes credit for emission reduction from a future BART extension to Colma.
TCM 17	Continue post-earthquake transit service	Continuation of ferry service initiated after the October 1989 earthquake and the expanded BART peak period service.
TCM 18	Sacramento-Bay Area Amtrak service	Implement near-term improvements recommended in ACR 132 Rail Study. Assumes three trains in each direction between Sacramento and the Bay Area.
TCM 19	Upgrade CalTrain service	Increase service frequency to 66 trains per day. Extend service to Gilroy.

continued ...

(Cont'd.)
Table C-1: Federal Air Quality
Contingency Transportation Control Measures

TCM 20	Regional High Occupancy Vehicle (HOV) Lane System Plan	Expand and improve HOV concept first proposed in TCM 4 by developing and implementing the HOV Lane Master Plan. Includes 221 directional miles of HOV lanes.
TCM 21	Regional Transit Coordination	Includes multiple coordination initiatives: fare coordination, service coordination.
TCM 22	Expand Regional Transit Connection (RTC) ticket distribution	Expand on-going MTC program to provide a regional clearinghouse for sale of transit tickets to employers; encourage employers to subsidize tickets.
TCM 23	Employer audits	Development of a program to review the TSM programs of selected employers in the region and to suggest actions to enhance programs. Will target specific large or mid-size employers and small employers for improved commute alternatives program.
TCM 24	Expand signal timing program to new cities	Establishes a program to provide technical assistance to cities in the form of traffic monitoring, design of signal timing plans, and hardware improvements.
TCM 25	Maintain existing signal timing programs for local streets	Involves the provision of technical assistance to cities for periodic program adjustments and coordination with adjacent cities.
TCM 26	Incident management on Bay Area freeways	Incident management is part of Caltrans' Traffic Operations Systems (TOS). Assumes emission reductions from the initial phases of TOS on the approaches to the Bay Bridge.
TCM 27	Update MTC guidance on development of local TSM programs	MTC report "Key Considerations for Developing Local Government TSM Programs" (December 1988) contains guidance on developing TSM programs and would be updated.
TCM 28	Local Transportation Systems Management (TSM) initiatives	This TCM accounts for effects of new initiatives, such as Golden Triangle Task Force and Contra Costa County Growth Management Program.

Table C-2: Transportation Control Measures Adopted by the Bay Area Air Quality Management District as part of the Bay Area Clean Air Plan to Meet the California Clean Air Act

	STATE TCMs	DESCRIPTION
TCM 1	Expand employer assistance programs	Assist with training employee transportation coordinators and city/county transportation demand management coordinators; with starting-up transportation management associations; and with telecommuting programs, employee commute surveys, vanpool programs.
TCM 2	Adopt employer-based trip reduction rule	BAAQMD to develop and adopt regional employer-based trip reduction rule.
TCM 3	Improve areawide transit service	Increase local bus service; continue post-earthquake increase in BART service; expand rail service; upgrade CalTrain service; convert transit buses to clean fuel vehicles.
TCM 4	Expedite and expand regional rail agreement	Based on MTC Resolution 1876.
TCM 5	Improve access to rail and ferry transit stations	Improve feeder bus service and bicycle access; at transit stations add parking and encourage preferential parking for electric vehicles; add private shuttles from transit stations to employment centers.
TCM 6	Improve intercity rail service	Implement new intercity rail service in Auburn-Sacramento-Oakland-San Jose corridor
TCM 7	Improve ferry service	Per MTC Regional Ferry Plan.
TCM 8	Construct carpool/express bus lanes on freeways, based on *2005 HOV Lane Master Plan*	Would expand existing 80 lane miles to 480 lane miles over next 15 years; implement park-and-ride lots, special HOV ramps, and express bus service.
TCM 9	Improve bicycle access and facilities	Establish Bicycle Advisory Committees and comprehensive bicycle plans; encourage bicycles on transit vehicles and on all bridges; encourage employers and developers to provide bicycle access and facilities.
TCM 10	Youth transportation	Allocate funds for discount youth transit tickets; encourage carpooling among students; convert school buses to clean-fuel vehicles.
TCM 11	Install freeway Traffic Operations System (TOS)	Implement TOS, which includes traffic surveillance, traffic advisory signs, incident management, ramp metering; develop automated electronic toll collection facilities.
TCM 12	Improve arterial traffic management	Expand local signal timing programs for cities; study signal pre-emption for buses; develop SMART streets to serve as reliever routes for congested freeways.

continued ...

(Cont'd.)

Table C-2: Transportation Control Measures Adopted by the Bay Area Air Quality Management District as part of the Bay Area Clean Air Plan to Meet the California Clean Air Act

TCM 13	Transit use incentives	Improve coordination between transit operators regarding routes, schedules, transfers, fares; expand distribution of transit passes and tickets; promote free feeder bus service to BART, CalTrain and ferries; consider fare reductions on off-peak.
TCM 14	Vanpool liability insurance	Assess vanpool market; consider need for publicly funded vanpool insurance program.
TCM 15	Provide financial carpool incentives	Encourage employers to provide subsidies and incentives for ridesharing; support federal and state legislation to increase tax incentives for ridesharing and transit.
TCM 16	Indirect source control program	The BAAQMD to develop rules to reduce vehicle trips to major activity centers such as airports, arenas, universities, residential development, shopping centers.
TCM 17	Conduct public education program	To stress measures the individual can take to help improve air quality; implemented by BAAQMD.
TCM 18	Zoning for higher densities in vicinity of mass transit stations	Encourage cities and counties to promote high density, mixed-use development near transit stations.
TCM 19	Air quality elements for general plans	To promote integration of land use, transportation and air quality planning, BAAQMD to work with cities and counties.
TCM 20	Conduct demonstration projects to develop new strategies for reducing vehicle emissions	Projects include telecommuting centers, electronic toll collection, alternative fuel vehicles.
TCM 21	Implement revenue measures	Develop revenue measures needed to fund mobility improvements and user incentives.
TCM 22	Implement market-based pricing measures	Use revenues for transportation alternatives and equity programs.
TCM 23	Ozone excess "no drive days" (voluntary)	Encourage public to reduce motor vehicle use on days of predicted ozone exceedances.

APPENDIX H

List of Candidate TCMs for the

San Francisco Bay Area's 1990 Transportation Control Measure Plan

Source: San Francisco No. 1, appendices.

Attachment A
SUGGESTED TRANSPORTATION CONTROL MEASURES LIST
(MTC Staff and Task Force Recommendations)

A. MARKETPLACE STRATEGIES: Economic Measures Which Affect How Autos are Used and How Often

- Gas Tax increase
- Bridge toll increase
- Toll Roads
- Automated ("high tech") roadway user fee
- Smog fees based on auto emission levels
- Parking: strategies to increase cost
  - lot fees (sliding scale, long-term v. short-term differentials)
  - levies on employer/commercial lots based on parking spaced used
- Auto free/no parking zones (restrict market supply)
- Taxation policies
  - tax credits for transit users, no-car households, those living close to jobs, manufacturers that produce clean fuels, clean vehicles, employees who don't drive, employers that don't provide parking
  - increased taxes on autos: property taxes
- Increased auto fees
  - registration fees
  - fees for infrastructure, health/research costs
- Employer travel allowances for all modes, equally
- Auto insurance strategies
  - rate decreases for alternative mode users
  - rate decreases for short commutes
  - rate increases on sliding scale for multi-vehicle owners
- Increased subsidies for transit; decreased fares
- Increased subsidies for carpool/vanpool

B. ENRICHING COMMUTER OPTIONS: Expand Regional Transit and Ridesharing System to Serve more Travellers

1. TRANSIT

- Extend regional transit systems; provide more passenger parking and feeder service
- Establish inter-regional rail service
- Increase service effectiveness of transit
  - decrease speeds/travel time/transfer time
  - increase reliability and frequency
  - increase convenience (reduce transfers, single pass instrument among systems)
  - increase amenities (e.g. "first-class" service: price upwards accordingly)
- Consolidate transit services
- Increase cost-effectiveness through competitive bidding
- Expand and restructure local and off-peak transit services

2. RIDESHARING and TRIP PLANNING/COORDINATION

- Construct Regional HOV System
- Increase carpool/vanpool provider options
  - vendor support
  - trial/demonstration vehicles available to new poolers
  - vanpool insurance pool
  - casual carpooling coordiantion/facilities
- Preferential Parking for HOVs
- Shuttle service between auxillary services and employment sites
- Employer Programs with various levels of participation
  - information and marketing services
  - active assistance (ride broker on-site, ride matching)
  - operational assistance (vanpool vehicles, shuttle transit pass sales, guaranteed ride home, auxillary services, bike facilities)
  - subsidies (preferential parking for HOVs, transit subsidies, vans/fleet vehicles)
  - alternative work policies (staggered or compressed work weeks, flex time, work at home or telecommuting)
- Guaranteed ride home for pool participants
- Expand RIDES' matching capabilities and services to employers
- Centralize ridematching services at employer sites
- Expand park and ride lots; place services closer to lots
- Aggressive marketing of all alternative modes (including public media advertising)
- In-home ridematching (computer access); more retail outlets
- Personalized ridematching and trip making services (by carpool or alternative mode)
- Employer in-house trip coordination (errands, meetings)
- Public meetings at transit accessible locations
- Fleet vehicles at employment site

3. BICYCLES

- Provide city bicycle paths and bicycle streets;regional bike route system
- Increase bicycle parking, storage and security facilities
- Bikes on buses/rail transit
- Designated bicycle days

4. OTHER OPTIONS

- Increased water transit options
- Pedestrian priorities policies- urban design (e.g. no limits like pedestrian control signals)
- Taxi reforms: increase service availability
- School buses/ridesharing for children

<u>C. MANAGE CONGESTION</u>: Manage freeways and local streets to reduce congestion

- Implement Traffic Operations System (TOS) for highways
  - incident management
  - ramp metering
  - message signs/traffic advisories
- Improve alternative routes for short trips
- Coordinate signal timing on local street systems
- Improve freeways ramps and merges
- Eliminate bottlenecks on existing freeway system
- Visual barriers on freeways to eliminate "driver gawking"

- o HOVs on local streets and arterials
- o Increased crackdown on double parking
- o "Don't block the intersection" rules
- o Change trucking delivery schedules
- o Separate HOV lanes for buses v. carpools
- o "Smart roads"
- o More public info regarding timed signals (directional signs)
- o Regulate timing of major event trip attractors (i.e. sporting events) to avoid peak hour rush
- o Bus/transit signal preemption
- o Transportation Management Program (TMP) during road construction
- o Permanent TMP programs (don't just implement during construction as mitigation measures)
- o Staggered school v. commute start times
- o CHP pace cars
- o Restrict weaving
- o Better driver education: harder tests; more frequent driving tests
- o Flexible/staggered work hours

D. REGULATE DRIVING

1. LIMIT AUTOMOBILE USAGE

- o Control gasoline supply
- o Limit car registration in the region
- o Assign driving days
- o Force phase out of older cars
- o Require stringent employer commute alternative programs
- o Control truck traffic
  - off-peak delivery and pick-up
  - voluntary v. mandatory programs
- o Restrict older (more polluting) car usage
  - Buy-back of older cars
  - Annual I&M program
  - Flat registration fees on cars or increased registration fee on older models
  - Citations for "smoking" vehicles
- o Reduce ownership of vehicles (e.g. prohibit extra cars)

2. LIMIT DRIVERS

- o Restrict DMV Licensing: deny license after certain number of accidents/ restrict driving to off-peak hours
- o Smart drivers: improve driver education
- o Limit parking availability

E. AUTO FACILITIES RESTRICTIONS

- o Limit further highway expansion
- o Limit parking space in the region
  - Limited parking balanced with alternative option/access
  - Revisions in parking codes
  - Developer parking caps
  - "Buy back" parking space/ convert to other uses
  - Municipally controlled parking (objective: easier control and regulation of lots)

F. TECHNOLOGICAL FIXES

1. CAR TECHNOLOGY

- Stronger Inspection and Maintenance Program/Emission Standards
- Weight and engine redesigns (including electric vehicles)
- Mitigate "cold start"effects

2. FUEL TECHNOLOGY

- Use oxygenated fuels
- Use alternative fuels
- Reduce toxicity of diesel fuel

3. TELECOMMUNICATIONS

- Work at home
- Integration of "techno alternatives" into organizational philosophy (i.e telecommuting programs and training)

G. EDUCATION AND INFORMATION

- Education re: auto use, health, and the environment
- Education on economics of long commute, "budgeting" travel, the advantages of trip linking; real costs of auto usage (health, etc.)
- City sponsored transit fairs
- School curriculum to include alt. modes; classes and field trips by public transit
- Regional transit information centers
- Computerized trip making info., air quality info.

H. GROWTH MANAGEMENT AND LAND USE

- Enact "Balanced Growth" Ordinances-- provide local housing before adding new jobs
- Jobs/housing balance (balanced by income ("affordability"), as well as geographically)
- Building permits conditioned on alternative mode programs
- Improved transit access between jobs and housing
- "Acceptable" transit infrastructure in neighborhoods
- Improved pedestrian access/improved site design
- Electric vehicle zones in commercial developments
- Mixed use development supporting transit use
- Increased densities; in-fill development (residential and non-residentia
- Tax revenue sharing to balance residential/non-residential development, and high/low density housing
- Regional approval of development
- Plan location/schedule construction of transit access prior to completin new development
- Developer bids: meet conditions for accessibility to alt. modes.
- Land use conversions to provide more houising in job-rich areas and jobs in housing-rich areas
- Modify zoning regulations to encourage mixed-use developments along transit corridors
- Local hiring preference
- Site designs to support alternatives to auto

APPENDIX I

Emission Reduction Potential of TCMs and Contingency Plan of San Francisco Bay Area's 1990 Transportation Control Measure Plan

Referred to on page 83.

Source: San Francisco No. 2, pages 35 to 41.

Emissions Reduction Targets for Bay Area State Transportation Control Measures

TCM Number	Description	Percentage Change in:					
		VMT	Trips	HC	CO	NO_x	CO_2
Employer-based Measures							
STCM 1	Employer Assistance Programs	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
STCM 2	Trip Reduction Ordinance	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Net for Employer-based Measures		-0.4	-0.4	-0.4	-0.4	-0.4	-0.4

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Emissions Reduction Targets for Bay Area State Transportation Control Measures

TCM Number	Description	Percentage Change in:					
		VMT	Trips	HC	CO	NO_x	CO_2
Mobility Improvements							
STCM 3	Improve Areawide Transit Service	-1.1	-1.3	-1.3	-1.2	-1.1	-1.1
STCM 4	Expedite and Expand Regional Rail Agreement	-0.6	-0.4	-0.5	-0.5	-0.6	-0.6
STCM 5	Improve Access to Rail Systems	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
STCM 6	Improve Intercity Rail Service	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1
STCM 7	Improve Ferry Service	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1
STCM 8	Carpool/Bus Lanes	-1.0	-0.9	-0.9	-0.9	-0.9	-1.0
STCM 9	Improve Bicycle Access	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1
STCM 10	Youth Transportation	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1
Net for Mobility Improvements		-3.3	-3.3	-3.3	-3.3	-3.2	-3.3

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Emissions Reduction Targets for Bay Area State Transportation Control Measures

TCM Number	Description	Percentage Change in:					
		VMT	Trips	HC	CO	NO_x	CO_2
Traffic Operations Management							
STCM 11	Freeway Incident Management Program	+0.15	< +0.1	-2.0	-2.2	+0.35	-0.2
STCM 12	Improve Arterial Traffic Management	< +0.1	< +0.1	-1.1	-1.1	< +0.1	-0.1
Net for Operations Management		+0.2	+0.1	-3.1	-3.3	+0.4	-0.3
User Incentives							
STCM 13	Reduced Transit Fares	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2
STCM 14	Vanpool Liability Insurance	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1
STCM 15	Carpool/Vanpool Incentives	-0.3	-0.2	-0.2	-0.2	-0.3	-0.3
Net for User Incentives		-0.5	-0.5	-0.5	-0.5	-0.5	-0.5

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Emissions Reduction Targets for Bay Area State Transportation Control Measures

TCM Number	Description	Percentage Change in:					
		VMT	Trips	HC	CO	NO_x	CO_2
Implementation Support (Blanks indicate measures that primarily support other TCMs)							
STCM 16	Indirect Source Review						
STCM 19	Air Quality Element of General Plan						
STCM 17	Public Education						
STCM 20	Demonstration						
	Monitoring						
Net for Implementation Support		0	0	0	0	0	0

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Emissions Reduction Targets for Bay Area State Transportation Control Measures

TCM Number	Description	Percentage Change in:					
		VMT	Trips	HC	CO	NO_x	CO_2
Alternative Revenue Concepts							
STCM 21	Bridge Tolls to $2.00	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Gas Tax Increase of $0.14 Per Gallon	-0.8	-0.7	-0.7	-0.7	-0.8	-0.8
	Registration Fee Increase of $4.00 Per Year	-	-	-	-	-	-
Net for Alternative Revenue Concepts		-1.3	-1.2	-1.2	-1.2	-1.3	-1.3
Transit/Land Use Integration							
STCM 18	Zoning Overlays for Higher Densities near Transit Stations	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1
Net for Transit/Land Use Integration		-0.1	-0.2	-0.2	-0.2	-0.1	-0.1

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Summary of Emissions Reduction Targets for Bay Area Air Quality Transportation Measures

Description	Percentage Change in:					
	VMT	Trips	HC	CO	NO_x	CO_2
Integrated TCM Package: Employer-based Measures	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Mobility Improvements	-3.3	-3.3	-3.3	-3.3	-3.2	-3.3
Traffic Operations Management	+0.2	+0.1	-3.1	-3.3	-0.3	+0.1
User Incentives	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Alternative Revenue Concepts	-1.3	-1.2	-1.2	-1.2	-1.3	-1.3
Transit/Land Use Integration	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1
Implementation Support	0	0	0	0	0	0
Net Result (Note: the joint effect is less than the sum over individual measures)	-5.1	-5.2	-8.3	-8.4	-5.5	-5.2

Notes:

1. These results assume full implementation of all TCMs and support elements in the mobility package. Smaller reductions would occur if the some measures were not fully implemented. Larger reductions for the mobility measures would occur if measures from the second tier (market-based) list were put in place.

2. Each TCM in the mobility package reflects a multifaceted set of actions. Target emissions reductions are based on proposed actions and available analysis tools as of December 11, 1990. Additional information about implementation, and improved analysis tools, will result in some adjustment of emissions projections as the Air District and MTC carry forward with the planning process.

Bay Area Air Quality Transportation Plan: Contingency Measures

Description	VMT	Trips	HC	CO	NO_x	CO_2
Market-Based Strategies with Added Incentives and Investment						
Regionwide Employee Parking Charge of $3.00 Per Day	-1.2	-1.5	-1.4	-1.4	-1.5	-1.2
Subsidized Transit and Ridesharing	-2.1	-2.5	-2.3	-2.3	-2.2	-2.1
Regionwide Non-employee Parking Charge of $0.01 Per Minute	-4.6	-5.8	-5.4	-5.4	-5.2	-4.6
Subsidized Off-Peak Transit	-1.5	-1.7	-1.6	-1.7	-1.5	-1.5
Gasoline Tax Increase to $2.00 Per Gallon	-8.1	-7.6	-7.9	-7.8	-8.0	-8.1
Mileage- and Smog-Based Registration Fee (average $125 per vehicle)	-0.2	-0.1	-4.5	-4.5	-1.2	0.0
Regionwide Congestion Pricing (LOS D)	-1.1	-2.1	-6.8	-6.8	+0.3	-6.3
Net for Market-Based Strategies	-18.5	-19.6	-26.5	-26.5	-18.5	-21.7

Notes: 1. These results assume full implementation of the Federal TCMs and the core measures of the State TCM Plan. Much smaller reductions would occur without the core measures in place.

APPENDIX J

Phase 3 of the Boston PMT Development Process

Source: Boston No. 9, appendix F.

Appendix F
Project Characteristics, Performance Measures and Evaluation Criteria

During the 18 months of the PMT Update process, over 70 potential expansions or changes to MBTA and MBTA-related services were examined in detail. This examination consisted of the determination of projected ridership for each project in 2020,[1] operating and capital costs, fare revenue, and service, traffic and air quality impacts. Each project was then evaluated based on a number of measures addressing utilization, cost-effectiveness, and a number of financial, air quality, and other impacts. This appendix describes the evaluation process, and describes and presents all of the project characteristics, performance measures, and qualitative rankings developed for each project examined in the PMT. (Appendix G describes the interpretation of these data, and conclusions, on a project-by-project basis.)

Evaluation Process

The evaluation of projects generally consisted of five steps: (1) project definition, (2) determination of project characteristics, (3) calculation of performance measures and the development of qualitative rankings, (4) interpretation of data, and (5) conclusions. For most projects, new data was developed or existing data was updated.[2] Each step consisted of the following:

1. **Project Definition** The first step was to define the assumed physical and operating attributes of each project. This included the mode, alignment, station locations, level of service, span of service, and changes in connecting and parallel services. For

[1]Note that through most of the PMT process, ridership estimates were produced for 2010. To provide for consistency with Regional and State Transportation plans, these estimates have been updated to reflect MAPC and CTPS projections of population, employment, and travel for 2020. (See also Appendix E.)
[2]Exceptions were Washington Street Replacement Service, Old Colony Commuter Rail Restoration, and South Boston Piers Transitway, and the North Station - South Station Rail Link. For the first three projects, which were "base case" projects, information for the EIR/ENFs is presented but no additional analysis was conducted. For the Rail Link, information developed by the Central Artery Rail Link Task Force was used in the PMT analysis.

each project, the mode and alignment were chosen in specific terms. However, station locations were more general, such as at a street intersection, rather than on a certain parcel. Operating characteristics (level of service and span of service) were generally defined to be the same as for other comparable services. Impacts on other services, if any, were defined based on the judgments of MBTA and project staff. A description of how each project was defined is included in Appendix G.

2. **Determination of Project Characteristics** A large number of "project characteristics" were developed for each project. These characteristics, which are described in detail in the next section, included projected ridership for each project in 2020, operating and capital costs, fare revenue, and service, traffic and air quality impacts. Some important notes about these figures are as follows:

   — Ridership was projected using CTPS' Regional Transit Model as described in Appendix E.
   — Operating costs were developed based on actual 1991 MBTA operating costs, allocated by mode on a cost per vehicle service hour basis. This information was provided by the MBTA Budget office.
   — Capital costs were developed using either unit costs derived from recently implemented projects or from recent feasibility studies or EIRs. All capital costs are presented in 1993 dollars.
   — Fare revenue is estimated based on the projected ridership and 1993 average fares for each mode and zone.
   — Air quality impacts are based on estimates of VMT changes that were produced during the ridership estimation process. (See Appendix H for additional information on air quality issues.)

3. **Calculation of Performance Measures/Development of Qualitative Rankings** Based on the ridership, cost, air quality, and other characteristics that were developed for each project, a number of quantitative performance measures were calculated. For issues for which quantitative measures could not be developed, a number of qualitative measures and rankings were developed. Both the quantitative and qualitative measures are described in detail in the Evaluation Criteria section of this appendix.

4. **Interpretation of Data** Once project characteristics, performance measures, and qualitative rankings had been developed, these data needed to be interpreted. With the diversity of project types represented in the list of proposed changes and expansions, not all of the evaluation criteria could be applied equally to all projects. However, in most cases, the criteria that were considered to be the most important were number of new transit trips, capital cost per new transit trip, net operating cost, travel time savings, percent emissions reduction, and cost per kilogram of Volatile Organic Compound (VOC) eliminated. The other factors were considered, especially in cases where the above mentioned factors did not capture all of the salient characteristics of a project (for example, in the restoration/replacement of trolley service to Arborway), but not to as great an extent as the aforementioned measures. The interpretation of the data and a discussion of the most important impacts of each project is included in Appendix G.

5. **Conclusions** Based on the interpretation of the available information described in step (4), conclusions were made as to each project's merit. These conclusions were used to develop the recommend program described in the PMT report.

It is important to note that projects were analyzed at level of detail appropriate for systems level planning. The objective was to identify those projects that would appear to be the most effective and worthy of further, more in-depth study. Many of the projects recommended in the PMT require environmental impact and alternatives analysis before they can proceed to design and construction.

It is also important to note that ridership projections, which are for the year 2020, depend to a great extent, on growth in population and employment. If these projects were built tomorrow, they would not achieve the ridership levels forecast by the regional model because the projected growth has not yet occurred. Operating costs, on the other hand, are presented in 1991 dollars, fare revenue figures are based on current (1993) fare levels, and capital costs are in 1993 dollars. Implicit within the use of these figures is the assumption that costs and fare revenue will increase at the same rate as inflation. Costs could rise faster or slower than inflation depending on the wage rate, labor agreements, changes in technical efficiencies in both construction and operations, and future fare increases.

Project Characteristics

A large number of quantitative project characteristics were developed for each project. As shown in Table F-1 and described below, these focused on ridership, service levels, operating and capital costs, fare revenue, air quality, traffic impacts, and service quality. Table F-1 contains all of the statistics associated with each project examined in the PMT. The columns are as defined below.

Ridership

- Total New Trips Total new trips attracted to the new/upgraded service or facility for the year 2020. This includes both riders diverted from the auto mode and riders diverted from other transit modes. Total new trips is equal to the total number of new passenger boardings on the service, regardless of the direction of travel.

- New Transit Trips The number of total new weekday transit trips on the new/upgraded service or facility for the year 2020. This figure includes only riders diverted from auto trips. It does not include any riders that may be diverted from other transit modes.

- Auto Reduction The reduction in the number of automobile trips that occurs as a result of the new/upgraded service or facility. This is the difference between the amount of traffic projected for 2020 with and without the service, and is based on an auto occupancy rate of 1.29 passengers per vehicle.

Amount of Service

- Vehicle Service Miles This is the net change in service miles traveled by vehicles offering the new service. A vehicle is defined as a single rail car or bus—a six-car Red Line train traveling for one hour would accumulate six vehicle service hours.

- Vehicle Service Hours This is the net change in service hours performed by vehicles offering the new service.

Costs/Revenues

- Total Capital Cost The cost to construct the new facility or service, including vehicle costs. The cost estimates are in 1993 dollars. The sources for the capital costs are based on estimates from MBTA consultant studies, estimates from the MBTA, or generated by CTPS using standard transit construction cost figures.

- Annualized Capital Cost The cost to maintain the facility on an ongoing basis. These costs, also in 1993 dollars, were calculated using the life-cycle costing method (see Chapter 6 for a full discussion).

- Annual Operating Cost The cost to operate the service. These figures were calculated by multiplying the number of vehicle service hours by the average hourly operating cost for that mode of transit vehicle. The average costs were provided by the MBTA.

- Annual Fare Revenue The amount of fare revenue expected to be generated by the new service. These figures were derived either through the regional model, or by applying average fares to the new ridership generated.

Air Quality

- VOC Reduction The number of kilograms of volatile organic compounds estimated to be eliminated by the project. These figures were derived by multiplying the reduction in vehicle miles traveled by an emissions factor from Mobile5A. (For further details, see Appendix H.)

Traffic

- VMT Reduction The number of vehicle miles traveled eliminated by drawing people out of automobiles and onto the new service. This figure is calculated by the regional model.

- VHT Reduction The number of vehicle hours of travel eliminated by drawing people out of automobiles and onto the new service. This figure is calculated by the regional model.

Service Quality

- Travel Time Savings The travel time savings that would be accrued by those transit users in the year 2020 who would be on the system before the improvements are made.

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s) Note 1	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s) Note 2	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
1. Upgrade the System															
A. Faster Commuter Rail Service (Express/Local 2010)															
• Rockport/Ipswich Line		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$870	30.6	25,063	1,288	803	200,750
• Haverhill/Reading Line		1,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,437	80.7	66,118	2,132	614	128,500
• Lowell Line		4,602	2,561	1,985	702	4	$17,052	$682	$156	$1,409	70.1	57,499	1,846	1,015	253,750
• Fitchburg Line		1,138	956	741	3,271	103	$72,906	$2,905	$4,196	$564	26.1	21,421	892	298	74,500
• Framingham Line		1,464	576	447	223	48	$18,300	$955	$1,942	$314	16.3	13,320	636	66	16,500
• Needham Line		555	158	122	330	37	$23,268	$931	$1,519	$50	1.5	1,245	83	63	15,750
• Franklin Line		2,580	1,245	865	1,643	72	$45,816	$2,033	$2,904	$711	26.6	21,788	439	143	35,750
• Attleboro/Stoughton Line		525	490	380	1,350	21	$20,790	$832	$847	$275	11.6	9,548	424	174	43,500
B. Bus Service Improvements Into Downtown Boston															
• Better Downtown Bus Circulation		11,875	7,220	5,597	707	76	$6,100	$504	$1,265	$1,341	76.6	62,814	3,895	1,733	433,250
• Sumner Tunnel Approach		110	0	0	0	-5	$100	$4	($86)	$0	0.0	0	0	L	L
2. Intermodal Connections															
A. Park and Ride Expansion**															
• Intercept Stations along Major Highways		14,310	3,980	3,085	NA	NA	$60,200	$2,408	L	$2,219	69.4	56,880	1,854	465	142,290
• Other Rapid Transit Expansion		14,490	3,690	2,860	NA	NA	$128,840	$5,158	L	$535	30.6	25,092	923	246	76,276
• Other Commuter Rail Expansion		19,080	8,352	6,474	NA	NA	$89,570	$3,583	L	$2,777	120.2	98,550	2,790	315	84,735
• Other Bus		2,410	1,640	1,271	NA	NA	$2,600	$104	L	$469	26.3	21,586	404	70	20,020
B. New Commuter Rail Stations/Additional Service															
• Alewife	3	1,020	348	270	NA	NA	$7,560	$322	[illegible]	$80	4.7	3,840	198	319	86,811
• Wonderland	3	7,200	1,080	837	339	11	$9,316	$1,066	$461	$247	9.5	7,770	278	1,276	342,075
• Riverside	3	876	876	679	107	12	$4,308	$134	$444	$507	6.1	4,983	249	676	164,944
• Mattapan	3	1,680	189	147	176	5	$8,160	$333	$125	$43	1.4	1,117	63	49	13,181
• JFK/UMASS	3	862	266	206	NA	NA	$1,560	$62	[illegible]	$61	5.4	4,466	252	266	71,554
• Ruggles		864	328	254	NA	NA	$1,560	$62	[illegible]	$75	3.4	2,776	212	144	38,736
3. Urban Core Distribution															
A. New Ferry Service**															
• North Station to Fan Pier and World Trade Center	4	1,378	L	L	NA		$2,089	$104	$1,555	$0	L	L	L	L	L
• North Station to Navy Yard Pier 4 and Logan Airport	4	713	L	L	NA		$1,702	$85	$1,348	$0	L	L	L	L	L
• South Station to Long Wharf and Navy Yard Pier 4	4	1,045	L	L	NA		$1,410	$71	$1,138	$0	L	L	L	L	L
• Navy Yard Pier 4 to Long Wharf and World Trade Ctr	4	380	L	L	NA		$1,713	$86	$2,045	$0	L	L	L	L	L
• South Station to Navy Yard Pier 11	4	831	L	L	NA		$1,358	$68	$638	$0	L	L	L	L	L
B. Circumferential Transit**	4														
• Core LRT: Sullivan – Ruggles		86,700	18,213	14,119	1,593	130	$1,078,885	$29,767	$4,865	$3,232	141.4	115,913	8,350	9,400	2,878,400
• Full LRT: Airport – JFK/UMass		149,525	34,375	26,647	3,580	365	$1,430,854	$35,776	$13,703	$8,101	184.1	150,825	11,719	8,244	1,910,864
• Bus Improvements		*To be determined in MBTA Crosstown Transit Feasibility St*					$2,350	$196	$1,500	$0					

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
3. Urban Core Distribution (Cont.)															
C. South Boston Piers: South Station to Boylston															
• w/High growth	5	36,000	7,800	2,100			$180,000	($1,050)	($1,594)	($40)	39.9	32,700		2,248	642,857
• w/ Lower growth	5	26,850	6,500	1,700			$180,000	$771	($456)	$280	31.8	28,100		1,733	495,567
D. N. Station–S. Station Rail Link**	4														
Phase 1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$1,85[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phase 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$1,78[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	4	57,000	23,000	17,828	37,492	[illegible]	$3,633,000	[illegible]	$47,000	$36,000	446.5	386,000	[illegible]	[illegible]	[illegible]
E. Red Line - Blue Line Connector**	4	19,210	4,972	2,354	1,480	15	$137,[illegible]00	$4,580	$456	$1,480	42.4	34,770	961	2,458	752,148
F. Connections to Logan Airport															
• Bus Service from North Station		718	90	70	156	23	$1,097	$91	$438	$12	1.8	1,437	33	59	16,874
• Bus Service from South Station		1,413	45	35	192	29	$1,367	$114	$549	$8	1.0	805	14	153	43,758
• Blue Line Spur to Logan Central Terminal		7,232	2,000	1,550	625	35	$29,400	$1,080	$1,040	$355	16.6	13,601	486	2,269	694,314
• Express Bus from Newton Corner		271	[illegible]	96	412	20	$827	$69	$383	$35	1.3	1,032	51	64	18,304
• Express Bus from Waltham (Rt 128 @ Winter St)		192	[illegible]	96	634	31	$1,097	$91	$581	$53	1.7	1,356	54	68	19,448
4. New Radial Services															
A. Blue Line Extensions															
• Wonderland to Lynn		11,340	4,860	3,767	7,540	255	$275,000	$11,800	$10,251	$1,431	80.3	49,440	3,600	893	273,258
• Bowdoin to Medford Hillside (Includes Blue-Red Conn.)		32,872	7,28[illegible]	5,646	8,210	350	$548,43[illegible]	$15,882	$10,894	$2,144	88.2	54,263	3,322	2,565	784,880
• Bowdoin to Riverside via Esplanade (Rivervision)		70,500	8,00[illegible]	6,202	13,700	462	$385,500	$32,700	$11,016	$1,688	89.6	57,060	3,800	3,292	1,007,250
• Bowdoin to Riverside via Huntington Ave		81,400	8,70[illegible]	6,744	14,420	455	$683,500	$33,636	$10,404	$1,864	71.6	58,660	3,900	4,847	1,483,080
• Gov't Center to Riverside via Newbury St		84,610	10,24[illegible]	7,938	13,700	500	$986,000	$33,600	$12,118	$2,207	101.4	83,150	3,400	6,244	1,910,813
B. Orange Line Extensions															
• Forest Hills to Route 128		13,648	4,704	3,647	-1,715	180	$249,03[illegible]	$9,454	$1,872	$957	40.2	32,921	2,522	1,625	466,650
C. Green Line Extensions															
• Lechmere to Medford Hillside**		11,560	3,6[illegible]	2,838	1,170	25	$288,000	$2,875	$2,111	$1,072	47.3	38,770	1,288	1,161	355,266
• Comm Ave to Oak Square	4	32,940	1,006	780	-890	125	$93,800	[illegible],769	$8,609	$425	8.6	7,232	260	568	173,808
• Restoration of E Line to Arborway**	4	36,160	[illegible]	119	-1,128	-179	$56,600	[illegible]202	($1,484)	$23	0.9	763	54	2,280	881,560
D. Red Line Extensions															
• Ashmont to Mattapan		4,718	1,2[illegible]	977	1,760	45	$54,800	[illegible]741	$1,331	$244	10.7	8,736	665	338	103,428
• Alewife to Lexington		8,883	2,37[illegible]	1,842	7,800	230	$590,038	$1,[illegible]19	$9,486	$700	43.3	35,508	1,992	737	225,522
E. Bus/Trackless Trolley Services															
• Arborway Trackless Trolley		36,697	[illegible]	245	-425	-130	$27,000	$576	($2,554)	$43	2.5	2,068	40	1,262	360,932
• Express Rt 1/128 to Boston via Route 1		2,473	[illegible]	1,507	761	50	$3,557	$201	$833	$724	33.1	27,094	1,472	698	199,628
• Express Rt 3/128 to Boston via 128 and I-93		3,140	[illegible]	1,826	916	56	$4,382	[illegible]	$933	$877	31.9	26,163	1,541	315	90,090
• Express Rt 3/128 to Alewife via Rts 128 and 2		2,473	[illegible]	1,587	682	31	$3,107	[illegible]	$516	$507	27.7	22,667	1,225	615	147,290
• Improved Express Service in the Mass Pike Corridor		523	[illegible]	250	89	6	$0	[illegible]	$83	$120	4.2	3,479	81	29	8,294

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles /Weekday	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
4. New Radial Services (Cont.)															
F. Commuter Rail Extensions															
• Ipswich Line: Ipswich to Newburyport**	4														
Existing Line Improvements		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$870	30.6	25,063	1,288	[illegible]	[illegible]
Newburyport Extension Segment		1,638	1,438	1,115	1,184	38	$42,800	$1,712	$1,663	$1,253	27.2	22,325	1,225	[illegible]	[illegible]
Total		3,788	2,901	2,249	4,956	68	$61,400	$2,447	$2,880	$2,124	57.8	47,388	2,513	258	88,402
• Haverhill Line: Wakefield to Topsfield															
Existing Line Improvements		4,056	1,924	1,491	-395	2	$5,000	$167	$3,500	$957	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Topsfield Extension Segment		767	546	423	4,531	156	$87,442	$3,769	$3,117	$308	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		4,823	2,470	1,915	4,136	158	$92,442	$3,936	$6,617	$1,265	63.7	52,182	2,340	306	82,314
• Haverhill Line: Haverhill to Plaistow NH	4,6														
Existing Line Improvements		4,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,436	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Plaistow Extension Segment		689	286	222	144	27	$26,216	$1,046	$1,173	$283	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		5,226	3,172	2,459	2,357	84	$65,320	$2,577	$3,500	$1,718	NA	NA	NA	NA	NA
• Lowell Line: Lowell to Nashua, NH															
Existing Line Improvements		5,759	3,198	2,479	2,544	41	$17,052	$682	$1,785	$1,759	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nashua Extension Segment		1,482	520	403	1,557	67	$51,652	$1,777	$2,907	$562	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		7,241	3,718	2,882	4,100	108	$68,704	$2,459	$4,692	$2,321	100.3	82,251	4,713	3,134	843,046
• Framingham Line: Framingham to Worcester**	4														
Existing Line Improvements		684	264	205	[illegible]	[illegible]	$0	$0	[illegible]	$144	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Worcester Extension Segment		6,012	3,204	2,484	5,382	166	$116,964	$4,281	$7,245	$4,563	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		6,696	3,468	2,688	5,382	166	$118,964	$4,261	$7,245	$4,707	81.9	67,140	2,580	1,214	326,586
• Framingham Line: Framingham to Marlborough	4									$1					
Existing Line Improvements					[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Marlboro Extension Segment		1,632	774	600	6,140	196	$73,600	$4,028	$8,572	$813	31.5	25,848	1,428	287	64,336
Total		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
• Franklin Line: Forge Park/495 to Milford															
Existing Line Improvements		1,928	930	721	138	-7	$45,816	$2,033	($284)	$644	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Milford Extension Segment		383	83	64	517	53	$27,973	$1,891	$2,313	$169	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		2,311	1,013	785	655	46	$73,789	$3,924	$2,029	$813	23.0	18,833	308	131	35,239
• Franklin Line: Walpole to Foxborough															
Existing Line Improvements		1,538	810	628	2,676	47	$13,545	$542	$1,894	$415	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foxborough Segment		38	8	6	671	21	$14,104	$552	$908	$8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total		1,576	818	634	3,347	68	$27,649	$1,094	$2,802	$423	20.2	16,568	285	117	31,473
G. Other New Commuter Rail Services															
• New Bedford/Fall River Lines	4	6,465	2,820	2,186	10,670	255	$288,000	$7,665	$12,205	$2,647	83.3	68,279	NA	NA	NA
• New Mills Line		1,823	855	663	3,292	128	$66,728	$2,778	$5,565	$1,201	28.0	22,920	1,200	203	54,807
• Additional CR Service to Dedham Corporate Center		630	0	0							0.0	0	0	0	0

Project	Note	Ridership: Total New Trips (/Weekday)	Ridership: New Transit Trips [illegible] (/Weekday)	Ridership: Auto Reduction (/Weekday)	Amount of Service: Veh Ser Miles (/Weekday)	Amount of Service: Veh Ser Hours (/Weekday)	Costs/Revenues: Total Capital Cost ($000s)	Costs/Revenues: Ann Capital Cost ($000s)	Costs/Revenues: Ann Oper Cost ($000s)	Costs/Revenues: Ann Fare Revenue ($000s)	Air Quality: VOC Reduction (kg/WD)	Traffic: VMT Reduction (/WD)	Traffic: VHT Reduction (/WD)	Service Quality: Travel Time Savings (Hrs/WD)	Service Quality: Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
5. Suburban Circumferential Movement															
A. Route 128 Circumferential Bus Service		3,474	3,474	2,693	5,340	250	$7,906	$664	$4,823	$861	44.2	36,270	848	NA	NA
B. Feeder Bus to Rapid Transit at Riverside		690	490	380	[illegible]	48	$1,350	$113	$799	$139	9.6	7,840	120	13	3,250
C. Feeder Bus to Commuter Rail in Needham	7	340	0	0	[illegible]	18	$60	$20	$113	$0	0.0	0	0	0	0

Notes:

1. Capital costs are in 1993 dollars.
2. Revenue figures are based on current (1993) fare levels
3. Ridership is daily transfer volume
4. Parallel Study
5. Results from DEIS/SDEIR, November 1992. High growth scenario is comparable to 2010 PMT forecasts
6. Results from "Draft Report: Ridership Potential: Plaistow, NH - Boston, MA Commuter Rail Service," Frederic R. Harris, Inc., November 1992
7. This service is assumed to be privately operated. The capital cost of vehicles would be included in the contract cost for operations.

Codes:

NA = Not Available or Not Applicable

L = Low or Insignificant

** Central Artery Mitigation/SIP Project

Evaluation Criteria

Using the project characteristics described in the previous section, a number of quantitative performance measures were developed. In addition, in order to consider non-quantitative impacts, a number of qualitative measures were also developed. As described below, these quantitative and qualitative measures became the basis for the evaluation of projects.

The use of the criteria was aimed at achieving the following objectives:

- Pursuing the most cost-effective of the proposed projects.
- Evaluating projects fairly and consistently.
- Using quantifiable performance-based standards to the maximum feasible extent.

The proposed performance measures were developed based on a number of considerations, including the policies in the PMT Phase 2 report, consistency with other similar studies, the intent of ISTEA, and the criteria used by MBTA Advisory Board's Capital Planning Committee. The resulting performance measures fall into nine categories: (1) Utilization, (2) Cost-Effectiveness, (3) Financial Impacts, (4) Air Quality Impacts, (5) Service Quality and Coverage, (6) Impact on Existing System, (7) Economic Impacts, (8) Compatibility with Land Use Plans, and (9) Compatibility with Other Plans.

As mentioned above, the criteria that were considered to be the most important were number of new transit trips, capital cost per new transit trip, net operating cost, travel time savings, percent emissions reduction, and cost per kilogram of volatile organic compound eliminated. The other factors were used to evaluate projects, but not to as great an extent.

In detail, the performance measures that were used were as described below. These measures are presented on a project-by-project basis in Table F-2.

Utilization

- Total New Trips Total new trips attracted to the new/upgraded service or facility for the year 2020. This includes both riders diverted from the auto mode and riders diverted from other transit modes. Total new trips is equal to the total number of new passenger boardings on the service, regardless of the direction of travel.

- New Transit Trips The number of total new weekday transit trips on the new/upgraded service or facility for the year 2020. This figure includes only riders diverted from auto trips. It does not include any riders that may be diverted from other transit modes.

- Riders/Vehicle Service Hour (VSH) and Riders/Vehicle Service Mile (VSM) These two figures provide a measure of how well utilized a service would be. A vehicle is defined as a single rail car or bus—a six-car Red Line train traveling for one hour would accumulate six vehicle service hours.

	[illegible]				Cost Effectiveness					Air Quality Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)
1. Upgrade the System											
A. Faster Commuter Rail Service (Express/Local 2010)											
• Rockport/Ipswich Line	2,150	1,463	71 7	0 6	72%	$25,427	$1,005	$4	$346	0.04%	$608
• Haverhill/Reading Line	4,537	2,886	79 1	2 1	62%	$27,089	$1,061	$12	$890	0.10%	$485
• Lowell Line	4,602	2,561	1,198 4	6 6	804%	$13,317	$533	$3	-$1,253	0.08%	$243
• Fitchburg Line	1,138	856	11 0	0 3	13%	$152,523	$6,077	$39	$3,632	0.03%	$2,790
• Framingham Line	1,464	576	[illegible]	6 6	16%	$63,542	$3,316	$58	$1,628	0.02%	$1,126
• Needham Line	555	158	[illegible]	1 7	3%	$294,532	$11,785	$59	$1,469	0.00%	$15,319
• Franklin Line	2,580	1,245	[illegible]	1 6	24%	$73,600	$3,266	$57	$2,193	0.03%	$1,724
• Attleboro/Stoughton Line	525	490	[illegible]	0 4	32%	$84,857	$3,394	$19	$572	0.01%	$1,785
B. Bus Service Improvements into Downtown Boston											
• Better Downtown Bus Circulation	11,875	7,220	156 3	16 6	106%	$1,690	$140	$1	-$76	0.09%	$80
• Sumner Tunnel Approach	110	0	NA	NA	NA	NA	NA	NA	-$86	0.00%	NA
2. Intermodal Connections											
A. Park and Ride Expansion**											
• Intercept Stations along Major Highways	14,310	3,980	[illegible]	NA	NA	$30,251	$1,2[illegible]	$17	NA	0.08%	$868
• Other Rapid Transit Expansion	14,490	3,690	[illegible]	NA	NA	$69,886	$2,79[illegible]	$69	NA	0.04%	$4,212
• Other Commuter Rail Expansion	19,080	8,352	[illegible]	NA	NA	$21,449	$858	$42	NA	0.14%	$745
• Other Bus	2,410	1,640	[illegible]	NA	NA	$3,171	$127	$5	NA	0.03%	$99
B. New Commuter Rail Stations/Additional Service											
• Alewife	1,020	348	NA	NA	NA	$43,448	$1,853	$4	-$80	0.01%	$1,614
• Wonderland	7,200	1,080	627 5	[illegible] 2	54%	$17,252	$1,873	$3	$214	0.01%	$983
• Riverside	876	876	73 0	[illegible] 2	114%	$9,836	$306	$1	-$63	0.01%	$709
• Mattapan	1,680	188	373 3	[illegible] 5	35%	$86,243	$3,524	$25	$82	0.00%	$5,981
• JFK/UMass	952	266	NA	NA	NA	$11,729	$469	$1	-$61	0.01%	$286
• Ruggles	884	328	NA	NA	NA	$9,512	$380	$2	-$75	0.00%	$481
3. Urban Core Distribution											
A. New Ferry Service**											
• North Station to Fan Pier and World Trade Center	1,378	L	NA	NA	NA	NA	[illegible]	NA	$1,655	L	NA
• North Station to Navy Yard Pier 4 and Logan Airpor[t]	713	L	NA	NA	NA	NA	[illegible]	NA	$1,348	L	NA
• South Station to Long Wharf and Navy Yard Pier 4	1,045	L	NA	NA	NA	NA	[illegible]	NA	$1,138	L	NA
• Navy Yard Pier 4 to Long Wharf and World Trade C[enter]	380	L	NA	NA	NA	NA	[illegible]	NA	$2,045	L	NA
• South Station to Navy Yard Pier 11	831	L	NA	[illegible]	NA	NA	[illegible]	NA	$638	L	NA
B. Circumferential Transit**											
• Core LRT: Sullivan – Ruggles	86,700	18,213	666 9	[illegible]	66%	$118,474	[illegible]	$10	$1,633	0.17%	$7,629
• Full LRT: Airport – JFK/UMass	149,525	34,375	409 7	[illegible]	45%	$83,250	[illegible]62	$19	$7,602	0.22%	$7,771
• Bus Improvements	To be determined in MBTA Cross-[illegible] Transit Feasibility St[udy]										

Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development

	Utilization				Cost Effectiveness					Air Quality Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)
3. Urban Core Distribution (Cont.)											
C. South Boston Plan: South Station to Boylston											
• w/High growth	36,000	7,800	NA	NA	3%	$46,154	-$260	-$2	-$1,554	0.05%	$4,512
• w/Lower growth	26,850	6,500	NA	NA	-61%	$55,385	$237	$2	-$736	0.04%	$5,853
D. N. Station—S. Station Rail Link**	67,000	23,000	NA	1.5	77%	$315,013	$0	NA	$11,000	0.54%	$8,136
E. Red Line - Blue Line Connector**	18,210	4,972	1,280.7	13.0	325%	$55,310	$1,842	$6	-$1,024	0.05%	$3,241
F. Connections to Logan Airport											
• Bus Service from North Station	718	80	31.2	4.6	3%	$24,378	$2,024	$5	$426	L	NA
• Bus Service from South Station	1,413	45	48.7	7.4	1%	$60,756	$5,040	$3	$543	L	NA
• Blue Line Spur to Logan Central Terminal	7,232	2,000	206.6	11.6	34%	$29,400	$1,080	$2	$685	0.02%	$1,772
• Express Bus from Newton Corner	271	124	13.6	0.7	9%	$13,330	$1,106	$4	$348	0.00%	$657
• Express Bus from Waltham (Rt 128 @ Winter St)	182	124	6.2	0.3	9%	$17,694	$1,469	$5	$529	0.00%	$683
4. New Radial Services											
A. Blue Line Extensions											
• Wonderland to Lynn	11,340	4,860	44.5	1.5	14%	$113,160	$4,856	$43	$8,820	0.07%	$4,550
• Bowdoin to Medford Hillside	32,872	7,283	83.9	3.6	20%	$150,606	$4,361	$20	$8,750	0.08%	$8,284
• Bowdoin to Riverside via Esplanade (Riverview)	70,500	8,000	152.6	5.1	15%	$246,375	$8,175	$32	$8,320	0.08%	$14,157
• Bowdoin to Riverside via Huntington Ave	81,400	8,700	178.9	5.6	18%	$203,103	$7,732	$23	$8,540	0.09%	$12,345
• Gov't Center to Riverside via Newbury St	84,610	10,240	169.2	6.2	18%	$182,578	$6,563	$18	$9,811	0.12%	$9,720
B. Orange Line Extensions											
• Forest Hills to Route 128	13,648	4,704	75.8	-0.4	51%	$105,882	$4,010	$20	$915	0.05%	$6,201
C. Green Line Extensions											
• Lechmere to Medford Hillside**	11,560	3,661	462.4	8.9	51%	$48,074	$1,571	$8	$1,039	0.06%	$1,860
• Comm Ave to Oak Square	32,940	1,006	263.5	-37.0	5%	$186,481	$7,480	$22	$8,184	0.01%	$10,631
• Restoration of E Line to Arborway**	36,160	136	-202.0	-32.1	-2%	$834,808	$32,478	$3	$1,507	0.00%	$60,824
D. Red Line Extensions											
• Ashmont to Mattapan	4,718	1,260	104.8	2.7	18%	$46,984	$2,763	$17	$1,087	0.01%	$5,142
• Alewife to Lexington	8,880	2,376	38.6	1.1	7%	$486,865	$10,200	$54	$8,786	0.05%	$13,821
E. Bus/Trackless Trolley Services											
• Arborway Trackless Trolley	38,697	316	-297.7	-91.1	-2%	$170,886	$3,770	$2	-$2,597	0.00%	$10,702
• Express Rt 1/128 to Boston via Route 1	2,473	1,844	49.5	3.2	67%	$3,660	$207	$1	$109	0.04%	$108
• Express Rt 2/128 to Boston via 128 and I-93	3,140	2,355	66.1	3.4	84%	$3,721	$207	$3	$56	0.04%	$137
• Express Rt 3/128 to Alewife via Rts 128 and 2	2,473	2,047	79.8	3.6	98%	$3,036	$160	$1	$9	0.03%	$112
• Improved Express Service in the Mass Pike Corridor	523	322	104.6	7.6	144%	$0	$0	$0	-$37	0.01%	$0

	Utilization				Cost Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
4. New Radial Services																										
F. Commuter Rail Extensions																										
• Ipswich Line: Ipswich to Newburyport**																										
Existing Line Improvements	2,150	1,463	71.7	0.6	72%	$25,427	$1,005	NA	$347	0.04%	$608															
Newburyport Extension Segment	1,638	1,438	43.0	1.4	75%	$59,527	$2,381	NA	$410	0.03%	$1,571															
Total	3,788	2,901	55.6	0.8	74%	$42,330	$1,687	$35	$756	0.07%	$1,062															
• Haverhill Line: Wakefield to Topsfield																										
Existing Line Improvements	4,056	1,924	2,385.9	-10.3	27%	$5,198	$174	NA	$2,543	NA	NA															
Topsfield Extension Segment	767	546	4.9	0.2	10%	$320,299	$13,806	NA	$2,810	NA	NA															
Total	4,823	2,470	30.6	1.2	19%	$74,851	$3,187	$48	$5,352	0.08%	$1,452															
• Haverhill Line: Haverhill to Plaistow NH																										
Existing Line Improvements	4,537	2,886	79.1	2.1	62%	$27,099	$1,061	NA	$891	NA	NA															
Plaistow Extension Segment	689	286	25.6	4.8	24%	$183,326	$7,314	NA	$891	NA	NA															
Total	5,226	3,172	62.0	2.2	49%	$41,185	$1,625	NA	$1,781	NA	NA															
• Lowell Line: Lowell to Nashua, NH																										
Existing Line Improvements	5,759	3,198	140.8	2.3	99%	$10,664	$427	NA	$26	NA	NA															
Nashua Extension Segment	1,482	520	22.3	1.0	19%	$198,662	$6,835	NA	$2,345	NA	NA															
Total	7,241	3,718	67.4	1.8	49%	$36,958	$1,323	$3	$2,371	0.12%	$685															
• Framingham Line: Framingham to Worcester**																										
Existing Line Improvements	684	264	NA	NA	NA	NA	NA	NA	NA	NA	NA															
Worcester Extension Segment	6,012	3,204	36.2	1.1	63%	$74,260	$2,660	NA	$2,538	NA	NA															
Total	6,696	3,468	40.3	1.2	65%	$68,607	$2,457	$13	$2,538	0.10%	$1,452															
• Framingham Line: Framingham to Marlborough																										
Marlboro Extension	1,632	774	8.3	0.3	9%	$190,181	$10,408	$63	$7,75[illegible]	0.04%	$2,334															
• Franklin Line: Forge Park/495 to Milford																										
Existing Line Improvements	1,928	930	-275.4	14.0	-227%	$98,529	$4,372	NA	-$928	NA	NA															
Milford Extension Segment	383	83	7.2	0.7	7%	$674,048	$45,566	NA	$2,144	NA	NA															
Total	2,311	1,013	50.2	3.5	40%	$145,684	$7,747	$111	$1,216	0.03%	$3,212															
• Franklin Line: Walpole to Foxborough																										
Existing Line Improvements	1,538	810	32.9	0.6	22%	$33,444	$1,338	NA	$1,479	NA	NA															
Foxborough Segment	38	8	1.8	0.1	1%	$3,526,050	$138,000	NA	$900	NA	NA															
Total	1,576	818	23.3	0.5	15%	$67,602	$2,675	$35	$2,379	0.02%	$1,368															
G. Other New Commuter Rail Services																										
• New Bedford/Fall River Lines	6,465	2,820	25.4	0.6	22%	$204,255	$5,436	NA	$9,558	0.10%	$3,457															
• New Mills Line	1,823	855	14.3	0.6	22%	$156,089	$6,498	$51	$4,364	[illegible]	$2,386															
• Additional Service to Dedham Corporate Center	630	0	NA	NA	NA	NA	NA	NA	NA	NA	NA															

	Utilization				Cost Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
5. Suburban Circumferential Movement																										
A. Route 128 Circumferential Bus Service	3,474	3,474	12.0	0.7	18%	$4,552	$382	NA	$3,962	0.05%	$179															
B. Feeder Bus to Rapid Transit at Riverside	680	490	14.4	NA	17%	$5,510	$450	$35	$650	0.01%	$141															
C. Feeder Bus to Commuter Rail in Needham	340	0	18.8	NA	0%	NA	NA	NA	$113	0.00%	NA															

Key:
- [white box] = no improvement, no likely impact, or negative impact
- [half-shaded box] = small improvement or small positive impact
- [black box] = significant improvement, or possible large positive impact

L = low or negligible effect
NA = not applicable or not available
** = required by amendments to the State Implementation Plan/Central Artery agreement

Cost-Effectiveness

- Farebox Ratio This figure, which equals fare revenue divided by the operating cost, shows the cost-effectiveness of a project in terms of how much of the operating cost would be recovered through fare revenue. The service being examined can be compared to existing service on this basis. This measure only addresses the cost of operating the service and does not take into account the cost of constructing it.

- Investment/New Daily Transit User This figure represents the total capital cost of a project divided by the total number of individuals[3] that would be drawn to the transit system (out of automobiles) by the new service.

- Annualized Cost/New Daily Transit User This figure provides a measure of the total cost of the project (operating and capital) on an annual, ongoing basis per individual diverted from private automobiles. It is a measure of the cost of attracting new riders.

- Annualized Cost/Hour of Travel Time Savings This figure provides a measure of the total cost (operating and capital) per hour of travel time saved by existing riders. It is a measure of the benefit of the project to existing riders.

- Annual Operating Subsidy This figure represents the annual increase in operating subsidies (not including debt service) that would be required to operate the new service. It equals the operating cost of the project minus fare revenues that would be generated.

Air Quality Impacts

- Percent Emissions Reduction This figure represents the percent reduction of regional volatile organic compound emissions resulting from the project and the ridership it attracts.

- Capital Cost/Kg of VOC Eliminated This figure represents the capital cost to eliminate one kilogram of VOC per weekday. It measures how cost-effective these projects are as measures to improve regional air quality.

Service Quality and Coverage

Most measures of service quality and coverage are subjective in nature. Certain characteristics could be quantified, but in most cases, subjective judgments were made based on a consensus judgment of the PMT Working Committee.

- Better Connections (Intermodalism) Improved connections between modes and transit services would attract new transit riders and benefit existing riders. As such, some of the benefits of these projects are addressed through the cost-effectiveness measures described above. However, one of the key goals of ISTEA is to promote the integration of various components of the transportation system. It is also one of the policies from the Phase 2 report that is guiding Phase 3 efforts.

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[3]The number of individuals was approximated by dividing total ridership by two.

Examples of projects that would provide better connections would be the Red–Blue Connector, the North Station-South Station Rail Link, improved roadway, pedestrian, and bicycle access to stations, new Logan services, and additional park-and-ride facilities.

In this category, a judgment was made on whether the new service improved connections in terms of (1) no improvement, (2), small improvement, and (3) significant improvement.

- System Accessibility All new projects must meet the requirements of the Americans with Disabilities Act (ADA). However, some projects may have additional benefits beyond accessibility of the individual project (for example, what would be the impact on accessibility of replacing much of the existing Somerville bus service with a Green or Blue line extension to Medford Hillside?) The impact of these types of changes was rated in three categories: (1) no improvement or negative impact, (2), small improvement, and (3) significant improvement.

- Distribution of Service Would there be an equitable distribution of service, and would there be improved service to transit dependent populations? Judgments were made based on characteristics of specific areas such as the amount of transit service relative to total population and population density, transit miles to highway miles, route miles per town, etc.

- Unmet Needs Based on whether or not one or more unmet needs could be identified that would be served, a judgment was made of: (1) no improvement, (2), small improvement, and (3) significant improvement.

- Travel Time Savings A major impact of reducing in-vehicle travel times and eliminating transfers is that service is improved for existing riders. This impact is reflected in "Total Travel Time Savings" figure. However, the total does not show the benefit on a per passenger basis, thus making it difficult to use this figure to determine the benefit relative to other projects. To determine the relative benefits of decreasing travel times, the travel time savings per existing trip was calculated. From the resulting per trip figures, a judgment was made of (1) no improvement, (2), small improvement, and (3) significant improvement based on relative differences.

  For example, a Green Line extension of Medford Hillside would save 1,161 hours of travel time each weekday for those who now make bus trips. For the 7,900 riders that would shift from buses to the Green Line, each would save an average of nine minutes per trip. This nine minute figure can be compared to the equivalent figure for other projects.

- Safety/Security Few, if any of the projects examined were aimed specifically at safety or security. This instead was a secondary impact, with a judgment made of (1) no improvement, (2), small improvement, and (3) significant improvement.

- Comfort/Convenience As with safety and security, few, if any of the projects were aimed specifically at improving convenience and/or comfort. This also was a secondary impact, with a judgment made of (1) no improvement, (2), small improvement, and (3) significant improvement.

- Crowding Impacts of the new service on crowding on other services were identified (for example, the reduction in Green Line Central Subway crowding that would result from a Blue Line to Riverside). From this, a judgment was made of (1) no improvement, (2), small improvement, and (3) significant improvement.

Impact on Existing System

Three criteria were used for this area, each with ranking categories of (1) negative impact, (2) no impact, or (3) positive impact:

- Preservation of Existing System Projects that would help preserve the existing system could fall into a number of categories, such as station modernization, track upgrades, equipment purchases, etc.

- Preservation of Future Options This would include projects such as purchase of abandoned rights-of-ways, construction of facilities designed to accommodate future expansion, etc.

- Efficiency/Effectiveness This would include projects that allowed an existing service to be operated more efficiently [illegible] that shifted ridership away from an overcrowded service, etc.

Economic Impacts

- Economic Development Potential Assessments of economic impacts reflect judgments based upon the type of service and the area served: (1) no likely impact, (2), small positive impact, and (3) possible large [illegible] impact.

- Potential for Private-Section Participation Assessments of potential for private-sector involvement were subjective, with judgments made based upon the type of service and the area served: (1) not likely (2), possible, and (3) likely. The private-sector involvement considered in this category would be beyond typical involvement such as design and construction.

Land Use Impacts

There are a number of differing perspectives on how transportation facilities and [illegible] should guide and/or reflect land use. MAPC's MetroPlan 2000 sets forth a regional plan that encourages compact development and discourages "sprawl" development. The relevant policies set forth in the PMT Phase 2 report are that new transportation services should "encourage development in the urban core" and that "support compact development." These policies are generally consistent with the goals of MetroPlan 2000, although there can be differences of opinion as to which of the two policies is more important and how the two are interpreted (for example, a commuter rail extension that encourages urban core development can be viewed as discouraging compact development in the suburbs). Given existing differences in opinion, the projects were evaluated separately on their effects on the urban core and on compact development in the suburbs. The impacts were assessed as (1) does not support, (2) supports moderately, and (3) supports strongly.

APPENDIX K

Example of How Boston's PMT Phase 3 Project Evaluation Process Applied to a Specific Project

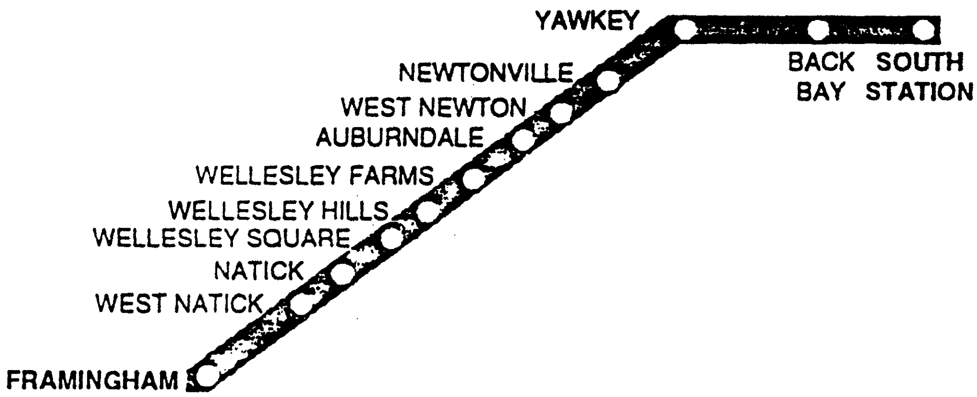
Source: Boston No. 9, p. G-31 to G-41.

Framingham Line Improvements

Existing Service

Currently, the Framingham Line serves 12 stations (see Figure G-12). (Trains only stop at Yawkey Station, near Fenway Park, shortly before and after Red Sox home games.) During peak periods, peak-direction trains stop at all stations (except Yawkey) at headways of 30 to 35 minutes. Most AM peak outbound trains skip some or all intermediate stops.[8] During the mid-day, service operates at headways of one hour and 45 minutes to two hours, and all trains stop at all stations. During the evenings, headways are up to two hours. All outbound evening trains stop at all stations, but only the last two inbound evening trains do so.

Figure G-12
Framingham Line Service



PMT Alternatives

For the PMT analysis, three service expansion alternatives were examined:

1. A combination of faster running times, increased service levels, and express service on the existing line.

2. An extension to Worcester, combined with faster running times, increased service levels and express service.

3. An extension to Marlborough, combined with faster running times, increased service levels, and express service on the existing line to Framingham.

[8]The first two outbound trips, at 5:00 and 5:20 AM, are essentially equipment-shifting moves, required because there is no layover facility at Framingham. To avoid conflicts with inbound schedules, the next three outbound trains have to use a track that has no access to platforms at some stations.

1. Faster Running Times, Increased Service Levels, and Express Service

The first alternative involves service improvements to the existing line. These include track and right-of-way improvements to increase the maximum operating speed to 70 mph, the operation of increased levels of service, and peak period express trains.

During peak periods, express trains would stop at the Framingham, West Natick, Natick, Wellesley Square, Wellesley Hills, and Wellesley Farms stations, and then run non-stop to Back Bay (see Figure G-13). Local trains would make all stops between Wellesley Farms and South Station. Express and local trains would both operate at 30 minute headways. This would result in 30 minute headways at all outer stations, except Wellesley Farms, where headways would be 15 minutes. Train frequencies would be similar to the present ones at all stations except Wellesley Farms, where service would double. During off-peak periods, present schedules would be retained.

Figure G-13
Express/Local Service Configuration

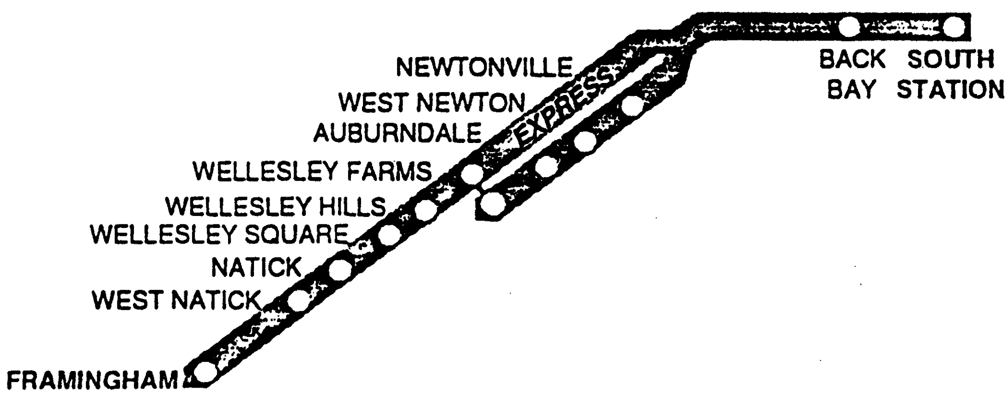


Table G-20
Faster Framingham Line Service: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Framingham	50	—	40
West Natick	46	—	37
Natick	41	—	32
Wellesley Square	36	—	27
Wellesley Hills	32	—	23
Wellesley Farms	28	23	21
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

Compared to present service, express trains with higher maximum speeds would reduce travel times by seven to 10 minutes, or by 20 to 25 percent, at outer stations. Time savings on local trains would be smaller, at four to five minutes, or 18 to 24 percent.

2. Worcester Extension

This project would consist of a 23 mile extension of the Framingham commuter rail line (doubling its length) from the present terminal in Framingham through Ashland, Southborough, Westborough, Grafton, and Millbury to Worcester. Preliminary feasibility studies have been completed, and design and engineering work is underway.

There would be six stations on the extension:

Station	Parking	Fare Zone
Ashland	400	7
Southborough	400	7
Westborough	400	7
Grafton	400	8
Millbury	400	9
Worcester	500	10

Table G-21
Worcester Extension: Travel Times to South Station (in minutes)

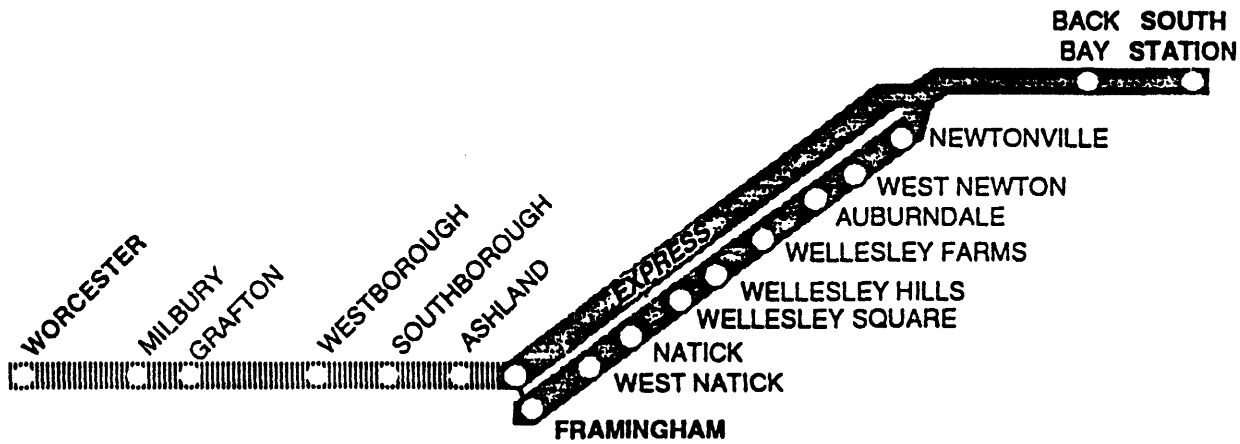
	Existing Service	Future Local	Future Express
Worcester[9]	—	80	67
Millbury	—	73	60
Grafton	—	69	56
Westborough	—	59	46
Southborough	—	52	39
Ashland	—	47	34
Framingham	50	44	31
West Natick	46	41	—
Natick	41	36	—
Wellesley Square	36	31	—
Wellesley Hills	32	27	—
Wellesley Farms	28	23	—
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

[9]Times from Worcester are two minutes greater than those included in the Feasibility Study due to the addition of Millbury Station.

The alignment for a Framingham-Worcester extension would be the Conrail Main Line. This is the primary route for railroad freight to and from Boston and points in southeastern Massachusetts. It also carries some Amtrak intercity passenger trains.

During peak periods, a combination of express and local trains would be run. In the AM peak, present local service from Framingham to Boston would be retained, but one train would originate at Worcester instead of Framingham. Four new inbound trains would originate at Worcester, make all stops to Framingham, and then run non-stop to Back Bay Station. In the PM peak, all present outbound Framingham local trains would be extended to Worcester. Four new trains would run non-stop from Back Bay to Framingham and then make all stops to Worcester. During off-peak hours, present schedules would be retained, but the outer terminal for all trains would be changed from Framingham to Worcester.

Figure G-14
Service Configuration with Worcester Extension



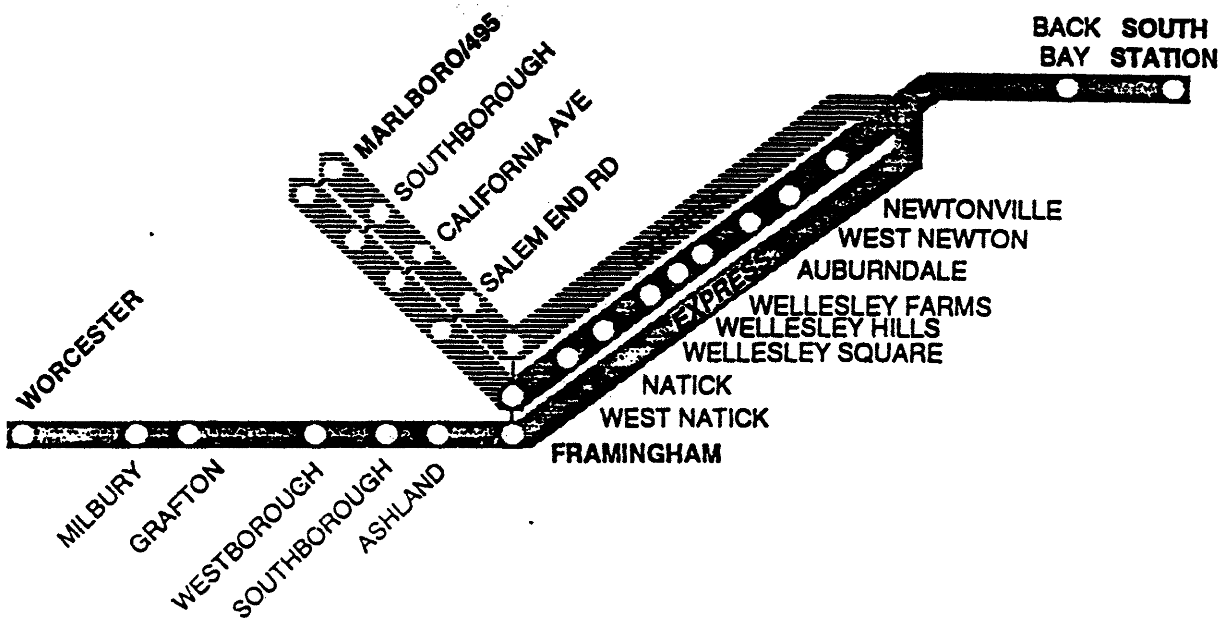
3. Extension to Marlborough with Faster Running Times and Express Trains

Alternative 3 involves a 9.5-mile extension of the Framingham commuter rail line to [illegible] I-495 near the Southborough-Marlborough border (see Figure G-15). This extension, originally proposed as an alternative to the Worcester extension, was examined in the PMT as being run along with the Worcester extension. For purposes of analysis, the service in Alternative 2 was used as the base case against which Alternative 3 was compared. The Marlborough extension would use the Conrail Fitchburg Secondary Track, currently used only for freight service.

There would be four stations on the extension:

Station	Parking	Fare Zone
Salem End Road in Framingham	750 spaces	5
California Ave in Framingham	500 spaces	6
Southborough Center	250 spaces	6
Marlborough at I-495	1,000 spaces	7

Figure G-15
Service Configuration with Marlborough Extension



All service on this extension would operate to and from Marlborough. During peak periods, a combination of express and local trains would be operated. All trains would stop at all stations on the extension and at Framingham. Express trains would then run non-stop to Back Bay, but locals would serve all stops east of Framingham. Express and local trains would both be operated at 60-minute headways. This would provide overall average 30-minute headways at stations on the extension.

With a Marlborough extension, there would be a reduction in peak-period service to and from Worcester. At Framingham station, overall AM peak inbound and PM peak outbound service would include a train every 15 minutes. Half-hourly express trains would alternate with half-hourly locals. Each of these would, in turn, alternate between Worcester and Marlborough trains. There would be no Framingham short-turns. Service to stations between Framingham and Boston would be the same as in the base case, but would be provided by local trains running alternately from Worcester and Marlborough.[10]

During off-peak periods, only local service would be operated on the Marlborough extension. Worcester service would be the same as in the base case, but an equal number of Marlborough trains would be added. This would double service at stations from Framingham to Boston.

Travel times from existing stations to South Station would be the same under Alternatives 2 and 3, as shown in as shown in Tables G-21 and G-22. Compared to present service, travel times to Boston from most stations on local trains would be reduced by four to six minutes.

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[10]Because of differences in running times for express and local trains it would be impossible to establish a schedule with uniform headways at all stations served by both even if equal numbers of trains started from all terminals. (For example, an express train leaving Framingham 15 minutes after a local would arrive at South Station only two minutes later.)

These savings would result from faster speed limits that could be implemented with or without any extensions beyond Framingham. The travel time from Framingham to South Station on express trains would be 31 minutes, or a reduction of 19 minutes compared to the present 50 minute schedule for local trains. Framingham express trains could also be operated with no further extensions, but Framingham alone has insufficient demand potential to justify such service.

Table G-22
Marlborough Extension: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Marlborough	—	65	52
Southborough	—	59	46
California Ave	—	55	42
Salem End Road	—	48	35
Framingham	50	44	31
West Natick	46	41	—
Natick	41	36	—
Wellesley Square	36	31	—
Wellesley Hills	32	27	—
Wellesley Farms	28	23	—
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

Ridership Impacts

Under Alternative 1, faster service, including the operation of express trains, would increase ridership on the existing Framingham Line by 1,460 trips per weekday. Of these, 570 (39 percent) would be new transit trips (see Table G-23). This is the third-lowest number of new transit trips for running time improvements on existing commuter rail lines examined for the PMT. (Similar improvements on the Needham Line would attract only 158 new riders.)

In Alternative 2, the Worcester extension combined with faster service and express trains would attract 6,700 new Framingham Line trips per weekday, including 3,470 diversions from automobiles. Most of these trips would be on the extension: 6,010 of the total trips, and 3,200 of the new transit trips. The remainder would be attracted by the faster service on the existing line, including express service from Framingham. Boardings by station on the extension would be as follows:

Worcester	1,045
Millbury	370
Grafton	335
Westborough	620
Southborough	1,770
Ashland	1,870
Total	6,010

Ridership at most individual stations on the extension would be relatively high, but the highest ridership would be at the two innermost stations. To put these figures in perspective, of 97 outer stations in the existing system, only six now have higher ridership than projected for Southborough and only five have higher ridership than projected for Ashland. Excluding the Fall River and New Bedford extensions, which would effectively be new lines, the Worcester extension would attract the highest number of total trips and diversions from automobiles of all commuter rail extensions examined for the PMT.

Table G-23
Ridership Impacts of Framingham Line Improvements

	Total Trips	New Transit Trips
Alternative 1 (Express Service: No Extensions)		
Existing Line Improvements	1,460	580
Alternative 2 (Worcester Extension)		
Existing Line Improvements	690	270
Worcester Extension Segment	6,010	3,200
Total	6,700	3,470
Alternative 3 (Marlborough Extension)		
Marlborough Extension Segment Only	1,630	775

In Alternative 3, a Marlborough extension constructed along with a Worcester extension would attract relatively low total ridership: 1,630 trips per weekday, of which 775 would be diverted from automobiles. The remainder would be diverted from other transit services, primarily the Worcester extension. The low estimated ridership is the result of the overlapping service areas of the Worcester and Marlborough extensions. Every station on a Marlborough extension would be within four miles of either a new station on the Worcester extension or Framingham Station.[11]

On a station by station basis, ridership at all Marlborough extension stations except Southborough would be low:

Marlborough	460
Southborough	865
Salem End Road	125
California Avenue	180
Total	1,630

[11]The Worcester Feasibility Study ("Commuter Rail Extension Feasibility Study: Framingham to Worcester, Milford & Marlborough," Stone & Webster Civil & Transportation Services, Inc., January 1990) examined the impacts of a Marlborough extension without a Worcester extension. In this case, Marlborough extension would be approximately 3.5 times higher and only slightly lower than ridership on the Worcester extension.

Costs and Cost-Effectiveness

The existing Framingham Line is in good physical condition and can already accommodate service with higher maximum operating speeds. However, the operation of express trains to and from Wellesley Farms would require the construction of a layover facility, at approximately $1.2 million, to prevent scheduling conflicts between express and local trains. In addition, two new train sets would be required, at a cost of $17.1 million (two locomotives and 12 cars). Therefore, the total capital cost to institute express service would be $18.3 million (see Table G-24). Operating costs would be increased by $1.9 million per year, of which only 16 percent ($0.3 million) would be covered by increased fare revenue.

Table G-24
Costs of Framingham Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Alternative 1 (Express Service: No Extensions)				
Existing Line Improvements	$1.9m	$0.3m	$18.3m	$31,800
Alternative 2 (Worcester Extension)				
Total	$7.2m	$4.7m	$119.0m	$34,300
Alternative 3 (Marlborough Extension)				
Total	$8.6m	$0.8m	$73.6m	$95,100

The route of the Alternative 2 extension from Framingham to Worcester currently carries limited Amtrak intercity passenger service (two round trips to Washington via Springfield and one round trip to Chicago per day). The line is relatively well maintained, but would require further upgrading to permit the running times and express service assumed for the PMT. (The present maximum speed limit is 50 mph, and part of the line has been reduced to single track.) There are no stations between Framingham and Worcester now. The total cost for station, track and right-of-way improvements, and for signaling and communications is estimated at $84.9 million. In addition, four new train sets would be needed at a cost of $34.0 million, bringing the total cost to $119.0 million.[12]

The Worcester extension would improve peak-period service at Framingham Station by adding express trains to Boston and increasing the number of departures. Service at stations between Framingham and Boston would not change except for minor schedule adjustments. Therefore, all ridership increases at existing stations would occur at Framingham. Any allocation of the cost of Worcester express service to Framingham Station would necessarily be arbitrary. Demand at Framingham would not support non-stop service to Boston without a Worcester extension. Therefore, benefits and costs of Alternative 2 are not shown separately for the existing line and the extension.

[12]Earlier estimates put the cost of a Worcester extension at approximately $80 million. The $118.9 million estimates includes higher station costs for high-level platforms and related changes for ADA compliance ($5.9 million) plus vehicle costs ($34.0 million).

Worcester extension service would increase operating costs by $7.2 million per year, and would generate approximately 65 percent of these costs in fare revenue ($4.7 million). This is the second-highest revenue to cost ratio for any commuter rail extension examined for the PMT, below only that for Newburyport service (75 percent). The capital cost per new rider would be $34,300, which would be the second lowest cost among the extensions examined to date (again after Newburyport).

The Marlborough extension would operate on the Conrail Fitchburg Secondary line, which is currently used only for freight service. This line would require considerable rehabilitation and installation of a signal system. The total cost for station, track and right-of-way improvements, and for signaling and communications is estimated at $48.0 million. The schedule assumed in the analysis of Alternative 3 would require three more train sets than needed for Alternative 2. With one locomotive and six coaches per train, these would cost $25.6 million.[13] Including the cost of the six new train sets, the total cost would be $73.6 million.

Ridership estimates were developed only for the extension segment of Marlborough service, and thus estimates of operating revenues are available for that segment only. As with the case of the Worcester extension, the existing Framingham Line would receive more service as the result of the Marlborough extension, but any allocation of Marlborough service costs to the present line would have to be arbitrary. In any case, the Marlborough extension would show low cost-effectiveness. The net difference in annual operating costs between the Worcester service of Alternative 2 and the combined Marlborough and Worcester service of Alternative 3 would be $8.6 million per year. The additional revenue generated from new transit riders would be only $0.8 million per year, or 9.5 percent of operating costs. The capital cost per new transit rider ($95,100) would place the Marlborough line among the more costly commuter rail extensions examined.

Air Quality Impacts

Alternative 1 improvements to the existing Framingham Line alone would reduce regional emissions by 0.02 percent (see Table G-25). This is the second lowest air quality benefit for improvements to an existing service. (Only Needham Line improvements would have lower benefits.) The capital cost per kilogram of VOC eliminated per day would be in the middle range of improvements to existing lines, at $1.1 million.

The Worcester extension would reduce regional emissions by 0.10 percent. This figure is relatively high; with one exception, the only PMT projects with comparable air quality benefits are significantly more expensive. (The one exception is the provision of better bus circulation within downtown Boston. Projects with greater air quality benefits but higher costs include the North Station–South Station Rail Link, a circumferential rail line, and Blue Line extensions that include the Red-Blue Connector.) The capital cost per kilogram of VOC eliminated by weekday by Worcester service would be $1.5 million. This is a moderate cost for a rail extension.

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[13]For purposes of analysis, this project was originally defined so that the same service frequencies would be provided on the Worcester and Marlborough extensions. The resulting ridership projections indicate that less frequent service on the Marlborough line would be appropriate. This could reduce vehicle requirements and associated capital costs as well as operating costs.

Marlborough service would reduce regional emissions by 0.04 percent. The capital cost per kilogram of VOC eliminated per weekday would be $2.3 million, making this one of the most costly PMT commuter rail alternatives in this measure.

Table G-25
Air Quality Impacts of Framingham Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elm/Weekday
Existing Line Improvements	0.02%	$1,126,100
Worcester Extension	0.10%	$1,452,400
Marlborough Extension (Extension Segment Only)	0.04%	$2,334,000

Conclusions

The operation of Alternative 1 express service on the existing Framingham Line would attract only 580 new transit trips per weekday. The cost per new rider ($31,800) would be significantly higher than those of service improvements on the Rockport/Ipswich, Haverhill/Reading and Lowell Lines, but lower than the comparable costs for all other existing lines. Because the number of diversions from automobiles would be small, the air quality benefits would be low, with a 0.02 percent reduction in regional emissions. The cost per kilogram of weekday VOC eliminated ($1.1 million) would be in the mid-range of such costs for improvements to existing commuter rail lines. It would, however, be low to moderate compared with costs for new services.

A Worcester extension would serve a total of 6,700 trips per weekday, of which 3,470, or 52 percent would be new transit trips. This is the highest number of new transit trips that would be attracted by any commuter rail extension examined in the PMT, and is higher than the number of new trips that would be attracted by most other kinds of new services as well. (Some exceptions are the North Station–South Station Rail Link, the Red Line–Blue Line Connector, and a rapid transit extension to Medford Hillside.) The $119 million capital cost of the extension would average $34,300 for each new transit rider attracted. This is lower than the comparable cost for any commuter rail extension examined except Newburyport or for any Red, Blue, or Orange Line extension.

A Worcester extension would also reduce regional emissions by 0.10 percent, which is high relative to most individual projects. The only rail projects—commuter rail, rapid transit, or light rail—with greater air quality benefits would be significantly more expensive. The capital cost per unit of air quality benefit (kg of VOC eliminated per weekday) would be in the middle range for commuter rail extension projects. The Worcester extension would also recover 65 percent of its $7.2 million annual operating costs from fares. This is the second-highest revenue to cost ratio of any commuter rail extension examined, and is much higher than that of the existing commuter rail system as a whole.

Most of the service area of a Marlborough extension would overlap that of a Worcester extension. Therefore, the increase in ridership as a result of operating both extensions instead of a Worcester extension alone would be relatively small—only 775 new transit riders per weekday. A Marlborough extension would be among the most expensive PMT projects measured in capital cost per new transit rider and per unit of air quality improvement. It would also be expensive to operate and would generate only 9.5 percent of its operating costs in new fare revenue.

APPENDIX L

Memorandum Sent to Massachusetts RPA's Regarding Funding Estimates for the TIP

Source: Boston No. 7.

The Commonwealth of Massachusetts
Executive Office of Transportation and Construction
Ten Park Plaza, Boston, MA 02116-3969

William F. Weld
Governor

Argeo Paul Cellucci
Lieutenant Governor

James J. Kerasiotes
Secretary

Nathaniel W. Karns, Director
Berkshire County Regional
Planning Commission
10 Fenn Street
Pittsfield, MA 01201

Dear Mr. Karns:

I am forwarding to you by attachment the target funding estimates for Federal Fiscal Years 1996 thru 1998. These estimates should be used in preparing the final versions of the MPO's FFY 96-98 Transportation Improvement Program.

The funding estimates are separated for Federal and Non-Federal Aid projects. The previous treatment of Non-Federal Aid projects as part of the main body has created concerns about satisfying all of the issues associated with financial constraint, particularly related to the availability of funds prior to passage of a Transportation Bond Bill. To avoid these issues, Non-Federal Aid projects should be included as an informational appendix to the TIP. The only exceptions are regionally significant projects included in the air quality conformity analysis that are funded under the Non-Federal Aid program. They are required to be part of the main body of the TIP.

The base funding of $150 million in federal funding has been maintained for the statewide program. The amount that is used for purposes of establishing the targets has been reduced by approximately $13 million. This amount reflects statewide programs such as the Transportation Demand Management Program, the Infrastructure Improvements and Bridge Inspections that were previously listed in each TIP. Since the presence of these statewide projects has complicated the regional financial constraint analysis, they are to be included in the TIP but it should be noted that the resources required are provided separately.

TITLE 23
TRANSPORTATION FUNDING ESTIMATES
FFY 98

Expected Apportionment	$730,000,000
CA/T Needs (CA/T minus MHS)	$518,960,000
Mega Projects	
Route 146 (1998 Phased Obligations)	$72,480,000
Statewide Enhancement Program	$1,500,000
Statewide Infrastructure	$12,940,000
Statewide Federal Program *	$137,060,000
Statewide Federal Program Plus State Match *	$171,325,000
Total Statewide Federal Program Plus State Match **	$263,800,000

* Amount To Be Applied to Regional Formula, excludes Statewide Enhancement and Infrastructure Programs and "Mega" Projects

** Including Statewide Enhancement and Infrastructure Programs and "Mega" Projects

MPO Estimates (percentages from MARPA Formula)

MPO	Formula	Federal Program
BCRPC	3.56%	$6,091,097
CCC	4.59%	$7,863,365
CMRPC	8.69%	$14,883,612
FCPC	2.54%	$4,353,241
MVC	0.31%	$533,401
MVPC	4.43%	$7,588,061
MAPC	42.97%	$73,626,562
MRPC	4.46%	$7,639,681
NPEDC	0.22%	$378,543
NMCOG	3.91%	$6,693,324
OCPC	4.56%	$7,811,746
PVPC	10.81%	$18,514,181
SRPEDD	8.96%	$15,348,187

STATE BOND BILL
TRANSPORTATION FUNDING ESTIMATES
FFY 98

Expected Funding $200,000,000

MPO Estimates (percentages from MARPA Formula)

MPO	Formula	Federal Program
BCRPC	3.56%	$7,110,575
CCC	4.59%	$9,179,472
CMRPC	8.69%	$17,374,711
FCPC	2.54%	$5,081,852
MVC	0.31%	$622,678
MVPC	4.43%	$8,858,090
MAPC	42.97%	$85,949,583
MRPC	4.46%	$8,918,349
NPEDC	0.22%	$441,900
NMCOG	3.91%	$7,813,598
OCPC	4.56%	$9,119,213
PVPC	10.81%	$21,612,936
SRPEDD	8.96%	$17,917,043

APPENDIX M

The Method for Placing a Project on the Boston TIP & Sample Letters and Forms

Source: Boston No. 5, p. 16-18 and 28-37.

The Method for Placing a Project on the TIP

When a new TIP is being developed, all the communities of the MAPC region are notified and asked to submit those projects they would like included on the TIP. This annual solicitation for projects takes place during the first three months of the calendar year. The list of projects submitted by the communities is compiled with those submitted by the MPO agencies and projects that remained from the previous TIP. Once a Draft TIP is developed, it is sent out to all MPO agencies (See The Metropolitan Planning Organization), all the communities of the Boston MPO region, the Joint Regional Transportation Committee and the Cape Ann Transit Authority for review. The TIP is then revised according to comments received and the MPO votes to approve the TIP.

The TIP may be routinely amended to provide some flexibility in scheduling project construction. If projects must be delayed or removed from the TIP, an opportunity for other projects to be moved forward is available.

In general, in order for MAPC to include a highway project in the Annual Element of the TIP, the community needs to have secured concurrence from the Massachusetts Highway Department District Highway Director and Project Review Committee. A commitment that the project can be designed and advertised for construction within the Fiscal Year of the Annual Element must be provided by the community. Proposed projects for the 2nd and 3rd year of the TIP do not require the same level of review prior to placement within the TIP. This is particularly true for maintenance projects such as road resurfacing that will not require right of way acquisition, extensive permits or the preparation of design plans.

The following process should be followed by the community if the project is on a federal aid eligible, locally maintained roadway. If the community is proposing improvements to a state maintained roadway, the community is not usually involved in design, engineering, right of way acquisition and so on. However, on a locally maintained roadway, the community must assume a high degree of responsibility for the project.

The following steps explain the recommended process of placing a project on the TIP. **However, this process should be used only as a guide.** The individual aspects of a project may require more or less steps, depending on its complexity. Furthermore, many of these steps can occur simultaneously.

1. The community becomes aware of an existing or potential transportation problem.

2. The community writes to the Massachusetts Highway Department District Highway Director asking for assistance with the problem. The letter should

include information such as why improvements are needed, a description of the proposed improvements. the level of local support for the project. a commitment that the project will be designed by the community and any right-of-way acquisition will be purchased by the community. (See Sample Letter - Project Initiation by Community to MHD District Office)

3. The community submits a copy of the above letter to the Metropolitan Area Planning Council (MAPC). It is recommended that the community also submit an MAPC Project Request Form.

4. The Massachusetts Highway Department (MHD) District Office investigates and reviews the request.

5. The MAPC considers the project in terms of regional needs and compliance with the Regional Development Plan for Metropolitan Boston. MetroPlan 2000 and the Transportation Plan for the Boston Region.

6. The MHD District Highway Director may ask the community to prepare a Project Justification Report.

7. The community submits a Project Justification Report (if required) which is prepared at local expense.

8. The MHD District Highway Director notifies the community whether it supports the project.

9. The community hires a design engineer to prepare preliminary designs of the proposed improvements and to determine if the project requires environmental review. The community municipal engineer can also prepare the required documents.

10. The design engineer prepares the necessary information on the project such as the nature of the problem. the type of improvements needed and an estimate of the cost

11. The MHD District Office submits the project to the Project Review Committee of the Massachusetts Highway Department

12. The MHD Project Review Committee approves or disapproves the project.

13. The MHD District notifies the community in writing if the project has been approved by the Project Review Committee.

14. The MAPC, in representing the communities, includes the project when the Draft TIP is developed by the MAPC or submits the project at the time amendments to the TIP are proposed.

15. The Draft Transportation Improvement Program or the TIP amendments are reviewed by the SSC and approved for distribution.

16. The Draft TIP or TIP amendments are reviewed by the public under the approved public participation procedures of the TIP.

17. The Metropolitan Planning Organization votes on approving the Final Transportation Improvement Program or the amendments to the TIP.

18. The community hires a design consultant to prepare the engineering documents. The community municipal engineer can also prepare the required documents.

19. The design engineer prepares the documents and submits them to the MHD for approval. Depending on the complexity of the project, submittals may be required at 25%, 75% and 100% design. Public hearings and environmental permits may also be required.

20. The MHD advertises the project for construction.

21. The MHD awards the contract for the project to the qualified low bidder.

22. The contractor constructs the project.

Sample Letters and Forms

Included on the next few pages are sample forms and letters that communities should be aware of when initiating a project.

MAPC TIP Project Request Form (Blank)

It is recommended that the community submit this form to MAPC when requesting a project.

MAPC Project Status Reports

These reports are sent to the communities from the MAPC Project Status Database. Updated reports can be obtained by contacting the MAPC.

Project Initiation by the Community to the MHD District Office

This is a sample letter of what should be included when a community first proposes a project to the MHD District office.

Project Approval by the MHD Project Review Committee

This is a sample letter from the MHD District office explaining Project Review Committee approval and community responsibilities.

The Development of the Transportation Improvement Program for FY 95-97

PROJECT REQUEST FORM

FOR THE BOSTON METROPOLITAN AREA

Metropolitan Area Planning Council

Prepared by the Metropolitan Area Planning Council
60 Temple Place
Boston, MA 02111
(617) 451-2770
FAX (617) 482-7185

IF THERE ARE PROJECTS YOUR COMMUNITY WOULD LIKE TO HAVE PLACED ON THE TRANSPORTATION IMPROVEMENT PROGRAM (TIP), PLEASE FILL IN SECTIONS 1, 2, 3, AND 4 AS COMPLETELY AS POSSIBLE AND RETURN TO THE MAPC.

1. PROJECT LOCATION (INCLUDE STREET NAMES AND, IF APPLICABLE, STREET ROUTE NUMBERS)

COMMUNITY:
LOCATION:
AT:
FROM:
TO:
WORK ALSO IN:

2. PROJECT REQUEST AND DESCRIPTION

DATE OF REQUEST:
COMMUNITY PROJECT CONTACT PERSON:
TYPE OF PROJECT REQUESTED (CHECK ONE):

__ROAD RECONSTRUCTION
__ROAD RESURFACING
__INTERSECTION IMPROVEMENTS
__BICYCLE/PEDESTRIAN IMPROVEMENTS
__TRANSIT IMPROVEMENTS
__OTHER ____________________

DESCRIPTION OF THE PROJECT: PLEASE PROVIDE A MORE DETAILED DESCRIPTION OF THE PROJECT BELOW

3. PROJECT DATA

ROADWAY FUNCTIONAL CLASSIFICATION (CHECK ONE): __COLLECTOR __ARTERIAL __OTHER ___________
ROADWAY WIDTH: _____
ROADWAY LENGTH: _____

IS THE PROJECT PART OF A PAVEMENT MANAGEMENT SYSTEM?:
WHAT IS THE NAME OF PAVEMENT MANAGEMENT SYSTEM?:

WHO MAINTAINS THE ROADWAY OR FACILITY? __STATE __LOCAL __OTHER ___________

WHO IS THE PROJECT ENGINEER?:

WHAT IS THE PERCENTAGE OF ENGINEERING COMPLETE?:

IS RIGHT OF WAY ACQUISITION REQUIRED?: IF YES, WHEN WILL ROW BE ACQUIRED?:

SCHEDULED ADVERTISING DATE:

COST ESTIMATE:

4. APPROVALS REQUIRED (PROJECTS CAN ONLY BE CONSIDERED FOR A FUTURE ELEMENT OF THE TIP (YEAR 2 OR 3) IF APPROVALS HAVE NOT YET BEEN OBTAINED)

HAS THE MHD DISTRICT HIGHWAY DIRECTOR APPROVED THE PROJECT?:
HAS THE MHD PROJECT REVIEW COMMITTEE APPROVED THE PROJECT?:
WHAT IS THE % OF ENGINEERING APPROVED BY MHD?:

7. MISCELLANEOUS NOTES ON PROJECT

Metropolitan Area Planning Council

Transportation Improvement Program

PROJECT STATUS REPORTS

For the Community of

BOLTON

MAPC SUBREGION - MAGIC

<u>Community TIP Contact</u>
HAROLD BROWN
HWY SUPERINTENDENT

Please review these Project Status Reports and notify the MAPC whenever changes are made or more information is available on your projects. Those projects not ready for advertising during the programmed fiscal year may be delayed or removed from the TIP.

Metropolitan Area Planning Council

If you have updated information or questions regarding this report, contact:

Christopher C. Skelly
TIP Coordinator
MAPC
60 Temple Place
Boston, MA 02111
(617) 451-2770
FAX (617) 482-7185

This Report was printed on
27-Jan-95

A Description of this Report

This Report contains projects currently listed in the TIP and proposed projects not yet listed in the TIP. Projects currently listed in the TIP are listed in Section 5 - TIP Information under Fiscal Year as 95, 96 or 97 depending on the appropriate federal fiscal year (October 1 - September 30). Proposed projects not yet listed in the TIP are listed as PR. These are projects that will be considered for inclusion in the TIP at a future time. These projects could be considered if other programmed projects are delayed and an amendment to the TIP is required. Otherwise, they will be considered when the next TIP is developed.

List of Abbreviations Found in this Report

CDC - Concentrated Development Center
CMAQ - Congestion Mitigation/Air Quality (A Federal Funding Program)
DHD - MHD District Highway Director
EOTC - Executive Office of Transportation and Construction
EWO - Engineering Work Order
IM - Interstate Maintenance (A Federal Funding Program)
IC - Inner Core (An MAPC Subregion)
IT - Interstate Transfer (A Federal Funding Program)
MAGIC - Minuteman Advisory Group on Interlocal Coordination (MAPC Subregion)
MAPC - Metropolitan Area Planning Council
MBTA - Massachusetts Bay Transportation Authority
MW - Metrowest Growth Management Committee (MAPC Subregion)
MHD - Massachusetts Highway Department
MPO - Metropolitan Planning Organization
NFA - Non Federal Aid (A Funding Program Utilizing State Funds Only)
NHS - National Highway System (A Federal Funding Program)
NSPC - North Suburban Planning Council (An MAPC Subregion)
NSTF - North Shore Task Force (An MAPC Subregion)
PR - Proposed Project (A project not yet included in the TIP)
PRC - Project Review Committee of the MHD
PROJIS - Project Information System (The MHD Transportation Database)
ROW - Right of Way
SSC - South Shore Coalition (An MAPC Subregion)
SSC - Subsignatory Committee of the MPO
STP - Surface Transportation Program (A Federal Funding Program)
STP EARMK - STP Earmark (A Federal Funding Program)
STP ENHMT - STP Enhancement (A Federal Funding Program)
SWAP - Southwest Advisory Planning Committee (An MAPC Subregion)
TIP - Transportation Improvement Program
TRIC - Three Rivers Interlocal Council (An MAPC Subregion)

MAPC
Metropolitan Area
Planning Council

The Transportation Improvement Program for FY 95-97

PROJECT STATUS REPORT

Prepared by the Metropolitan Area Planning Council
(617) 451-2770
FAX (617) 482-7185

BOLTON
MAPC SUBREGION: MAGIC
MHD DISTRICT: 3

LISTED BELOW IS THE MOST UP-TO-DATE INFORMATION THE MAPC HAS REGARDING TIP PROJECT REQUESTS IN YOUR COMMUNITY. PLEASE READ OVER THE INFORMATION CAREFULLY AND NOTIFY THE MAPC IF ADDITIONAL INFORMATION IS AVAILABLE OR CORRECTIONS ARE NECESSARY. UNLESS THE MASSACHUSETTS HIGHWAY DEPARTMENT WILL BE DESIGNING AND ENGINEERING THE PROJECT, IT IS UP TO THE COMMUNITY TO PROVIDE THE NECESSARY INFORMATION IN SECTIONS 1, 2, 3 AND 4 FOR CONSIDERATION IN THE TIP. PLEASE CONTACT CHRISTOPHER C. SKELLY AT MAPC (617) 451-2770 IF YOU HAVE ANY UPDATED INFORMATION OR QUESTIONS.

1. PROJECT LOCATION (INCLUDE STREET NAMES AND, IF APPLICABLE, STREET ROUTE NUMBERS)

MHD PROJECT NUMBER: UNKNOWN

COMMUNITY: BOLTON
LOCATION: I-495
AT: ROUTE 117
FROM: NA
TO: NA
WORK ALSO IN:

IS THE PROJECT IN AN MAPC CONCENTRATED DEVELOPMENT CENTER (CDC)?: NO

2. PROJECT REQUEST AND DESCRIPTION

DATE OF MOST RECENT REQUEST: 8/5/494
TYPE OF PROJECT REQUESTED: INTERSECTION IMPROVEMENTS
DESCRIPTION OF THE PROJECT: INTERSECTION IMPROVEMENTS

3. PROJECT DATA

ROADWAY FUNCTIONAL CLASSIFICATION:
PROJECT WIDTH: 0 PROJECT LENGTH: 0
PROJECT/FACILITY MAINTAINED BY: COMM OF MA
PROJECT ENGINEER: UNKNOWN
IS PROJECT PART OF PAVEMENT MGT SYSTEM?: NAME OF PM SYSTEM:
IS ROW REQUIRED?: UNKNOWN IF YES, WHEN WILL ROW BE ACQUIRED?:
% ENGINEERING COMPLETE: 0%

SCHED ADV DATE: 1/1/00 (IF LISTED AS 1/1/00, A SCHEDULED ADVERTISING DATE IS NEEDED)
COST ESTIMATE: $320,000.00

4. APPROVALS REQUIRED

MHD DISTRICT HIGHWAY DIRECTOR APPROVAL: UNKNOWN
MHD PROJECT REVIEW COMMITTEE APPROVAL: UNKNOWN
% ENGINEERING APPROVED BY MHD: 0%

5. TIP INFORMATION (Information in this section will be completed by the MAPC and the State)

FISCAL YEAR: PR
FUNDING CATEGORY: UNKNOWN
AMENDMENT: NO
LATEST AMENDMENT DATE: NA
CHANGE TO: NA

6. PROJECT CONSTRUCTION (WHEN THIS PROJECT IS ADVERTISED FOR CONSTRUCTION, PLEASE NOTIFY THE MAPC)

HAS THE PROJECT BEEN ADVERTISED?: NO
ADVERTISED DATE:
HAS THE PROJECT BEEN BID?: NO
AWARD DATE:
AMT OF BID:

7. MISCELLANEOUS NOTES ON PROJECT

8/5/94 PROJECT PROPOSED BY BD OF SELECTMAN TO THE DISTRICT HIGHWAY DIRECTOR.

Metropolitan Area Planning Council

The Transportation Improvement Program for FY 95-97

PROJECT STATUS REPORT

Prepared by the Metropolitan Area Planning Council
(617) 451-2770
FAX (617) 482-7185

BOLTON
MAPC SUBREGION:
MHD DISTRICT:

LISTED BELOW IS THE MOST UP-TO-DATE INFORMATION THE MAPC HAS REGARDING TIP PROJECT REQUESTS IN YOUR COMMUNITY. PLEASE READ OVER THE INFORMATION CAREFULLY AND NOTIFY THE MAPC IF ADDITIONAL INFORMATION IS AVAILABLE OR CORRECTIONS ARE NECESSARY. UNLESS THE MASSACHUSETTS HIGHWAY DEPARTMENT WILL BE DESIGNING AND ENGINEERING THE PROJECT, IT IS UP TO THE COMMUNITY TO PROVIDE THE NECESSARY INFORMATION IN SECTIONS 1, 2, 3 AND 4 FOR CONSIDERATION IN THE TIP. PLEASE CONTACT CHRISTOPHER C. SKELLY AT MAPC (617) 451-2770 IF YOU HAVE ANY UPDATED INFORMATION OR QUESTIONS.

1. PROJECT LOCATION (INCLUDE STREET NAMES AND, IF APPLICABLE, STREET ROUTE NUMBERS)

COMMUNITY: BOLTON
LOCATION: ROUTE 117
AT:
FROM:
TO:
WORK ALSO IN:

MHD PROJECT NUMBER:
IS THE PROJECT IN AN MAPC CONCENTRATED DEVELOPMENT CENTER (CDC)?: 0

2. PROJECT REQUEST AND DESCRIPTION

DATE OF MOST RECENT REQUEST:
TYPE OF PROJECT REQUESTED:
DESCRIPTION OF THE PROJECT: RAMPS

3. PROJECT DATA

ROADWAY FUNCTIONAL CLASSIFICATION
PROJECT WIDTH: PROJECT LENGTH:
PROJECT/FACILITY MAINTAINED BY: COMM OF MA
PROJECT ENGINEER: UNKNOWN
IS PROJECT PART OF PAVEMENT MGT SYSTEM?: NAME OF PM SYSTEM:
IS ROW REQUIRED?: IF YES, WHEN WILL ROW BE ACQUIRED?:
% ENGINEERING COMPLETE.

SCHED ADV DATE: (IF LISTED AS 1-1-99, A SCHEDULED ADVERTISING DATE IS NEEDED)
COST ESTIMATE: $0.00

4. APPROVALS REQUIRED

MHD DISTRICT HIGHWAY DIRECTOR APPROVAL: UNKNOWN
MHD PROJECT REVIEW COMMITTEE APPROVAL: UNKNOWN
% ENGINEERING APPROVED BY MHD.

5. TIP INFORMATION (Information in this section will be completed by the MAPC and the State)

FISCAL YEAR: PR
FUNDING CATEGORY: NFA
AMENDMENT:
LATEST AMENDMENT DATE:
CHANGE TO:

6. PROJECT CONSTRUCTION (WHEN THIS PROJECT IS ADVERTISED FOR CONSTRUCTION, PLEASE NOTIFY THE MAPC)

HAS THE PROJECT BEEN ADVERTISED?:
ADVERTISED DATE
HAS THE PROJECT BEEN BID?:
AWARD DATE:
AMT OF BID: $0.00

7. MISCELLANEOUS NOTES ON PROJECT

1/13/95 PROJECT PROPOSED BY PETER DONOHUE, MHD DHD

Metropolitan Area
Planning Council

The Transportation Improvement Program for FY 95-97

PROJECT STATUS REPORT

Prepared by the Metropolitan Area Planning Council
(617) 451-2770
FAX (617) 482-7185

BOLTON
MAPC SUBREGION: MAGIC
MHD DISTRICT: 3

LISTED BELOW IS THE MOST UP-TO-DATE INFORMATION THE MAPC HAS REGARDING TIP PROJECT REQUESTS IN YOUR COMMUNITY. PLEASE READ OVER THE INFORMATION CAREFULLY AND NOTIFY THE MAPC IF ADDITIONAL INFORMATION IS AVAILABLE OR CORRECTIONS ARE NECESSARY. UNLESS THE MASSACHUSETTS HIGHWAY DEPARTMENT WILL BE DESIGNING AND ENGINEERING THE PROJECT, IT IS UP TO THE COMMUNITY TO PROVIDE THE NECESSARY INFORMATION IN SECTIONS 1, 2, 3 AND 4 FOR CONSIDERATION IN THE TIP. PLEASE CONTACT CHRISTOPHER C. SKELLY AT MAPC (617) 451-2770 IF YOU HAVE ANY UPDATED INFORMATION OR QUESTIONS.

1. PROJECT LOCATION (INCLUDE STREET NAMES AND, IF APPLICABLE, STREET ROUTE NUMBERS)

MHD PROJECT NUMBER: 600580

COMMUNITY: BOLTON
LOCATION: ROUTE 117
AT: NA
FROM: I-495
TO: STOW TL
WORK ALSO IN:

IS THE PROJECT IN AN MAPC CONCENTRATED DEVELOPMENT CENTER (CDC)?: NO

2. PROJECT REQUEST AND DESCRIPTION

DATE OF MOST RECENT REQUEST: 4/1/494
TYPE OF PROJECT REQUESTED: ROAD RECONSTRUCTION
DESCRIPTION OF THE PROJECT: ROAD RECONSTRUCTION

3. PROJECT DATA

ROADWAY FUNCTIONAL CLASSIFICATION:
PROJECT WIDTH: PROJECT LENGTH:
PROJECT/FACILITY MAINTAINED BY: UNKNOWN
PROJECT ENGINEER: UNKNOWN
IS PROJECT PART OF PAVEMENT MGT SYSTEM?: NAME OF PM SYSTEM:
IS ROW REQUIRED?: UNKNOWN IF YES, WHEN WILL ROW BE ACQUIRED?:
% ENGINEERING COMPLETE: 0%

SCHED ADV DATE: 9/1/95 (IF LISTED AS 1 1/2, A SCHEDULED ADVERTISING DATE IS NEEDED)
COST ESTIMATE: $1,500,000.00

4. APPROVALS REQUIRED

MHD DISTRICT HIGHWAY DIRECTOR APPROVAL: APPROVED
MHD PROJECT REVIEW COMMITTEE APPROVAL: APPROVED - 4/28/94
% ENGINEERING APPROVED BY MHD: 0%

5. TIP INFORMATION (Information in this section will be completed by the MAPC and the State)

FISCALYEAR: 96
FUNDING CATEGORY: NFA
AMENDMENT: NO
LATEST AMENDMENT DATE: NA
CHANGE TO: NA

6. PROJECT CONSTRUCTION (WHEN THIS PROJECT IS ADVERTISED FOR CONSTRUCTION, PLEASE NOTIFY THE MAPC)

HAS THE PROJECT BEEN ADVERTISED?: NO
ADVERTISED DATE:
HAS THE PROJECT BEEN BID?: NO
AWARD DATE:
AMT OF BID:

7. MISCELLANEOUS NOTES ON PROJECT

4/4/94 PROJECT LISTED IN PROJIS
4/28/94 PROJECT APPROVED BY THE MHD PROJECT REVIEW COMMITTEE
7/1/94 PROJECT CHANGED FROM STP TO NFA BY EOTC.
1/13/95 MHD DHD STATED THAT TOWN IS IN PROCESS OF HIRING A DESIGN CONSULTANT. PROJECT SHOULD REMAIN IN FY 96

Project Initiation by the Community to the MHD District Office

Town of Grover's Corner

Grover's Corner, Massachusetts

XXXXX X. XXXXXXXXX, P. E.
District Highway Director
MHD District X
XXXXXX, MA XXXX

Subject: Lakeview Road Traffic Improvement Request

Dear Mr. XXXXXX,

This is an official request from the town of Grover's Corner to the Massachusetts Highway Department for assistance in correcting a traffic problem on Lakeview Road in this town, which runs from Main Street (Route 140) to Granite Street, a distance of one and one-half miles.

The problem on Lakeview Road is one of safety. According to the most recent accident data compiled by the Chief Simson of the Grover's Corner Police Department, ten separate vehicular accidents have occurred on Lakeview Road in the last eight months. Four persons involved have required hospitalization. An examination of the MHD accident data covering the three previous years reveals an average of eleven reported accidents per year on this road.

It is the opinion of the Grover's Corner Public Works and Police Departments that Lakeview Road's width (14 feet on average), winding alignment, and road surface conditions (which vary from fair to intolerable), each contribute to an unacceptable level of safety.

The town of Grover's Corner is requesting that the MHD widen the existing Lakeview Road, as well as straighten its present alignment. It is the town's belief that this work could be paid for with federal and state funds, as Lakeview is on the Federal Aid system.

Grover's Corner is aware of required lane and shoulder widths for the use of federal funds. The town now owns five feet on either side of the existing roadway. The nearest structures to the road are set back approximately 30 to 40 feet. Therefore, land takings are not foreseen as a major problem. The town of Grover's Corners is willing to obtain all necessary rights of way.

My office has received numerous calls and personal visits from community residents concerned about the dangerous nature of Lakeview Road. The Board of Selectmen has informally contacted residents of Lakeview Road as well as members of the Planning Board regarding this improvement proposal. and each of those contacted has expressed support for this reconstrution request.

The MHD's assistance in rectifying this situation would be appreciated by both myself and the town of Grover's Corner.

Sincerely,

Silas Peckham. Chairman
Board of Selectman
Town of Grover's Corners

cc: David C. Soule, Metropolitan Area Planning Council

MASS HIGHWAY William F. Weld, Governor · Argeo Paul Cellucci, Lieutenant Governor · James J. Kerasiotes, Secretary · Laurinda T. Bedingfield, Commissioner

April 25, 1994

Mr. Joseph J. Durant, Chairman
Town of Hudson Board of Selectmen
Hudson Town Hall
78 Main Street
Hudson, MA 01749

SUBJECT: TOWN OF HUDSON - ROUTE 62 (CENTRAL STREET) "3R" PROJECT, BEGINNING AT THE ROUTE 62/COOLIDGE STREET INTERSECTION AND PROCEEDING EASTERLY TO THE ROUTE 62/WILKINS STREET INTERSECTION, A DISTANCE OF APPROXIMATELY 1.6 MILES

Dear Mr. Durant:

We are pleased to inform you that the Project Review Committee (PRC) of the Massachusetts Highway Department has approved the subject project for Federal-Aid STP funding.

This approval is contingent upon several other steps. First and foremost the project must be included in the approved Statewide Transportation Improvement Program (TIP) which covers three Federal Fiscal Years. As you know, the TIP is financially constrained. In the event that this project does not make the TIP, it will be carried in the pending list for informational purposes. Eligibility for Federal participation on design and Right-of-Way costs also require inclusion in the TIP. Secondly, all projects, even though in the TIP, are subject to the availability of State and Federal Funding at each stage.

We accept the offer of the Town of Hudson to assume the design responsibility for this project. It should also be noted that the approval of the PRC is contingent upon the Town's acceptance of responsibility for the acquisition of all necessary R.O.W. takings and/or easements, and for the preparation of environmental documents, if required.

If you have any further questions, please do not hesitate to contact Mr. John Hoey, District Projects Development Engineer at (508) 754-7204.

Very truly yours,

Peter J. Donohue,
District Highway Director

KBF/kbf-hud62cnt
cc: Edward Bates, Metropolitan Area Planning Council
Honorable State Senator Robert A. Durand
Honorable State Representative Patricia A. Walrath
J. W. Hoey, K. B. Fox, P. A. Leavenworth, M. O. Pile

APPENDIX N

Memorandum Describing TCM Analysis Methods Used by the Boston CTPS

Source: Boston No. 7.

CTPS

State Transportation Building
Ten Park Plaza, Suite 2150
Boston, MA 02116-3968
(617) 973-7100
Fax: (617) 973-8855

CENTRAL
TRANSPORTATION
PLANNING
STAFF

MEMORANDUM

TO: Clean Air Technical Advisory Committee — February 12, 1993

FROM: Karl H. Quackenbush

RE: TCM Analysis -- Regional Modeling and Other Approaches

1.0 INTRODUCTION

This memorandum is designed to give Technical Advisory Committee members some guidance on the topic of Transportation Control Measure (TCM) analysis. To that end, the memorandum presents information about how CTPS has approached TCM analyses in the past and what analytic tools have been used. Special emphasis is given to the CTPS regional model. There is a section that describes the model so that the Committee may gain a rudimentary understanding of how it works, and the model's potential role in TCM analyses is a theme that runs through much of the memorandum.

The first section of the memorandum breaks past CTPS analyses of TCM's into their typical constituent parts in order to provide at least one conceptual framework for thinking through such analyses. The second section discusses alternative analysis approaches that can be used within that framework, including the use of the regional model. The third section describes the CTPS regional model in more detail and the final section synthesizes all information into a summary of guiding principles and possible analysis approaches for specific categories of TCM's.

2.0 TYPICAL THREE-STAGE TCM ANALYSIS PROCESS

Past analyses of TCM's at CTPS, model-based and otherwise, have typically entailed sequentially estimating the TCM's impacts first on traveler behavior, then on the transportation system and finally on emissions. These three analysis stages are described very generally below.

2.1 Predicting Traveler Response

Traveler response refers to how travelers will react to the implementation of a TCM. The primary effect of a TCM may be to switch some travelers to non-automobile modes, while the effect of another may be to shift auto travelers from peak to off-peak travel times. Some TCM's may elicit multiple traveler responses. Following, are some responses TCM's could elicit.

- Mode shifts: Switching from automobile to transit or to non-motorized modes.
- Occupancy shifts: Switching from single-occupant to multiple-occupant autos.
- Temporal shifts: Shifting travel from peak to off-peak times.
- Travel path shifts: Switching from one highway route to another or switching from one transit route to another while still traveling between the same origin and destination.
- Destination shifts: Certain types of trips might be made to closer destinations, hence shortening trip lengths.
- Change workplace/residence location. A possible long-term response that could have the ultimate effect of shortening trips or causing mode shifts.

- Reduced tripmaking: Some travelers might forego certain trips altogether.

In some cases, traveler responses can be predicted probablistically within the regional model. For example, the regional model will predict the probability of travelers switching from auto to transit in response to reduced transit fares. This will occur in the mode choice portion of the model chain in which relationships between travel costs and mode choices that have previously been statistically estimated reside. On the other hand, the traveler response to certain other TCM's must be estimated informally and judgmentally, perhaps on the basis of reported experience elsewhere, as there is no formal mechanism for doing so in the regional model or otherwise.

2.2 Estimating Transportation System Impacts

Once traveler response to a TCM has been estimated, the resulting impacts of that response on the transportation system must be estimated. The transportation system of interest can be the regional system, a single intersection or something in between.

The following system impacts are of interest for regional air quality analysis:

- Changes in the number of automobile vehicle trips.
- Changes in vehicle miles traveled (VMT) resulting from both trip reductions and shorter trips
- Changes in speeds.

A TCM that leads to a reduction in automobile vehicle trips will reduce cold and hot start emissions as well as VMT. Reductions in VMT can occur due to both trip reductions and shortening of trip lengths. Increases in speeds can occur on specific roadways due to reductions in traffic and/or increases in capacity.

System impacts can be estimated with much precision, as when a regional model is run to calculate speed changes on all roadway links in the system, or more roughly, as when average regional trip length is multiplied by an assumed change in the number of vehicle trips in order to estimate VMT change.

2.3 Estimating Emissions Impacts

Impacts on emissions are calculated using outputs of the transportation system analysis, together with emissions factors. At CTPS, we use EPA's MOBILE model to produce emissions factors. We have been using MOBILE 4.1, but anticipate switching to the newer MOBILE 5.0 soon. We run MOBILE once for a given analysis year (as opposed to once for every TCM analysis), using a host of inputs that describe such things as local meteorological, fleet-mix and Inspection/Maintenance program characteristics. The program outputs emissions factors for Volatile Organic Compounds (VOC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOX).

These factors are applied to VMT and speeds derived from the transportation systems analysis. This step yields estimates of total emissions associated with a particular TCM. These emissions are compared to those associated with the same system in the absence of the TCM in order to derive the change in emissions associated with the TCM.

3.0 ALTERNATIVE ANALYSIS APPROACHES

The three-stage TCM analyses done by CTPS tend to have been accomplished using one of three approaches: regional model-based, partially regional model-based and non-regional modeled-based. In addition, there have been TCM's for which we could not derive a credible analysis approach. Each of these approaches is described below.

3.1 Regional Model-Based

Many TCM's can be readily represented in the regional model in order to predict traveler response and system impacts. Good examples of these exist among the transit service improvements now being tested in the Program for Mass Transportation.[1] Transit line extensions, headway improvements and running time improvements can all be coded directly into the model, and changes in regional trips, VMT and speeds can all be automatically output and used for emissions estimation. The model chain, in these cases, contains variables that are sensitive to the TCM action being tested.

In a sense, these are the easiest analyses to conduct because a routenized and validated procedure exists, and if it is followed properly, a valid estimate can usually be obtained. On the other hand, these can be the lengthiest analyses because setting up and running the model, and summarizing and interpreting the output, can be very time-consuming. For that reason, we generally like to run the model only when it clearly represents the superior analytic approach.

A major issue with regard to TCM's and regional models is that these models were not developed with TCM testing in mind. Instead, regional models came about in order to test the effects of fairly large-scale capital investments such as highways and rail lines. That is not to say these models cannot be used for TCM testing, but there are many TCM's whose effects are small enough that they are well within the error-range of regional models. There are many other TCM's that a regional model is simply not sensitive to.

Currently, there is a great deal of research and discussion in the modeling field pertaining to actual and perceived mismatches between the kinds of policy questions now being asked and the kinds of answers that regional travel models can give. The Clean Air Act Amendments and ISTEA have generated many of these questions and some of them have to do specifically with the ability of regional models to provide guidance in TCM/air quality matters. For example, critics (both modelers and non-modelers alike) have cited the inability of most regional models to deal with non-motorized modes as a drawback to their use in TCM analysis.

At CTPS, we are addressing some of these concerns in the course of updating our model chain. Even still, regional models will probably never be able to analyze the impacts of many kinds of TCM's either because those TCM's imply very small changes in system impacts or because no analytic device, model-based or otherwise, can successfully predict their impacts.

3.2 Partially Regional Model-Based

There are TCM's that do not lend themselves to being directly modeled, but for which portions of the regional model can be run. These are TCM's for which the model cannot itself predict traveler response. What we have done in some of these cases has been to estimate traveler response using judgmental techniques and then to use the regional model to calculate system impacts. For example, in a study of corridor improvement options done for the Massachusetts Highway Department, peak period traffic reductions resulting from a hypothetical Transportation Management Organization (TMO) were predicted. We assumed an employee participation rate in the TMO area and, based on a literature search, assumed a particular percent reduction in peak-period vehicle trips that might be achieved among those participating employees in the TMO. We then manually adjusted the vehicle trips in the model downward and assigned them to the highway network. In other words, we assumed a traveler response using our judgment and then ran part of the model to estimate what would happen in the system, given that assumed response. Finally, we applied emissions factors to the traffic assignment outputs.

---

[1] *The Program for Mass Transportation is this region's long-range plan for public transportation. It is currently being updated and will eventually constitute the transit element of the region's overall transportation plan.*

3.3 Non-Regional Model-Based

There are many TCM's for which running even part of our regional model has not been an option, either because the model was not directly sensitive to the TCM in question, because there was no time to run the model or because the model was deemed to be too blunt an instrument with which to conduct the analysis. In these cases, we resorted to sketch planning and other kinds of analyses.

Sometimes, we relied on case study information provided in the literature to provide guidance on likely TCM impacts in our region. In still other cases, even though we may not have run any part of our model, we still used information derived from previous model simulations. In fact, many of the reports now appearing that discuss sketch planning and other approaches for TCM analysis assume that the analysts will have access to data from regional models. Geographic-specific mode shares, average vehicle occupancies, average trip lengths -- these are all data items that could be obtained from a regional model and then used in a "back of the envelope" analysis.

There are several reports out that provide guidance on TCM analysis techniques and case study information when regional models are either unavailable or not suitable. Some of these reports that CTPS has copies of are as follows:

- EPA and Pacific Environmental Services, Inc., Transportation Control Measures: State Implementation Plan Guidance, September 1990.
- Systems Applications International for U.S. EPA, Methodologies for Estimating Emission and Travel Activity Effects of TCM's, July 1992.
- Cambridge Systematics, Inc. et. al. for U.S. EPA, Transportation Control Measure Information Documents, March 1992.
- Sierra Research, Inc. for San Diego Association of Governments, Methodologies for Quantifying the Emission Reductions of Transportation Control Measures, October 1991.
- Northeast Association of State Highway and Transportation Officials Task Force on Transportation Demand Management, Transportation Demand Management in the Northeast, Catalog of TDM Techniques, April 1991.
- Analytics, Inc. for the Small Business Innovative Research Program, Transportation Systems Center, An Assessment of Travel Demand Management Approaches at Suburban Activity Centers, July 1989.
- COMSIS Corporation for FHWA, Evaluation of Travel Demand Management (TDM) Measures to Relieve Congestion, February 1990.

Many TCM's represent small-scale traffic flow improvements. Actions such as intersection improvements and arterial widenings have been analyzed with traffic engineering software packages designed for these purposes. If, for instance, signal retiming at an intersection was contemplated as a TCM, we ran the so-called CINCH program which estimates the extent to which vehicular delay can be reduced by signal retiming and other actions.[2] That information, together with MOBILE emissions estimates, allowed us to calculate VOC and CO reductions.

[2] The CINCH computer program was written by Dan Beagan, now of the Massachusetts Highway Department. It is used to analyze signalized and unsignalized intersections using methods outlined in: Transportation Research Board: National Research Council, Highway Capacity Manual, Special Report 209, 1985.

3.4 Non-Quantifiable

A final category of TCM's consists of those whose impacts we are not able to quantify, or at least to quantify in any meaningful way. In other words, it is anyone's guess as to what the impacts would be of projects in this category. Examples of these might be employer-based tax incentives or awards to companies for doing a good job of reducing trips. The behavioral effects of these cannot be estimated in our models, regional or otherwise, and it is difficult to imagine how their impacts would be quantified as there is very little information on which to even base an educated guess. Therefore, we could probably not credibly analyze the potential impacts of some of these programs.

4.0 THE CTPS REGIONAL MODEL AND EMISSIONS ESTIMATION PROCESS

The CTPS regional model covers an area extending west to the vicinity of I-495, north to New Hampshire and South to Plymouth and Rhode Island. With it, we simulate travel for 1990, 2000, 2010 and 2020. It is being used currently in the Program for Mass Transportation planning process and it has recently been used in corridor studies done for the MHD. Last year, it was also used to conduct a portion of the region's TIP conformity analysis. (Other portion's of the conformity analysis were done using traffic engineering models.)

The regional model is now undergoing a major updating on the basis of a 1991 household travel survey, the 1990 Census and other information. An interim updated model is due to be ready around the end of March 1993 and the final version will be done next year. The interim model will not be ready in time to perform TCM testing for the Task Force. Therefore, the following description relates to the structure of our model as it now exists. Most of the improvements represented by the interim model relate to variable sensitivity and comprehensiveness. That is, the new model will be sensitive to a larger number of factors than the existing model and it will allow us to perform a variety of types of modeling -- transit, highway, HOV -- in a more integrated fashion.

Our model chain is similar to that used in most large urban areas of North America. These model chains are commonly referred to as four-step urban travel demand forecasting models. The four steps consist of trip generation, trip distribution, mode split and assignment.

4.1 Trip Generation

Trip generation consists of translating population, employment and land use into estimates of daily person trips. This first step is a critically important one because it determines the basic level of tripmaking that will occur in the transportation system. Subsequent steps take this level of tripmaking as a given and simply allocate it spatially, temporally and modally. At CTPS, trips are generated for four purposes: home-based work, home-based school, home-based other and non-home-based. A home-based trip has either its origin or destination at home. Trips are generated on the basis of traffic analysis zones (TAZ's), of which there are currently 775 in the CTPS model region.

In the CTPS regional model chain, walk and bicycle trips are not dealt with in either the trip generation or subsequent steps. Only motorized trips are included in the process. Therefore, we are not able to explicitly estimate the effects some TCM's may have in switching travelers from autos to the walk and bike modes. In order to do so, we would have to make assumptions about how many trips to remove from the set of motorized trips and carry that modified set of trips through the model chain.

The effects of certain policies, TCM's or otherwise, can be simulated by changing trip generation. In past testing of concentrated development schemes for MAPC, for instance, we altered the spatial allocation of regional population and employment in order to generate a different allocation of trips among the TAZ's in the region. We then carried these new trips through the rest of the four-step process in order to estimate system impacts.

(We will soon have a land use allocation model linked to the four-step process, but not in time to perform TCM testing for the Task Force. We will obtain allocations of population and employment from the land use model for use in trip generation. Moreover, we will be able to test the effects of alternative transportation investments on land use allocation because we will build in the necessary "feedback loops" from the four-step process back to the land use model.)

4.2 Trip Distribution

In trip distribution, the daily person trips generated into and out of each TAZ are linked together into matrices or person trip tables -- one for each of the four trip purposes. The trip tables therefore represent the numbers of trips flowing from every TAZ to every other TAZ. The distribution model is a so-called gravity model because it is loosely based on the law of gravity. The number of trips originating in a given zone that are distributed to another zone is directly proportional to the total number of trips destined to that other zone. On the other hand, the number of trips originating in a given zone that are distributed to another zone is also inversely related to some measure of spatial separation between the two zones. In other words, the farther apart the destination zone is from the origin zone, all other things being equal, the smaller the share of the origin zone's trips it will receive.

We use a measure of spatial separation, termed impedance, that consists of a weighted average of automobile and transit travel times. These times are summarized from our computerized highway and transit networks. (More on these later.) When a transportation improvement, such as a transit extension or an HOV lane, is represented in the networks, the distribution model recomputes zone-to-zone travel impedances and redistributes trips to reflect that some TAZ's would be relatively more accessible to one another in the presence of the project. Note that the total number of trips in the system remains constant: they are simply re-distributed.

4.3 Mode Choice/Occupancy Shift

The mode choice model is by far the most conceptually and technically complex model in the four-step chain. It takes as input the four person trip tables output from trip distribution and predicts, for each zonal interchange, the share of travelers who will use each available travel mode. It does so by evaluating the times and costs (again summarized from the networks) of the competing modes, as well as certain characteristics of the [illegible] of the TAZ's they are traveling between. The models (a separate one for each trip purpose) have been statistically estimated on the basis of past travel survey data.

The mode choice model is probably the most important model in the chain for TCM testing. After all, the point of many TCM's is to cause travelers to switch from auto to transit. The mode choice model is the tool that can predict to what degree travelers would, in fact, switch modes. In many TCM analyses for which a regional model is not run, the relationships from an estimated mode choice model are nonetheless used, perhaps by embedding them in a spreadsheet and doing some "pivot-point" analysis (pivoting around existing mode shares).

The mode choice model currently used at CTPS is sensitive to the following major variables when predicting the choice between automobile and transit:

- Travel time -- in-vehicle
- Travel time -- out-of-vehicle (includes walking and waiting time)
- Travel costs -- out-of-pocket (gas, tolls, parking, fares)
- Auto ownership

Note that when choices exist among various transit modes -- say between taking feeder bus to a rail line versus taking an express bus all the way -- the most probable path or routing is determined not by the mode choice model, but by the transit network at another point in the model process.

The mode choice model currently in use does not predict automobile usage by occupancy level: that is, by drive alone versus 2-occupant carpool versus 3-occupant carpool, etc. Instead, we currently have a separate model that performs this function, but only for specific kinds of projects. Our occupancy shift model, which has been used recently in HOV studies done for the MHD, predicts how travel time improvements resulting from HOV lanes will shift travelers from single-occupant vehicles to carpools and vanpools.

The direct output of mode choice consists of four tables, by purpose, of transit person trips and four tables of automobile person trips. The four transit trip tables are summed into one transit person trip table. The four automobile person trip tables are converted into automobile vehicle trip tables using purpose-specific occupancies. These vehicle trips are then summed to a single table, and truck and taxi vehicle trips (estimated by means not described in this memo), are added.

The resulting daily transit persons and daily vehicle trips are assigned directly to their respective networks. In addition, they are factored down to represent tripmaking for specific times of day. We typically factor transit trips down to a morning peak hour table and vehicle trips down into five different time periods. These tables are then also assigned to their respective networks. The peak hour and/or peak period assignments allow us to analyze the interaction between peak demand and capacity.

Of interest in some TCM analyses is the number of auto trips not made as a result of travelers' switching to transit in response to a given action. Such reductions in auto trips are, of course, implied by the outputs from the mode choice model.

4.4 Trip Assignment

As was alluded to earlier, we build and maintain computer representations of the region's highway and transit networks. These represent the supply-side inputs to the travel forecasting process. The highway network consists of all express highway and major arterial roadways in the region, most minor arterials and many collector and local streets. The transit network consists of all MBTA rail and bus lines, all private express bus lines and many private local bus lines.

The networks are used to determine times and costs between zone pairs for input to trip distribution and mode choice. They are then ultimately used in trip assignment, the step in which trips by mode are "assigned" to specific roadway and transit routings through the system. It is from vehicle trip assignment that we obtain estimates of VMT and travel speed, which are then used in emissions estimation.

4.6 Regional Emissions Estimation

Currently, our regional emissions estimation process considers two transportation system variables -- VMT and travel speed. From a vehicle trip assignment, we obtain assigned vehicle volumes and congested travel speeds on each roadway link in the network. We then input that information, along with the distance of each link, into a program in which we have embedded MOBILE emissions factors. The program applies an appropriate emissions factor to the calculated VMT on each link (VMT = vehicle trips x link distance) based on that link's congested speed. It then sums resulting emissions estimates across all links to a regional total. It performs these calculations for VOC, CO and NOX.

We have not, in past modeling, accounted for emissions changes associated with changes in trip starts. We are now looking into the advisability of doing so and into ways of accounting for such changes in our modeling. We have also not attempted to account for secondary effects of TCM's. For example, we have not tried to account for usage by other family members of cars left at home by a traveler who switches to transit. It would be difficult to account for this in a regional model and the evidence surrounding the issue is somewhat mixed. Some analysis approaches appearing in the literature do recommend accounting for this phenomenon.

5.0 SYNTHESIS OF GUIDANCE ON TCM ANALYSIS

The preceding sections discussed a conceptual framework for TCM analyses, discussed distinct analysis approaches and reviewed the CTPS regional model. In this section, all of this information is synthesized into a set of guiding statements regarding TCM analysis. First, some general considerations are summarized and then the analysis of TCM strategies is summarized according to the twenty categories familiar to the Committee.[3]

5.1 Some Guiding Considerations

- The larger or broader the anticipated TCM impact, the greater the rationale for using the regional model.
- The smaller or more localized the anticipated impact, the greater the rationale for using "back of the envelope" techniques or case study information from the literature.
- The more specifically an action can be defined, the easier it may be to analyze.
- If an action clearly affects a specific component of travel cost or travel time, use of the regional model might be appropriate.
- For many TCM's, case study information will be far more valuable than any original analysis.
- Many TCM's -- transit, HOV, land use-based, are being analyzed now or will be analyzed soon in the context of other studies.
- There are several EPA, FHWA and other reports -- CTPS has several of them -- containing suggested non-model-based quantitative analysis approaches, some of which can be used by the Committee.
- The impacts of many TCM's simply cannot be credibly quantified.

5.2 Analysis Possibilities by TCM Category

This summary is not designed to explicitly include all TCM's the Committee is aware of or to be a definitive set of instructions on how to analyze TCM's. It is, rather, designed to identify a range of TCM's and possible analytic approaches based on information presented in preceding sections.

- Programs for Improved Public Transit: Specific transit route, headway and travel time changes can be coded into the regional model to predict changes in automobile trips, VMT, and highway travel speeds. It may be that, since numerous transit projects are now being analyzed in the Program for Mass Transportation, there will be little for the Committee to do in this area.
- High Occupancy Vehicle Facilities: Specific HOV lanes could be represented in our regional model to predict changes from single-occupant to multiple-occupant vehicles. This is a very time-consuming procedure, however, and the Regional Transportation Plan and HOV Systems Analysis are going to analyze these types of facilities later this year.
- Employer-based Transportation Management Plans: This is a very broad category. If specific actions that affect travel time or cost in specific geographic areas are identified, then their impacts can be modeled. If hypothetical effects on vehicle trips can be generalized from the literature, then these trips can be manually manipulated in the model and assigned to the network.

[3] *See Sonia Hamel's list entitled "Transportation Control Measures, Strategies for Discussion," February 1993.*

- Trip Reduction Ordinances: This is also a very broad category. Again, if specific reductions on vehicle trips can be hypothesized or "guesstimated" from the literature, then vehicle trips in the model can be manually reduced and then assigned to test for system impacts.

- Traffic Flow Improvements: Specific intersection improvements or arterial widenings and the like can be evaluated with traffic engineering software. Changes in delay can be calculated and used to calculate emissions impacts. Incident management programs per se cannot be analyzed effectively, but if specific actions can be identified, they could be analyzed using judgmental techniques.

- Parking Facilities for HOV's or Transit: When parking lots are connected to transit lines, they can be analyzed in the regional model. If they are to be staging areas for HOV's only, then a sketch-planning or other non-model technique can be employed. The MHD, with CTPS assistance, is starting now to comprehensively analyze park/ride demand at a host of sites around the region. The Committee should be careful not to duplicate that work.

- Vehicle Use Limitations/Restrictions: The effects of these are highly speculative. If specific reductions of vehicle trips can be hypothesized, then these can be manually manipulated and assigned in the regional model. Case studies of experience elsewhere might provide some insights.

- Programs for Provision of All Forms of High-Occupancy, Shared-Ride Services: The effects of things like improved marketing and commuter information programs are highly speculative. There may be quantitative tools available in the literature for addressing some of these. Again, case studies of experience elsewhere might provide some insights.

- Programs to Restrict or Limit Portions of the Road Surfaces of Certain Sections of the Metropolitan Areas to the Use of Non-Motorized Vehicles or Pedestrian Use: The effects of these are highly speculative and possibly very marginal. Case studies might help.

- Programs to Encourage Bicycle Use: We have no techniques readily available with which to analyze these. If one were willing to assume some reduction in motorized vehicles occurring in a specific geographic area in response to new bicycle facilities, the regional model's vehicle trips could be manually reduced and assigned. However, the probable effects of such programs are small enough that using the model might be overkill.

- Programs to Control Extended Idling of Vehicles: The effects of reduced idling in traffic queues might be analyzed with traffic engineering programs.

- Programs to Reduce Motor Vehicle Emissions Caused by Cold Start Conditions: Actions that cause travelers to leave their cars at home can be analyzed either in the regional model or with other quantitative analysis techniques.

- Employer-Sponsored Programs to Permit Flexible Work Schedules: The regional model cannot yet predict how travelers might shift from peak to off-peak travel times or from five-day to four-day work weeks, but if assumptions about this are made, based on experience reported in the literature, then trip tables can be manually manipulated and assigned in the model. For very localized programs, a non-model-based analysis, perhaps using basic trip flows reported from the models, might be employed.

- Programs and Ordinances to Facilitate Non-Automobile Travel, Provision and Utilization of Mass Transit, and to Reduce the Need for Single-Occupancy Vehicle Travel Generally: This is a very broad category. Much of what might fall into it is highly speculative. Depending on the specific measure identified, any one of several analysis approaches could be employed. Many measures would likely not lend themselves to any analysis.

- Programs for New Construction and Major Reconstruction of Paths, Tracks, or Areas Solely for Use by Pedestrians or Other Non-Motorized Means of Transportation: The effects of these are highly speculative. Case study information may prove most valuable.

- Programs to Encourage the Voluntary Removal of Pre-1980 Model Year Light Duty Vehicles and Trucks: These programs may not easily lend themselves to analysis, unless an assumption is made about the success of a particular program. Then, MOBILE could be rerun in order to obtain emissions factors based on different fleet-mix assumptions. These could then be applied to transportation system outputs.

- Measures for Cleaner Vehicles: Most of these do not appear to lend themselves to analysis.

- Land Use Measures: Land use assumptions underlying trip generation in the regional model could be manually modified in order to simulate system impacts of alternative policies. This is very time-consuming, however, and doing so may not fit into the Committee's rather compressed schedule. The Regional Transportation Plan process will probably entail doing just this sort of analysis.

- Parking Management Programs: If parking programs can be translated into parking cost impacts, they could be modeled in the regional model or they could be analyzed using other TCM analysis techniques. Some programs in this category would be very difficult to analyze by any means.

- Other: Most items listed in this category would be very difficult or impossible to evaluate. Refer to the section on guiding principles above.

APPENDIX O

Memorandum of Understanding: Traffic and Air Quality Mitigation for the Central Artery/ Third Harbor Tunnel Project. Also referred to as the CLF MOU in this thesis.

Source: Air Quality #2, pages V-320 to V-332.

MEMORANDUM OF UNDERSTANDING:

TRAFFIC AND AIR QUALITY MITIGATION

FOR THE

CENTRAL ARTERY/THIRD HARBOR TUNNEL PROJECT

1. Parties. The parties to this agreement are the Executive Office of Transportation and Construction of the Commonwealth of Massachusetts ("EOTC"), the Massachusetts Department of Public Works ("MDPW"), and the Conservation Law Foundation ("CLF")(hereafter collectively referred to as "the parties").

2. Need for Mitigation Measures. The parties agree that:

The Central Artery/Third Harbor Tunnel Project ("the Artery/Tunnel Project") can play a major role in producing significant long-term improvements in traffic congestion and air quality;

In order to ensure these improvements in conditions, the parties acknowledge the desirability of implementing new and expanded measures to provide transportation by alternative modes and to increase the efficiency of use of the highway system that includes the Central Artery and harbor tunnels;

The 1990 amendments to the Clean Air Act impose major new requirements on Massachusetts, making it essential for the Commonwealth to position itself to meet those requirements in a manner that enhances both environmental quality and economic prosperity; and

The implementation of the measures referred to in the preceding paragraphs will contribute to the long-term success of the project under the range of conditions that may prevail in the year 2010 and thereafter.

3. Nature of Commitments in This Agreement. The commitments described in this agreement should be incorporated into the certificate of the Secretary of Environmental Affairs on the final supplemental environmental impact report ("FSEIR") for the Artery/Tunnel Project and into the record of decision for the project issued by the Federal Highway Administration ("FHWA"). The parties agree to take all steps appropriate to their respective offices, and to use their respective authorities and means to the full extent necessary, in urging that the commitments be so incorporated.

These commitments shall be incorporated in the Artery/Tunnel Project, implemented, monitored and enforced to at least the same extent as other mitigation commitments made in the environmental impact statement or report, the secretary's certificate or the record of decision for the Artery/Tunnel Project. They are intended to supplement, not to limit or substitute for, commitments made in the other documents just mentioned. The commitments described herein are intended by the parties to be fully binding and enforceable under any applicable law.

4. Parking Freezes. The MDPW has undertaken a sensitivity analysis of the traffic forecasts used to predict air quality impacts of the project. In that sensitivity analysis, several critical input variables were tested to learn their effect on traffic volumes. The results of this analysis indicate that of all the public policy interventions examined, a parking control policy would be the most effective. A full parking freeze for Boston and Cambridge would lower regional trip ends by 135,000. The parties agree that parking policy represents one of the most important areas for improved environmental control and intervention. New or revised parking freezes that ensure high levels of service (or at least no further deterioration of service) and the attainment of air quality goals without increasing street or road capacity shall be put into effect for East Boston/Revere, South Boston, Downtown Boston and Cambridge and made part of the State Implementation Plan for Massachusetts under the Clean Air Act. The parties agree to take all steps appropriate to their respective offices, using their respective authorities and means to the full extent necessary, to attain these goals.

A. Each freeze shall impose a firm limit on the total number of parking spaces in the geographical area to which the freeze applies. Each such limit shall be calculated to ensure the attainment of level [illegible] and air quality objectives. In addition, it may be appropriate for some or all freezes to require holders of permits for new or existing spaces to establish aggressive employer-based transportation demand management programs, to provide preferences -- through set-aside, pricing, and other requirements and incentives -- for high-occupancy vehicle ("HOV") parking, and/or to provide appropriate preferences for short-term (non-commuter) parking. It may also be appropriate to issue permits on the basis of use-specific ratios of allowable parking spaces per 1000 square feet of space developed, and to vary the ratios used within different districts in a freeze area according to the districts' proximity to mass transit services.

B. The Metropolitan Planning Organization ("MPO") shall submit, in each of its parking freeze submissions to DEP, language which would require that the review and approval of additions to or changes in facilities providing parking spaces in each of the freeze areas shall be administered in accordance with a plan to be submitted to the Governor which sets forth the procedures by which the permitting of facilities in the area shall occur. In the case of the parking freezes implemented by the City of Boston, for example, these permitting procedures would be set forth as a proposed text of amendments to the current BAPCC "Procedures and Criteria for the Issuance of Parking Freeze Permits." Such procedures and criteria are subject to an open public hearing process conducted by DEP. The parties agree to take all steps appropriate to their respective offices, using their respective authorities and means to the full extent necessary, to ensure that they are effective in meeting the intent of the parking freeze.

C. Given that the MPO has, at the recommendation of the Secretary of Transportation and Construction ("Secretary"), proposed a South Boston parking freeze, the Secretary shall transmit the freeze to DEP within fourteen days from the date of this agreement. The parties shall in the ensuing months take all steps necessary to see that the South Boston parking freeze is adopted, and that the Cambridge and Downtown Boston freezes are revised, as quickly as possible in accordance with the previous paragraphs. The parties specifically agree that such revisions shall apply to all off-street spaces, and shall address the current problems created by exemption of employee spaces from the freeze concept.

5. Mass Transit. The use of mass transit by commuters, airport travelers and others in the Boston metropolitan area shall be maximized. EOTC shall complete and provide to the other parties no later than December 31, 1991, an initial study of transit improvement strategies in addition to those called for by this agreement and the FSEIR, and shall make every effort to reach a consensus with the other parties as to the conclusions and implementation of that study by March 31, 1992, at which time it should be addressed in a revised Program for Mass Transportation ("PMT"). The parties agree that all of the public transportation improvements discussed below, including rapid transit, commuter rail, bus, water shuttle and station and parking facility improvements will contribute to the success of the total transit plan. The parties also acknowledge that the implementation of other transit projects contained within the Artery/Tunnel Project, including the replacement of the Dewey Square Bus Station at South Station, the reconstruction of the

Airport Blue Line station, and the creation of the underground right of way for the South Boston Piers access transit project will contribute to the attainment of the Artery/Tunnel Project's environmental goals.

The parties recognize that implementation of most or all of the transit improvements addressed in this agreement is subject to public environmental review processes. If any planned improvement is found in the course of such a review process to have environmental impacts which render the project infeasible, EOTC shall develop and implement a substitute transit facility or service that will serve at least the same number of passengers in the same transportation corridor as the transit improvement contemplated by this agreement. In implementing transit improvements under this agreement, EOTC shall confer with the other parties on a quarterly basis in the manner described below.

EOTC shall also do the following.

A. All of the improvements listed in Appendix A to this agreement shall be completed. EOTC shall make every effort to complete each improvement by the last day of the calendar year stated as the year of completion in Appendix A. EOTC shall begin the operation of each new facility or service by the last day of the calendar year following the stated year of completion.

B. Although new circumferential transit facilities were not assumed in the FSEIS/R forecasts, EOTC shall determine whether and how to connect radial transit service corridors outside the central business district (provide one or more permanent circumferential transit facilities). On the basis of a feasibility study of various alternatives, EOTC shall complete and provide that study to the other parties no later than December 31, 1994, and shall make every effort to reach a consensus with the other parties as to whether and how to provide permanent circumferential transit facilities by September 30, 1995.

C. EOTC agrees to pursue with due diligence the program to attain three hour travel speeds for high speed rail between New York and Boston, as its highest inter-city transportation priority. Second, EOTC agrees to pursue high speed rail services along the inland route connecting Hartford, Springfield and Worcester to Boston. Third, EOTC agrees to work cooperatively with the States of Maine and New Hampshire to attain high speed rail service between Boston and Portland, Maine.

Fourth, EOTC agrees on the desirability of extending

Northeast Corridor service north of South Station, possibly on a new alignment. Toward that end, EOTC shall determine whether and how to provide a rail connection between South Station and Logan Airport on the basis of a feasibility study for such a connection. EOTC shall complete and provide that study to the other parties no later than December 31, 1991, and shall make every effort to reach a consensus with the other parties as to whether and how to provide such a connection by March 30, 1992. EOTC shall complete a preliminary study of the compatibility of planned construction work for the Artery/Tunnel Project with such a connection and provide that study to the other parties no later than February 28, 1991, and shall make every effort to carry out design and construction work for the Artery/Tunnel Project so as not to interfere with the development of a rail connection between South Station and Logan Airport.

D. Given the success of the Massport Braintree terminal project, and given the progress in establishing a multi-modal terminal in Natick, the Secretary shall make every effort to obtain from the Massachusetts Port Authority by June 30, 1991, commitments (1) to develop suburban "remote terminal" facilities designed to reduce automotive travel to Logan Airport, and (2) to expand HOV facilities and services within Logan Airport and to coordinate them with other HOV facilities and services, including those developed as part of or in connection with the Artery/Tunnel Project.

E. EOTC, in cooperation with MDPW, the Massachusetts Port Authority and the Massachusetts Turnpike Authority, shall complete and provide to the other parties by December 31, 1991, a feasibility study of the relocation of some of the existing Sumner Tunnel toll booths to a location along Route 1A, generally in the vicinity of the Airport Blue line station, that would allow for airport users to utilize separate toll booths from those approaching from other directions. Given the ability to differentiate subgroups of tunnel users, EOTC shall examine in that study the use of toll pricing to regulate trips to Logan Airport, acknowledging the needs of airport employees. EOTC shall make every effort to reach a consensus with the other parties as to how best to use toll pricing to regulate vehicle trips to the airport by March 31, 1992.

F. The parties agree that MBTA fares should be indexed so that they do not rise more rapidly than fuel, toll and other costs of automobile use, or than the rate of inflation, whichever rate of increase is lower. The parties shall make every effort to reach a written consensus by September 30, 1991, on a specific long-term means of accomplishing such indexing to the full extent possible under existing statutes.

G. EOTC shall complete and provide to the other parties no later than September 30, 1991, a feasibility study examining alternative means of providing a water shuttle service from Boston to the North Shore, which shall explore the special problems of commuter operations in open ocean waters and make recommendations concerning strategies to deal with this problem. EOTC shall make every effort to reach a consensus with the other parties as to how best to provide such service by December 31, 1991.

6. <u>Radial Capacity</u>. No expansion of the radial roadways to and from Boston shall be undertaken within the Route 128 radius. Capacity shall not be expanded in either direction through the addition of lanes on any of the radial roadways, although localized improvements necessary to increase safety or to enhance HOV access may be carried out. "Radial roadway" means a roadway whose major peak-hour function is to carry passenger and other vehicles to and from Boston. This commitment shall be incorporated in the State Implementation Plan for Massachusetts under the Clean Air Act. The parties agree to take all steps appropriate to other respective offices, using their respective authorities and means to the full extent necessary, to attain such incorporation.

7. <u>Regulation Governing Roadway Tunnel Ventilation Systems</u>. DEP has published in draft form a proposed regulation governing roadway tunnel ventilation systems in the Boston Metropolitan Air Pollution Control District. The parties shall make every effort to assist DEP in expediting the issuance of a final regulation in order to ensure the attainment and maintenance of the air quality goals of the Artery/Tunnel Project. The parties agree that all appropriate terms of this agreement, including but not limited to those pertaining to the triggering of expanded HOV measures, should be incorporated in any compliance plan that may be submitted for the Artery/Tunnel Project (see proposed 310 CMR 7.38(5)(November 1990)). All commitments in this agreement shall be implemented and enforceable whether or not the measures to be undertaken pursuant to those commitments are also required under the DEP regulation.

8. <u>High-Occupancy Vehicle Facilities</u>. The highest possible level of high-occupancy vehicle ("HOV") utilization shall be attained throughout the entire highway system that includes the Central Artery and harbor tunnels, to the full extent that individual HOV facilities and priority mechanisms

contribute to improved environmental quality and sound traffic management. Both commuters using highways to and from Boston and travelers, patrons and employees using highways to and from Logan Airport should utilize HOVs and mass transit. Conversely, the goal of the commitments made in this memorandum is to reduce to the maximum extent feasible single-occupancy vehicle travel by those two groups and others.

To that end, the parties agree that the actions described below shall be taken. The commitments outlined in this section shall be incorporated in the State Implementation Plan for Massachusetts under the Clean Air Act. The parties agree to take all steps appropriate to their respective offices, using their respective authorities and means to the full extent necessary, to attain such incorporation.

A. Interstate 93 ("I-93") North of the Southern Bank of the Charles River.

Southbound Direction. Prior to commencement of reconstruction of the Central Artery, from the area of the I-93 Charles River bridge, the existing southbound HOV lane shall be extended toward Route 128 to the northernmost point appropriate to maximize use of the lane, using appropriate lane demarcation mechanisms. This shall not be accomplished by the addition of a new lane or lanes to I-93. The Commonwealth will incorporate into the permanent design of the Charles River crossing an HOV lane extending down the exit ramp to Nashua Street, with a head of queue enforcement point at the ramp's intersection with Nashua Street, subject to the review and approval of the FHWA. EOTC and MDPW shall further study and implement additional HOV priority measures, as appropriate, such as metering systems or HOV lanes on ramps, for southbound traffic from the Charles River crossing to Route 128.

Northbound Direction. EOTC and MDPW shall implement appropriate HOV measures if and when such measures are triggered by traffic conditions in the manner described below. In the case of this highway segment, the parties expect a left-hand HOV lane, from the Charles River crossing to the northernmost point toward Route 128 appropriate to maximize use of the lane, to be an appropriate measure. Creation of such a lane shall not be accomplished by the addition of a new lane or lanes to I-93.

B. Southeast Expressway. EOTC and MDPW shall establish an HOV lane or lanes for north- and southbound traffic, from the Interstate 90/Interstate 93 interchange to at least a point immediately north of the Route 128-Route 3 interchange, and extending beyond to the southernmost point appropriate to maximize use of the lane or lanes, prior to May 31, 1993. EOTC shall establish such a lane or lanes sooner if triggered by traffic conditions in the manner described below. The best engineering mechanism to provide faster, more reliable, safe HOV flow shall be determined through a study which EOTC shall complete and provide to the other parties no later than June 30, 1991. The study shall examine relevant engineering, safety and environmental considerations. If an HOV lane or lanes is accomplished by the addition of a new lane or lanes to I-93 or Route 3, any such HOV lane shall remain as a permanent HOV lane and shall at no point be converted to use for general traffic.

C. Massachusetts Turnpike. The Secretary shall take all steps necessary to enhance and expand the Massachusetts Turnpike Authority programs supporting HOVs and to ensure the implementation of the following measures by the Massachusetts Turnpike Authority: a program of special HOV toll booths and full head-of-queue privileges, and wherever practical, specially demarcated lanes leading to those toll booths, at all appropriate turnpike interchanges; and the provision of electronic identification systems. In addition, the Secretary shall complete and provide to the other parties no later than June 30, 1992, a study, undertaken with participation of the Authority, to establish the best mechanism to improve the quality and reliability of HOV flow on the Turnpike between Route 128 and Boston. This study shall examine the feasibility of full-scale HOV lanes and other facilities and mechanisms on the Turnpike through Newton and Boston. Once the appropriate engineering solution has been established, it shall be triggered in the manner described below. Creation of HOV lanes shall not be accomplished by the addition of a new lane or lanes to the Turnpike.

D. Trigger Mechanisms. Preceding paragraphs of this section call for HOV measures to be undertaken in the northbound direction on Interstate 93 north of Boston, and additional HOV measures to be undertaken on the Massachusetts Turnpike, when triggered by traffic conditions. Those measures shall be undertaken for the construction and post-construction period after "triggers" calculated by the parties in the following manner have been reached. Each trigger shall consist of the difference, in minutes, between a pre-construction trip time and a construction period trip time. The specific pre-construction ("baseline") trip times and thresholds ("triggers") for implementing HOV measures, both during and after construction, shall be agreed to in writing by the parties no later than April 30, 1991. Triggers shall represent a perceptible deterioration from baseline conditions. The collection of data necessary to the determination of baseline trip times shall be undertaken by December 31, 1991.

E. Performance Standards. Performance standards shall be set for HOV trips along the entire length of each corridor referred to in this paragraph, and for trips between all important origins and destinations along each corridor. Specific performance standards shall be agreed to in writing by the parties no later than April 30, 1991. The performance standards shall be set to provide both a travel-time advantage of a sufficient amount and an extremely high level of reliability to HOVs. For example, an appropriate goal for the standards may be to maintain all HOV trip times at no more than 80 percent of non-HOV average trip time or, where adequate HOV flow now exists, at no more than 105% of current HOV average trip time. Standards shall be set, in minutes, for trips along the following corridors wherever HOV lanes or other facilities or mechanisms have been established: (1) Interstate 95-Interstate 93 interchange north of Boston and the Charles River crossing (during the construction period) and Logan Airport entrance (during the post-construction period), by way of Interstate 93 and the Callahan and Sumner Tunnels; (2) Interstate 95-Interstate 90 interchange and South Station (during the construction period) and Logan Airport entrance (during the post-construction period), by way of Interstate 90; and (3) Weymouth to South Station (during the construction period) and Logan Airport entrance (during the post-construction period), by way of the Southeast Expressway and Interstate 90.

F. Continuous Attainment of Performance Standards. Performance of HOV facilities shall be monitored on a continuous basis to determine whether additional measures or changes in HOV operations are warranted. All appropriate measures, such as metering or changes in the HOV eligibility standard, shall be used on a continual basis to the full extent necessary to maintain compliance with performance standards. Even when vehicles with two occupants do not qualify for HOV eligibility, taxis with single passengers may qualify for HOV eligibility. Trip times will be measured as described on page 5 of the construction Mitigation Appendix to the FSEIR for the project or as subsequently agreed to in writing by the parties.

G. Promotion and Enforcement for HOV System. An aggressive HOV promotion program shall be carried out by

EOTC according to a plan to be completed and provided to the other parties by EOTC prior to commencement of reconstruction of the Central Artery. EOTC shall make every effort to reach a consensus with the other parties as to the adequacy of the plan within ninety days from the date when the plan is submitted to the other parties. The plan will be based on a comprehensive review by EOTC, to be summarized in a written report to the other parties no later than April 30, 1991, of techniques used to manage or promote HOV use in other locations throughout the United States and Canada. Effective enforcement of the HOV system shall be provided by EOTC according to a plan to be completed and provided to the other parties by EOTC no later than the date when highway construction work begins for the Artery/Tunnel Project. EOTC shall make every effort to reach a consensus with the other parties as to the adequacy of the enforcement plan prior to December 31, 1991. EOTC shall also ensure that HOV studies targeted at the various needs of Logan Airport passengers, patrons, and employees are conducted.

H. EOTC and MDPW shall use best efforts to ensure that HOV facilities, including special bus and/or taxi lanes, are incorporated into the design, construction and reconstruction of City of Boston streets. The parties agree to consult on the progress of the development of City street designs and shall encourage the adoption of HOV lane designs wherever feasible and appropriate.

9. Mitigation Oversight. The parties agree to meet no less frequently than once in each calendar quarter, from the date of this agreement onward, to review the implementation of the commitments in this agreement and of other mitigation commitments for the Artery/Tunnel Project pertaining to traffic and air quality. The parties expect that more frequent meetings will often be necessary for the parties to confer, review studies and plans, and enter into subsequent agreements as provided in this agreement. EOTC and MDPW agree that when CLF considers additional monitoring or technical data to be necessary to carry out this agreement, EOTC and MDPW shall arrange to obtain such data in a timely and impartial manner. Such data shall be obtained through the services of an independent person or entity with relevant expertise, at the expense of EOTC and/or MDPW, where a reasonable difference of opinion exists regarding the nature or extent of the data to be obtained, the manner of data collection, or other such matters.

10. Future Support. In recognition of the importance of the Commonwealth's long-term commitments in this agreement to the attainment of transportation and air quality improvements, and on the condition that the commitments in this agreement are

incorporated into the certificate of the Secretary of Environmental Affairs on the FSEIR and into the record of decision issued by FHWA, CLF agrees not to commence, maintain or participate in any action or legal proceeding challenging the adequacy of the environmental documentation for the Artery/Tunnel Project, including the Central Artery North Area Project. CLF specifically reserves the right to take any action necessary to enforce this Memorandum of Understanding. CLF agrees to support actively and in good faith the Artery/Tunnel Project and the implementation of the improvements and other measures undertaken pursuant to this agreement or pursuant to other mitigation commitments in the documents referred to in section 3 above, while reserving the right to recommend further improvements that can be made without delaying the project. CLF specifically agrees to pursue intervention, subject to the approval of its Board of Directors, on behalf of the Commonwealth upon request in a law suit or law suits brought against the Commonwealth in which a third party (other than a state or federal regulatory agency) challenges the adequacy of the environmental documentation for the Artery/Tunnel Project, for the purpose of asserting the public interest in the transportation and air quality improvements resulting from the Artery/Tunnel Project and the mitigation measures undertaken in connection with the project. CLF agrees to take all steps consistent with this agreement and to use its resources vigorously in carrying out the commitments made in this paragraph.

Frederick P. Salvucci
Secretary of Transportation
and Construction

Jane F. Garvey
Commissioner of Public Works

Douglas I. Foy
Executive Director,
Conservation Law Foundation

Commonwealth of Massachusetts
Suffolk County

Sworn to and subscribed before me on this ?th day of December, 1990.

Carey B. Zimmerman, Notary Public
My commission expires January 10, 1997.

Appendix A

Project	Year of Completion
Commuter Rail	
Old Colony Line Extension	1995
Ipswich Line Extension to Newburyport	1993
Framingham Line Extension to Worcester	1995
Lynn Central Square Station and Parking Garage	1991
North Station High Platforms New Tracks	1991
South Station Track 12	1993
Rapid Transit	
South Station Access to Red Line	1991
Blue Line Connection from Bowdoin Station to Red Line at Charles Station	2010
Blue Line Platform Lengthening and Modernization	1997
Green Line Extension to Ball Square/ Tufts University	2010
Green Line Arborway Restoration	1996
Bus	
South Station Bus Terminal	1993
Lynn Transit Station Bus Terminal	1991
South Boston Piers Electric Bus Service	2000
Park & Ride	
Addition of 10,000 spaces systemwide, outside of Boston	1995
Addition of a further 10,000 spaces systemwide, outside of Boston	1998

APPENDIX P

Requirements Placed on Ozone, CO, or PM_{10} Non-attainment Areas By the Clean Air Act Amendments

Source: Document No. 23, p. T-1 to T-4, tables II to VII.

Table II
OZONE NONATTAINMENT AREAS:
REQUIREMENTS FOR DEFINING OZONE EMISSIONS PROBLEM

SERIOUS; SEVERE 1 & 2; EXTREME

MODERATE

MARGINAL

Ozone Emissions Inventory

Submit a 1990 emissions inventory by November 15, 1992 of all hydrocarbon sources, including mobile, stationary, and area sources, and revise every three years thereafter until attainment.

Ozone Emissions Reduction Targets

After the 1990 baseline emissions inventory is submitted in 1992, the State has 1 year, until November 15, 1993, to revise the SIP to show the control strategies that will reduce hydrocarbon baseline emissions 15% over the first 6 years following enactment (1990-1996). This reduction, referred to as reasonable further progress (RFP), should come from mobile, stationary and area sources by using a mixture of control strategies for all sources.

Emissions reductions from the following measures are not creditable toward the 15% reductions:

- EPA regulations related to vehicle exhaust or evaporative emissions control systems promulgated by January 1, 1990;
- EPA regulations related to controls on *Reid Vapor Pressure (RVP)*, a measure of fuel volatility, prior to enactment or required by the CAAA;
- measures to correct deficiencies in existing SIPs and *inspection and maintenance programs (I/M)*.

The 15% reduction must accommodate any population growth resulting in vehicle miles traveled (VMT) growth in the region, and can only be based on measures that go beyond those noted above, thus eliminating credit for the most effective control strategies. States can take credit for new CAAA measures, such as *reformulated gasoline*, new vehicle exhaust standards or evaporative controls. The latter two, however, may not reduce emissions significantly by 1996. State and local officials must be willing to go beyond current controls to achieve emission credit or reduce emission-producing activities. Achieving the 15% reductions without counting the above control strategies will be most challenging.

By November 15, 1994, demonstrate a reduction of 3% on average each year after 1996 until attainment under the selected control strategies. In addition to the demonstration, the State must make an air quality attainment demonstration using photochemical dispersion modeling or any other analytical method approved by the EPA.

By November 15, 1996, and every third year thereafter, show that the current aggregate vehicle milage, aggregate vehicle emissions, and congestion levels are consistent with those projections used for the area's demonstration of attainment. If current levels exceed projected levels, the State must submit a SIP revision within 18 months that includes strategies to reduce emissions to the original projected levels.

Note: Requirements are cumulative. For example, Moderate areas must also fulfill Marginal area requirements.

Table III
OZONE NONATTAINMENT AREAS:
REQUIREMENTS FOR REDUCING OZONE EMISSIONS

MARGINAL

Existing SIP Commitments - Implement current SIP commitments; correct SIP deficiencies.

Basic Inspection and Maintenance Program (I/M) - The basic I/M program should be revised to meet the requirements in the SIP, or EPA guidance, whichever is more stringent, if such a program were required before enactment of the CAAA.

MODERATE

Basic Inspection and Maintenance Program - The SIP is required to be revised to include a basic I/M program, regardless of whether such a program was required before the CAAA.

Stage II Vapor Recovery Program - Submit a Stage *II vapor recovery program* by November 15, 1992, that is designed to reduce emissions from refueling at retail fuel outlets for facilities that sell more than 10,000 gallons/month (50,000 gallons/month for independent small businesses).

Contingency Measures - Contingency provisions in the form of *transportation control measures* (TCMs), or other measures, must be provided for in the 1993 SIP submittal. Transportation control measures are directed toward reducing emissions by improving traffic flow, reducing congestion, or reducing vehicle use. These measures will take effect without further action by the State or the EPA at any point that the State fails to meet the 15% emission reduction targets required by 1996, fails to attain the NAAQS target date, or, in the case of areas designated serious and above, fails to meet the 3% annual emissions reductions required after 1996.

SERIOUS

Enhanced Inspection and Maintenance Program - Submit an enhanced I/M program by November 15, 1992, which meets all of EPA's requirements for enhanced I/M.

Clean-Fuel Fleet Program - Areas with a 1980 population of 250,000 or more must revise the SIP by May 15, 1994, to contain a clean-fuel vehicle program for centrally fueled fleets of 10 or more vehicles. The SIP must include programs to ensure the effectiveness of the clean-fuel fleet program.

SEVERE 1 & 2

Vehicle Miles Traveled (VMT) [illegible] - [illegible] traveled by all motor vehicles in a specified region. [illegible] and measures by November 15, 1992, for implementation to offset growth in [illegible] of trips.

Employer Trip Reduction - By November [illegible] employer trip reduction (ETR) program for employers of 100 or more [illegible] to increase the average passenger occupancy by not less than [illegible] occupancy for the area. Employer compliance plans are due 2 years after SIP submittal. [illegible] compliance 4 years after SIP submittal.

Reformulated Gasoline - [illegible] worst ozone areas, which include the following [illegible] Milwaukee, New York City, Philadelphia, and San [illegible] reformulated gasoline program.

EXTREME

Measures for Heavy-Duty Vehicles - Extreme areas may submit additional measures to reduce the use of high-polluting or heavy-duty vehicles during peak traffic hours.

Note: Requirements are cumulative. For example, Moderate areas must also fulfill Marginal area requirements.

Table V

CO NONATTAINMENT AREAS:
REQUIREMENTS FOR DEFINING CO EMISSIONS PROBLEM

SERIOUS

MODERATE ≥ 12.7 ppm

MODERATE < 12.7 ppm

Carbon Monoxide Emissions Inventory

Submit a 1990 emissions inventory and control plan by November 15, 1992, of all CO emissions, including mobile, stationary, and area sources, and revise every three years thereafter until attainment.

Carbon Monoxide Emission Reduction Targets

Attainment Demonstration - By November 15, 1992, demonstrate that attainment will be reached by the December 31, 1995 deadline. Also, provide provisions in the SIP for annual emission reductions necessary for reaching attainment.

Attainment Demonstration - By November 15, 1992, demonstrate. that attainment will be reached by the December 31, 2000 deadline. Also, provide provisions in the SIP for annual emission reductions necessary for reaching attainment.

Table VI

CO NONATTAINMENT AREAS:
REQUIREMENTS FOR REDUCING CO EMISSIONS

SERIOUS

MODERATE ≥ 12.7 ppm

MODERATE < 12.7 ppm

Oxygenated Gasoline - Areas with a design value of 9.5 ppm or above must submit a revision, by November 15, 1992, requiring gasoline with no less than 2.7% oxygen content in the nonattainment area during the winter months.

Basic Inspection and Maintenance Program (I/M) - The SIP is required to be revised to include a basic I/M program, if such a program were required before enactment.

Enhanced Inspection and Maintenance Program - Submit provisions for an enhanced I/M program by November 15, 1992, which meet all of EPA's requirements for such a program.

VMT Forecast - Revise the SIP by November 15, 1992, to include an annual VMT forecast until attainment. Reports shall contain annual updates of the VMT forecasts and estimates of actual VMT levels.

Contingency Measures - Contingency provisions in the form of TCMs or other measures must be identified in the 1992 SIP submittal to implement specific measures if any estimate of VMT exceeds predicted levels or the area fails to attain the NAAQS. These measures take effect without further action by the State or the EPA.

Clean-Fuel Fleet Program - Areas having a design value at or above 16 ppm and a 1980 population of 250,000 or more must revise the SIP by May 15, 1994, to contain a clean-fuel vehicle program for centrally fueled fleets of 10 or more vehicles. The SIP must include provisions to ensure the effectiveness of the program.

Vehicle Miles Traveled Limitations - Submit specific transportation control strategies by November 15, 1992, for implementation to offset growth in emissions from growth in VMT or number of trips.

Note: Requirements are cumulative. For example, Moderate (≥ 12.7 ppm) areas must also meet requirements for Moderate (< 12.7 ppm) areas.

Table VII
PM_{10} NONATTAINMENT AREAS

SERIOUS	MODERATE	SIP Submittal - Submit a SIP by November 15, 1991, demonstrating attainment of the NAAQS by December 31, 1994. Milestones - Meet quantitative milestones in the SIP which are to be achieved every 3 years.
		SIP Submittal - Submit a SIP no later than 4 years after reclassification of the area to serious. The SIP must demonstrate attainment of the NAAQS by no later than the 10th calendar year after the area's reclassification.

Note: Requirements are cumulative. Serious areas must also fulfill Moderate area requirements.

APPENDIX Q

Listing of Areas in Non-Attainment of

National Ambient Air Quality Standards for ozone, CO, or PM_{10}.

Source: Document No. 24, p. 88 to 92.

Attachment A

OZONE NON-ATTAINMENT AREAS

The following are areas (identified by central city or county) in non-attainment of the National Ambient Air Quality Standard for ozone

EXTREME-20 YEARS TO ATTAIN (2010)

Los Angeles South Coast Air Basin, CA

SEVERE-17 YEARS TO ATTAIN (2007)

Chicago Gary Lake County IL IN
Milwaukee Racine WI
Houston Galveston Brazoria, TX
NY Northern NJ Long Island, NY, NJ CT
Southeast Desert Modified Air Quality Management Area, CA

SEVERE-15 YEARS TO ATTAIN (2005)

Baltimore, MD
Philadelphia Wilmington Trenton, PA NJ DE MD
Ventura, CA
San Diego, CA

SERIOUS-9 YEARS TO ATTAIN (1999)

Atlanta, GA
Baton Rouge, LA
Beaumont Port Arthur, TX
Boston, Lawrence Worcester, MA, NH
El Paso, TX
Greater Connecticut, CT
Muskegon, MI
Portsmouth Dover Rochester, NH
Providence, RI (entire state)
San Joaquin, CA
Sacramento Metro, CA
Sheyboygan, WI
Springfield (western MA), MA
Washington, DC MD VA

MODERATE-6 YEARS TO ATTAIN (1996)

Atlantic City, NJ
Charlotte Gastonia, NC*
Cleveland Akron Lorain, OH
Dayton Springfield, OH*
Charleston, WV*
Cincinnati Hamilton, OH KY
Dallas Forth Worth, TX
Detroit Ann Arbor, MI*
Grand Rapids, MI
Kewaunee County, WI*
Lewiston Auburn, ME*
Manitowoc County, WI
Monterey Bay, CA*
Parkersburg, WVa*
Pittsburgh Beaver Valley, PA*
Reading, PA*
Salt Lake City, UT*
Santa Barbara, Santa Maria, Lompoc, CA
Toledo, OH*
Huntington Ashland, WV - KY
Knox and Lincoln Counties, ME
Louisville, KY-IN
Miami-Fort Lauderdale-West Palm Beach, FL*
Nashville, TN
Phoenix, AZ
Portland, ME
Richmond-Petersburg, VA*
San Francisco-Bay Area, CA
St. Louis, MO-IL

MARGINAL-(Attainment 1993)

Albany Schenectady Troy, NY*
Allentown Bethlehem Easton, PA-NJ*
Altoona, PA*
Birmingham, AL
Buffalo Niagara Falls, NY*
Canton, OH*
Columbus, OH*
Door County, WI
Edmonson County, KY*
Erie, PA*
Essex County (Whiteface Mountain), NY
Evansville, IN*
Greenbrier County, WV*
Hancock and Waldo Counties, ME
Harrisburg Lebanon Carlisle, PA*
Indianapolis, IN*
Jefferson County, NY*
Jersey County, IL*
Johnstown, PA*
Kent and Queen Anne's Counties, MD
Lake Charles, LA
Lancaster, PA*
Lexington Fayette, KY*
Manchester, NH
Memphis, TN*
Norfolk Virginia Beach- Newport News, VA*
Owensboro, KY*
Paducah, KY*
Poughkeepsie, NY
Reno, NV
Scranton Wilkes-Barre, PA*
Seattle-Tacoma, WA-Smyth County
White Top Mt., Bend-Elkhart, IN*
Sussex County, DE
Tampa St Petersburg Clearwater, FL*
Walworth County, WI*
York, PA*
Youngstown-Warren-Sharon, OH PA*
Portland Vancouver Air Quality Management Area, Oregon, WA

ATTAINMENT-(non-attainment in 1990, subsequently redesignated to attainment status)

Kansas City, MO KS
Greensboro-Winston Salem High Point NC
Cherokee County, SC
Raleigh Durham NC
Knoxville TN

CARBON MONOXIDE NON-ATTAINMENT AREAS

SERIOUS-Attainment by 12/31/2000
Los Angeles South Coast Air Basin CA

MODERATE-Attainment by 12/31/95

Anchorage AK	Denver Boulder CO
Fresno CA*	Las Vegas NV
NY Northern NJ Long Island, NY NJ CT	Provo UT
Seattle Tacoma WA*	Spokane WA

MODERATE-Attainment by 12/31/95

Albuquerque, NM	Baltimore MD*
Boston MA*	Chico CA*
Cleveland, OH*	Colorado Springs CO*
El Paso, TX	Fairbanks, AK
Fort Collins, CO	Grants Pass OR*
Hartford New Britain-Middletown, CT*	Klamath Falls OR*
Lake Tahoe South Shore, CA*	Longmont, CO*
Medford OR	Memphis TN*
Minneapolis St Paul, MN	Missoula, MT
Modesto, CA*	Ogden UT*
Philadelphia Camden County, PA, NJ*	Phoenix AZ
Portland Vancouver, OR WA	Raleigh Durham NC*
Reno, NV	Sacramento CA
San Francisco, Oakland San Jose, CA	San Diego, CA*
Stockton, CA	Washington, DC
Maryland VA*	Winston Salem NC*

ATTAINMENT

Syracuse NY	Duluth, MN

*Denotes areas which have complete ozone air quality monitoring data meeting the National Ambient Air Quality Standard during the period 1990-1992, the first step towards attainment

PM-10 NON-ATTAINMENT AREAS

MODERATE-Attainment by 12/31/94

New Haven, CT	Presque Isle, ME
Guaynabo PR	Clairton, PA
Steubenville Follansbee, OH-WV	Granite City, IL
Lyons Township, IL	Oglesby, IL
Southeast Chicago, IL	Lake County, IN
Vermillion County, IN	Detroit, MI
Rochester MN	St Paul, MN
Cuyahoga County, OH	Anthony, NM
El Paso TX	Aspen, CO
Canon City CO	Denver Metro, CO
Lamar CO	Pagosa Springs, CO
Telluride CO	Butte, MT
Kalispell MT	Lame Deer, MT
Libby, MT	Missoula, MT
Polson MT	Ronan, MT
Salt Lake County, UT	Sheridan, WY
Ajo, AZ	Hayden/Miami, AZ
Nogales AZ	Paul Spur/Douglas, AZ
Phoenix AZ	Rillito, AZ
Yuma AZ	Imperial Valley, CA
Mammoth Lake, CA	Searles Valley, CA
Reno, NV	Eagle River, AK
Mendenhall Valley, AK	Boise, ID
Bonner County, ID	Pinehurst, ID
Pocatello, ID	Grants Pass, OR
Klamath Falls, OR	LaGrande, OR

Medford, OR
Springfield/Eugene, OR
Kent, WA
Olympia/Tumwater/Lacey, WA
Seattle, WA
Spokane, WA
Tacoma, WA
Wallula, WA
Yakima, WA

MODERATE AREAS-Attainment 12/31/99

Whitefish, MT
Mono Lake, CA
Lakeview, OR

MODERATE AREAS-Attainment 12/31/2000

New York County (Manhattan), NY
Weirton, WV
Bullhead City, AZ
Sacramento County, CA
Shoshone County, ID
Steamboat Springs, CO
Thompson Falls, MT
Payson, AZ
San Bernardino County, CA
Oakridge, OR

SERIOUS AREAS-Attainment 12/31/2001

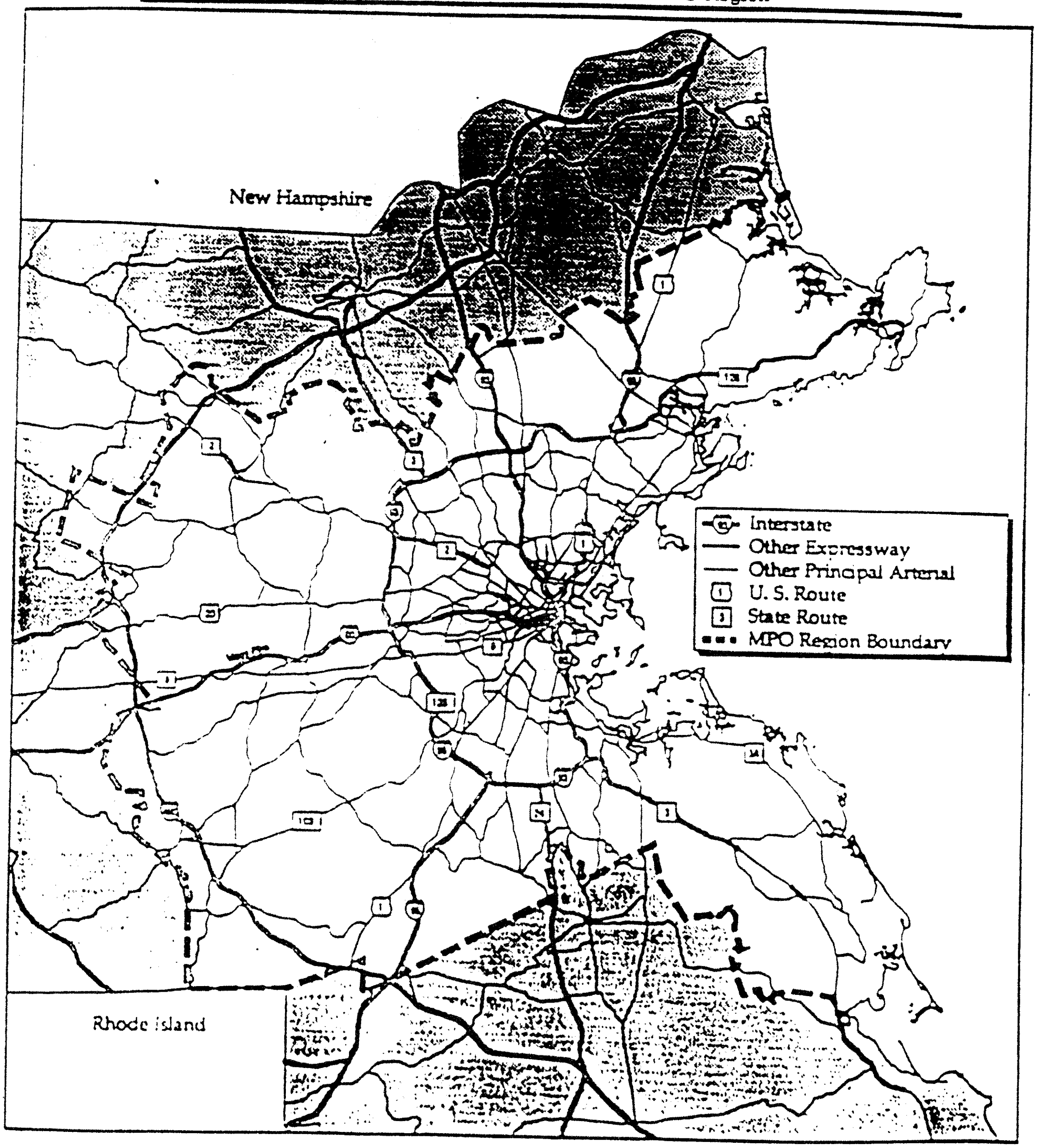
Coachella Valley, CA
San Joaquin Valley, CA
Las Vegas, NV
Owens Valley, CA
South Coast Basin, CA

APPENDIX R

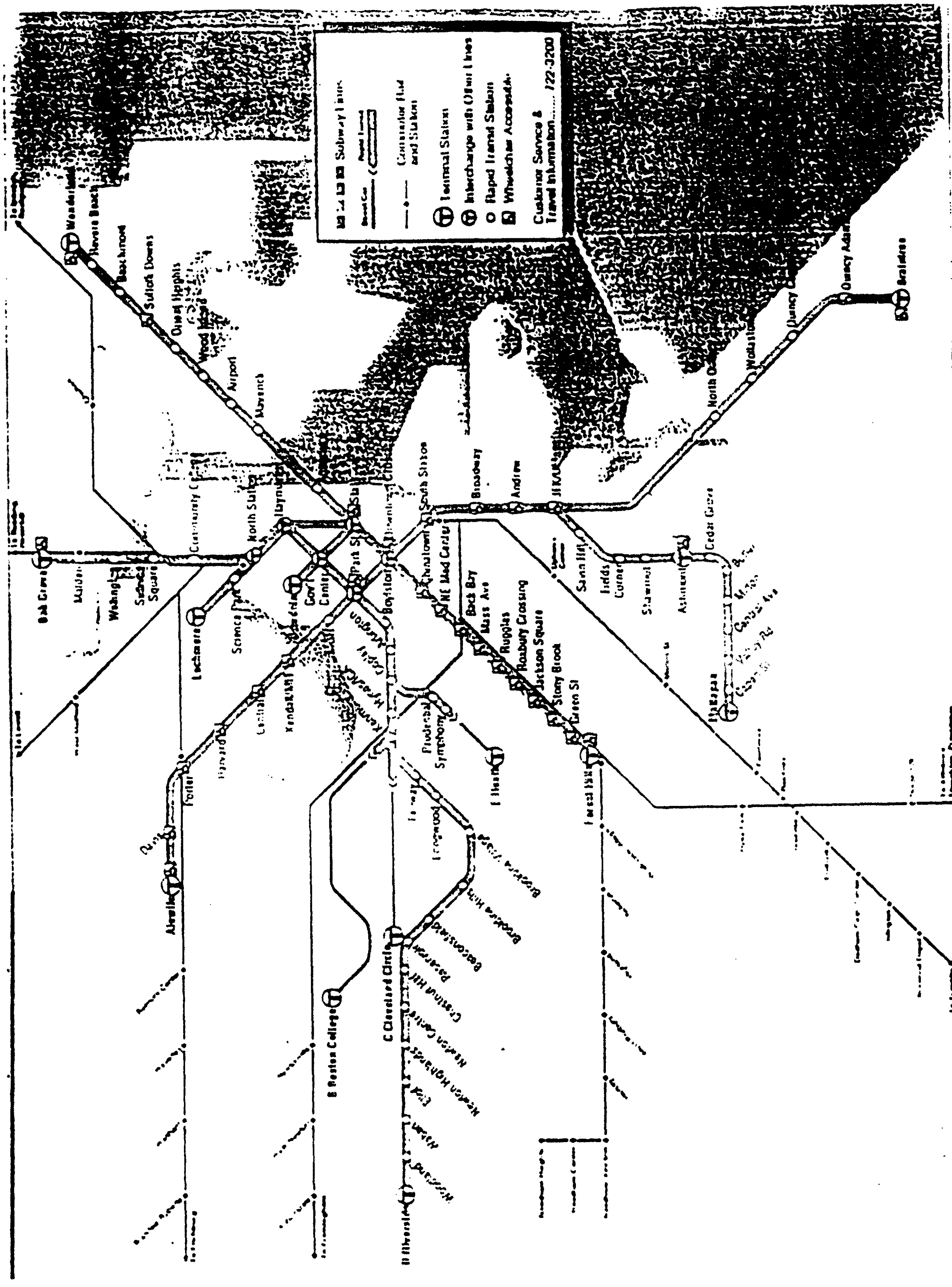
Various Tables and Figures Referred to in the Boston Case Study which is included in Appendix A of this thesis.

Sources listed on figures and tables which follow.

Figure 3.7-2: Principal Arterial Roadways in the Boston MPO Region[6]

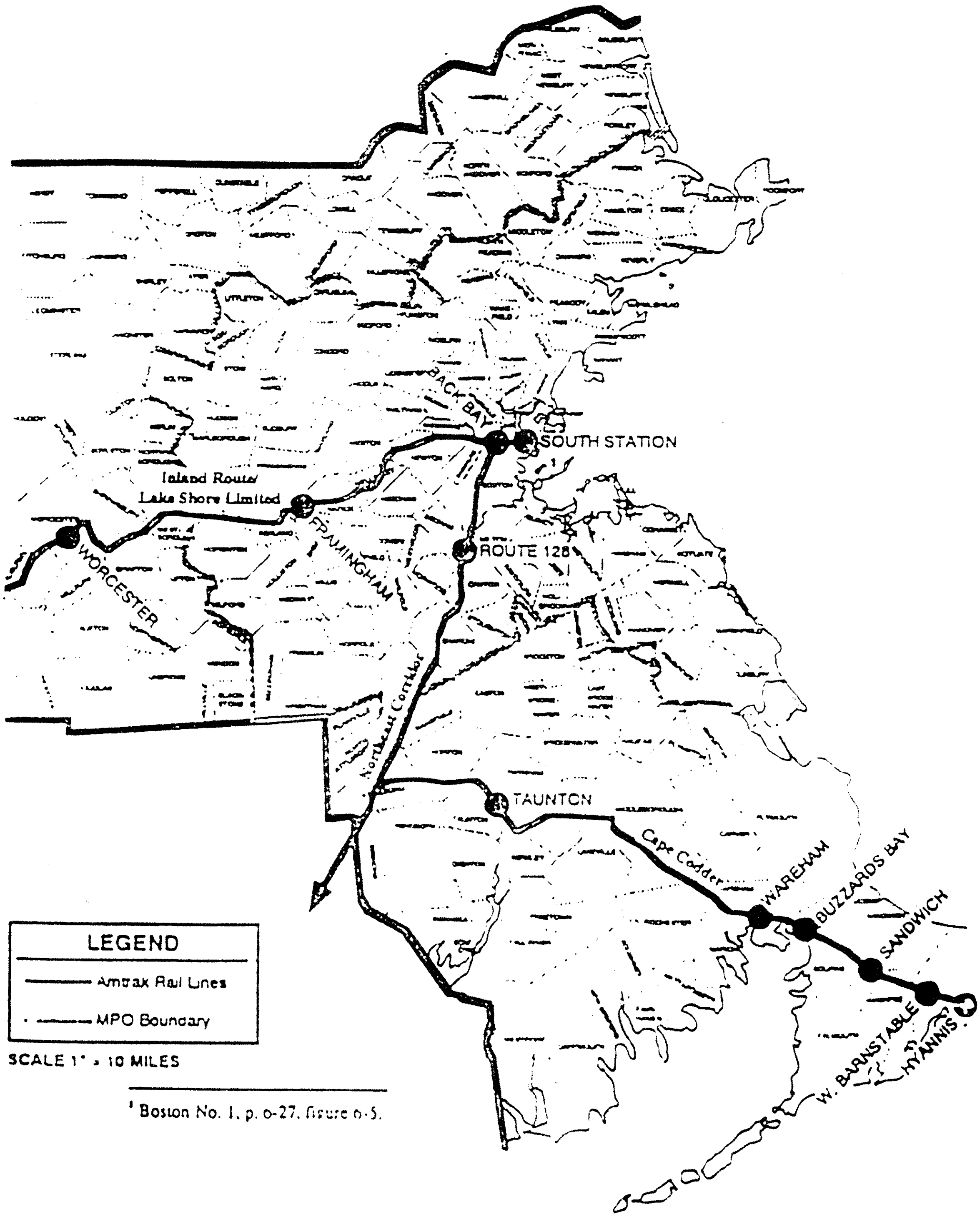


[6] Boston No. 1, p. 6-7.



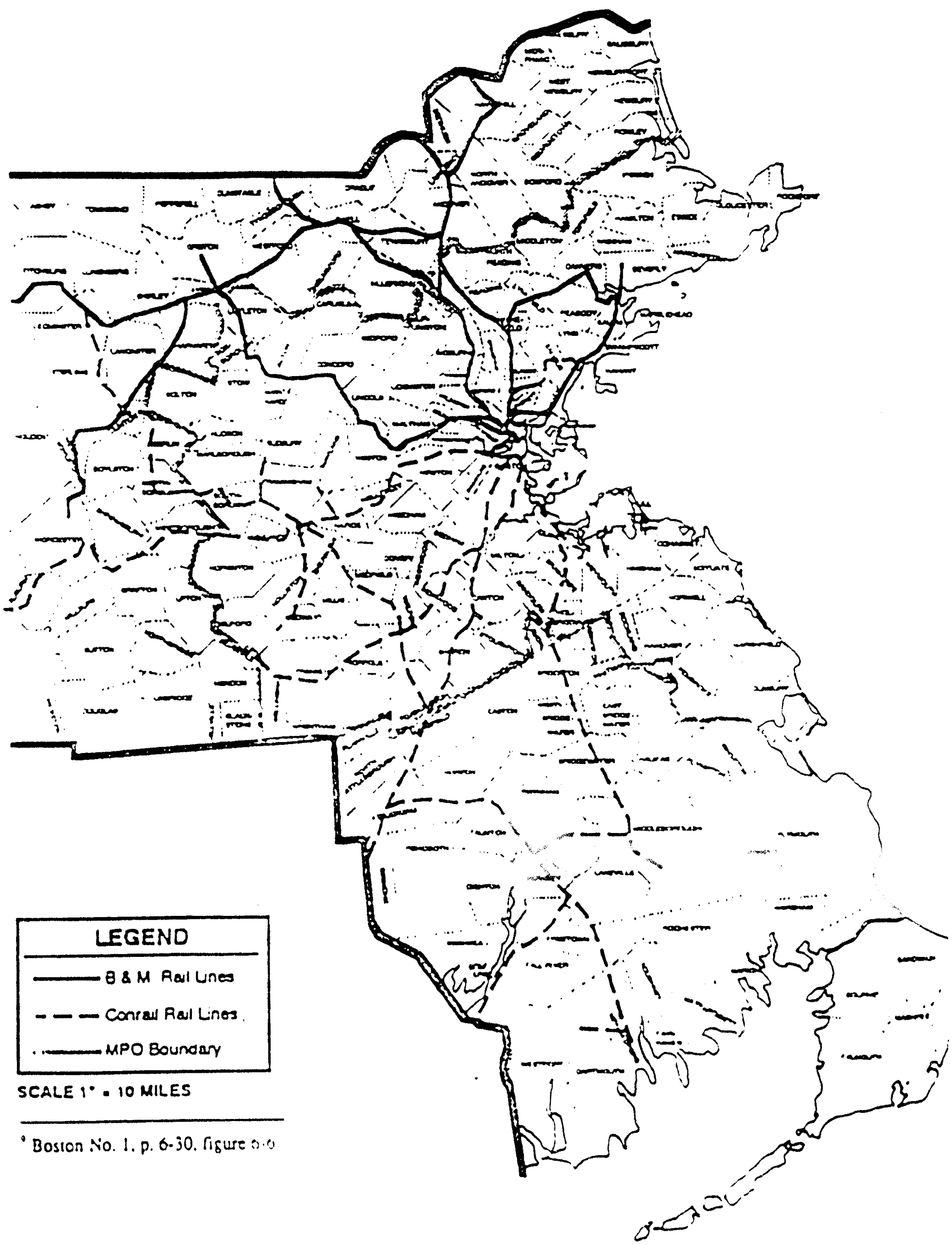
¹ Boston No. 1, p. 6-17, figure 6-1

Figure 3.7-4: Amtrak Passenger Rail Lines[3]



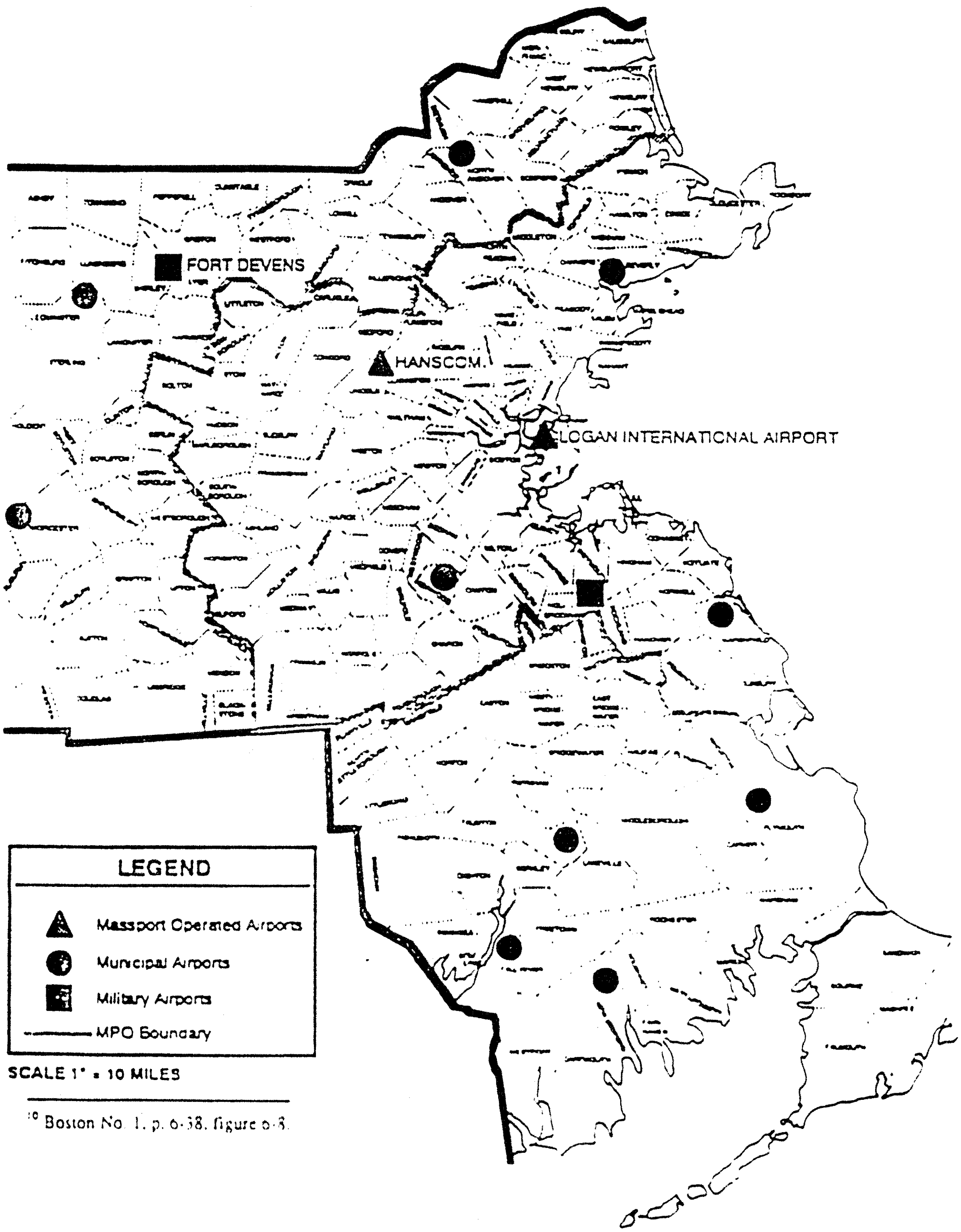
[3] Boston No. 1, p. 6-27, figure 6-5.

Figure 3.7-5: Class 1 Railroads' Freight Rail Lines[9]



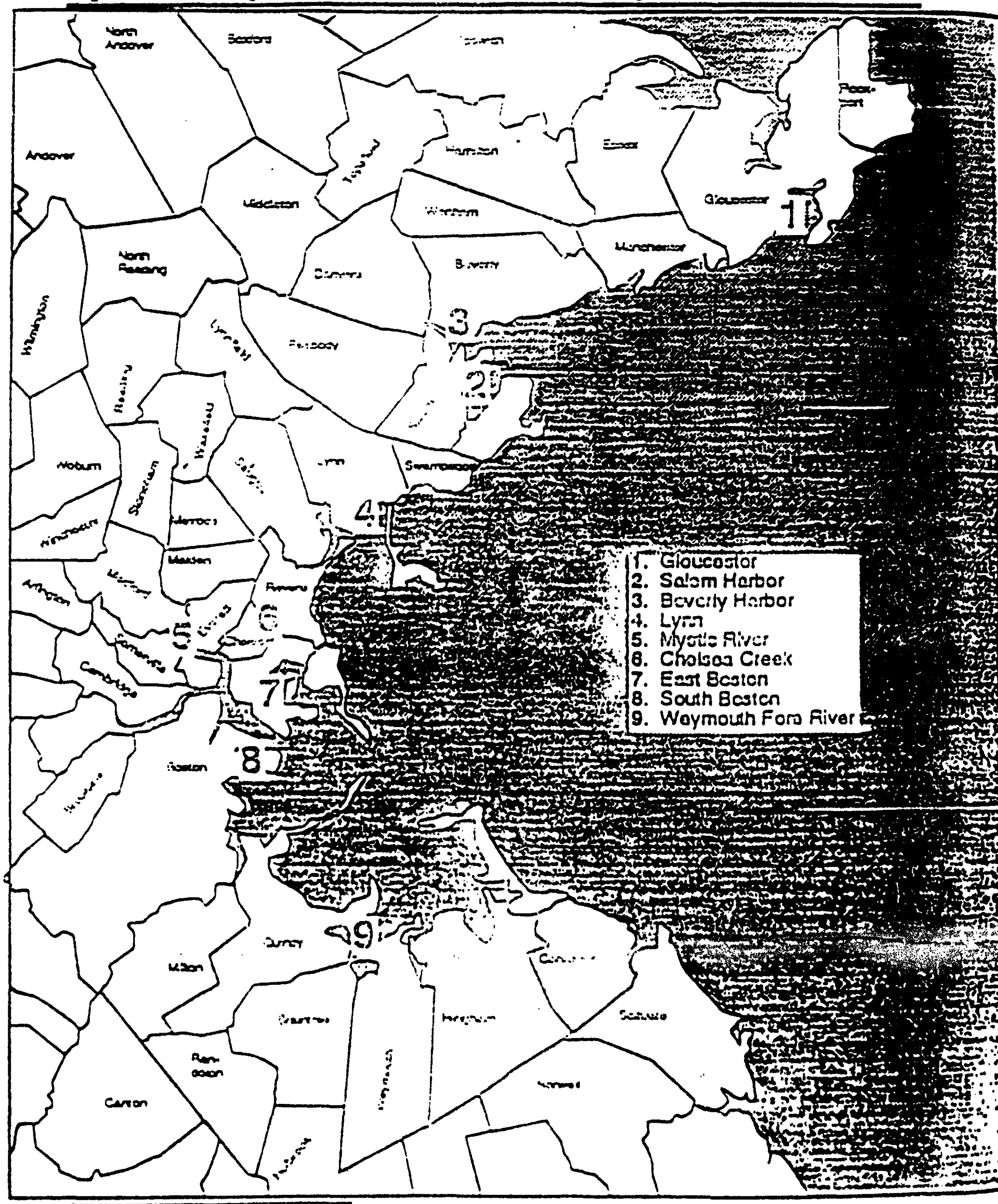
[9] Boston No. 1, p. 6-30, figure 6-6

Figure 3.7-6: Eastern Massachusetts Airports[10]



[10] Boston No. 1, p. 6-38, figure 6-8.

Figure 3.7-7: Designated Port Areas in the Boston MPO Region[11]



[11] Boston No. 1, p. 6-40, figure 6-9

15% Emission Reduction Requirement

STRATEGIES	Statewide		Western NA		Eastern NA	
	Needed: 243.6 (tpsd - VOC only) 15% reduction: 123 Growth offset: 0 Non-creditable: 96 Contingencies: 24.6		Needed: 39 (tpsd - VOC only) 15% reduction: 19 Growth offset: 0 Non-creditable: 16 Contingencies: 3.8		Needed: 206 (tpsd - VOC only) 15% reduction: 105 Growth offset: 0 Non-creditable: 80 Contingencies: 21	
	Reductions VOC	Balance	Reductions VOC*	Balance	Reductions VOC	Balance 1996
		243.6		38.8		206
Emission reduction strategies which are not creditable toward the 15% demonstration						
FMVCP (for 1996)	87	156.6	15	23.8	72	134
I/M Corrections	[illegible]	155.6	-0	23.3	1	133
RACT corrections	8	147.6	1	22.3	7	126
Emission reduction strategies which are creditable toward the 15% demonstration						
Stage II vapor recovery	27	120.6	4.6	18.2	22.4	103.6
Federal Phase I reformulated gasoline	27.5	93.1	4.7	13.5	22.8	80.8
50 ton VOC RACT	4	89.1	0.7	12.8	3.3	77.5
Enhanced Inspection and Maintenance	50	39.1	8.6	4.2	41.4	36.1
Reformulation of Architectural Coatings	14	25.1	1.9	2.3	12.1	24
High Occupancy Vehicle Lanes	TBD*	25.1	0	2.3	TBD	24
Substantial additional fringe parking	0.3	24.8	0	2.3	0.3	23.7
Incident management programs	1.0	23.8	0	2.3	1.0	22.7
Traffic flow improvements	1.32	22.5	0	2.3	1.32	21.4

** Boston No. 6, summary table

Contingency Measures						
Hazardous waste TSDF controls	TBD	22.5	TBD	2.3	TBD	21.4
Industrial wastewater treatment controls	6.2	16.3	1.1	1.2	5.1	16.3
Landfill gas controls	2.4	13.9	0.5	0.7	1.9	14.4
Automobile refinishing controls	10.2	2.7	1.4	<0.7>	8.8	5.6
Reformulation of clean-up solvents	'4	<1.3>	0.5	<1.2>	3.5	2.1
Reform. of consumer/commercial solvents	4.7	<6>	0.6	<1.9>	4.1	<2>
*TBD - To be determined						

Figure 3.7-9: Status Report of the 1982 SIP TCMs[16]

Transportation Control Measures Carried Forward from the 1979 SIP into the 1982 SIP	1993 Transp. Plan	Status in 1995
MBTA Plant Improvements		
- Green Line improvements	X	implemented and ongoing
- station modernization (Park, State, Washington		completed - other stations now being modernized (Blue Line)
- miscellaneous plant improvements		implemented and ongoing
MBTA Vehicle Fleet Improvements	X	implemented and ongoing
Commuter Rail Improvement Program	X	implemented and ongoing
MBTA Park n Ride Program		
- Alewife	X	complete - further expansion planned
- Quincy Adams	X	complete - further expansion planned
- Braintree	X	complete - further expansion planned
Reduction and Relocation of bus stops	X	implemented and ongoing
Urban Systems (TOPICS-type) Program	X	implemented and ongoing
Off-Street Parking Freeze - City of Boston		implemented and ongoing
Off-Street Parking Freeze - City of Cambridge		implemented and ongoing
Off-Street Parking Freeze - Logan Airport		implemented and ongoing
Public Information/Promotion		
- bus stop sign replacement		implemented and ongoing
- information kiosks		implemented and ongoing

[16]Boston No. 4, p. A-2-8 to A-2-12, table A-2.3.

Commuter Boat Service Demonstration (Hingham to Boston)	X	regular contract service ongoing
Downtown Crossing Pedestrian Zone		implemented and ongoing
Boston resident Parking Sticker Program		implemented and ongoing
Cambridge Resident Parking Sticker Program		implemented and ongoing
MDC On-Street Parking Ban		implemented and ongoing
MBTA Pass Program		implemented and ongoing
Masspool, Inc. (CARAVAN)	X	ongoing
Extension of I-93 HOV Lane to Charlestown	X	complete
MBTA Suburban Bus Program	X	implemented and ongoing
State/Local Financing Net Cost of T-Service - review of fare changes shall involve the public and consider environmental impacts		ongoing
Bicycle Racks at transit stations		ongoing
MDPW (MHD) Bikeway Program		ongoing
Variable Work Hours Program		ongoing
MBTA Idling Reduction Program		implemented and ongoing
Right-Turn on Red		implemented and ongoing
Charlestown Bus Garage		completed 1979
Bus Immersion Heater Program		discontinued
Improved Service Delivery		
- priority signals	X	implemented and ongoing
- automated fare collection	X	implemented and ongoing
- scheduling and routing modifications	X	implemented and ongoing
- passenger shelters	X	implemented and ongoing
Improved Service Evaluation		ongoing

Figure 3.7-11: Capital Cost, Ridership, and Air Quality Impacts of SIP and CA/T Mitigation Projects Yet to be Implemented[18]

Project	SIP	CA/T	Capital Cost	2020 Total Weekday Ridership	% Reduction in Regional Emissions
Old Colony CR Restoration	√	√	$560.0m	23,200	0.37%
Newburyport CR Extension	√	√	$41.0m	1,600	0.04%
Worcester CR Extension	√	√	$119.0m	6,700	0.10%
Blue Line - Red Line Connector	√	√	$137.5m	19,200	0.05%
Blue Line Station Modernization	√	√	$361.9m	NA	NA
Green Line Extension to Tufts	√	√	$88.0m	11,600	0.06%
Green Line Arborway Restoration	√		$56.6m	36,000	<0.01%
New Orange Line Vehicles		√	$131.0m	NA	NA
South Boston Piers Transitway	√	√	$355.9m	35,100	0.05%
Washington Street Replacement Service		√	$40.0m	10,200	<0.01%
400 New Buses		√	$88.0m	NA	NA
10,000 Add'l Parking Spaces by 12/31/96	√	√	$0.0m[2]		
10,000 Add'l Parking Spaces by 12/31/99	√	√	$107.0m		
2 Commuter Boat Facilities		√	TBD	4,600	<0.01%
Total			$2,085.9m	148,200	-0.68%

[18]Boston No. 6, p. 2-5, table 2-2.

Study Project	1993 Transp. Plan	Status in 1995
Development of issues to be addressed in the Program for Mass Transportation	X	PMT adopted 1994
Toll Pricing feasibility to Logan Airport		in progress
Feasibility of toll booth on Route 1A		completed June, 1994
Feasibility of water shuttle between Boston and North Shore		completed 1991
Transit improvements study - PMT	X	PMT adopted 1994
Feasibility of rail connection between South Station and Logan Airport		final report issued July, 1994
Expansion of size and number of Logan Express service parking and transit facilities	X	completed June, 1994
Expanding high occupancy vehicle lanes and services within Logan Airport	X	completed June, 1994
Connecting circumferential transit facilities and radial transit services	X	interim cross-town service started September, [illegible]
Upgrade rail service to NY; Worcester & Springfield, MA.; Hartford, CT.; and Portland, ME.	X	in progress
Examine indexing of transit fares	X	addressed in the Fiscal Year 1996 Annual Fare Report -completed March 1995
Feasibility of HOV Lanes on I-90 between I-93 and I-95	X	completed 1994

STATUS REPORT OF THE TCMs IN THE STATE IMPLEMENTATION PLAN AMENDMENTS

Construction Project	1993 Transp. Plan	Status in 1995
South Station Bus Terminal	X	Phase I completed, Phase II under way with completion in 1995
South Station Track #12	X	scheduled for completion in 1995
Ipswich Commuter Rail extension to Newburyport	X	Final design submitted, construction contract expected to be advertised in August, 1995
Old Colony Commuter Rail Extension	X	under construction
Framingham Commuter Rail Extension to Worcester	X	interim service started in September, 1994
20,000 new park and ride and commuter rail station parking spaces	X	ongoing, 10,000 completed by 1996, remaining by 1999
Blue Line Platform lengthening and modernization		Five stations re-opened in June 1995. Design work continues on downtown stations with designs complete in 1996/1997 with construction complete by 2000.
Green Line Arborway Restoration		Studies inconclusive, further study required
South Boston Piers Electric Bus Service	X	scheduled completion 2000
Green Line Extension to Medford Hillside (Tufts)	X	scheduled completion 2010
Blue Line Connection from Bowdoin Station to Red Line at Charles Station	X	scheduled completion 2010
I-93 Southbound HOV Lane to Mystic Avenue	X	completed
I-93 HOV Lane from Mystic Avenue to Route 128		further study required
I-93 (SE Expressway) HOV Lane from I-90 to Route 3	X	Scheduled opening, November, 1995

Transportation Control Measures Adopted Between 1979 and 1982	1993 Transp. Plan	Status in 1995
Improved Public Transit -Newton Rider Bus Service		Commuter rail service, express bus and local bus routes were modified or improved; these changes rendered this TCM unnecessary.
- Insurance Discounts for Private Bus Riders		discounts for MBTA pass holders
Area-Wide Ridesharing Programs	X	ongoing
On-Street Parking Controls - Resident Parking Sticker Programs - Boston Tow and Hold Program - Cambridge Zoning Ordinance Change		ongoing
Pedestrian Malls - Auto Restriction Zones		implemented and ongoing
Employer-Based Ridesharing Programs - Airport Ridesharing Program		ongoing
Road Pricing to Discourage Single-Occupant Vehicles - Mass Pike, Callahan/Sumner Carpool Incentive Program		ongoing
Interstate 93 Southbound HOV Lane	X	implemented, ongoing and planned to be extended
Traffic Flow Improvements - Urban Systems Projects	X	ongoing
Fringe Parking/Park and Ride Lots	X	ongoing

Figure 3.7-12: SIP and CA/T Mitigation Service Expansion Projects (without substitutions) (All figures in 1993 dollars)[19]

	SIP	CA/T Mitigation	Capital Cost
Short-Term			
Old Colony Commuter Rail Restoration			
Plymouth and Middleborough Lines (underway)	√	√	$480.0m
Greenbush Line	√	√	$80.0m
Worcester Commuter Rail Extension	√	√	$119.0m
South Boston Piers Transitway	√	√	$355.9m
Washington Street Replacement Service		√	$40.0m
400 Buses		√	$88.0m
10,000 Additional Parking Spaces by 12/31/96	√	√	$0.0m[6]
10,000 Additional Parking Spaces by 12/31/99	√	√	$107.0m
Newburyport Commuter Rail Extension	√	√	$42.8m
2 Commuter Boat Facilities		√	TBD
Subtotal Short-Term			$1,312.7m+
Long-Term			
Green Line Extension to Medford Hillside	√	√	$88.0m
Blue Line - Red Line Connector	√	√	$137.5m
Arborway Restoration/Replacement	√		$56.6m
Subtotal Long-Term			$282.1m
Total: Short-Term + Long-Term			$1,594.8m+

[19] Boston No 8, p. 5-7, table 5-2.

Table 3.7-3: SIP and CA/T Mitigation Service Expansion Projects (without substitutions, all figures in 1993 dollars)[25]

	SIP	CA/T Mitigation	Capital Cost
Short-Term			
Old Colony Commuter Rail Restoration			
Plymouth and Middleborough Lines (underway)	√	√	$480.0m
Greenbush Line	√	√	$80.0m
Worcester Commuter Rail Extension	√	√	$119.0m
South Boston Piers Transitway	√	√	$355.9m
Washington Street Replacement Service		√	$40.0m
400 Buses			$88.0m
10,000 Additional Parking Spaces by 12/31/96	√	√	$0.0m[24]
10,000 Additional Parking Spaces by 12/31/99	√	√	$107.0m
Newburyport Commuter Rail Extension	√	√	$42.8m
2 Commuter Boat Facilities		√	TBD
Subtotal Short-Term			$1,312.7m+
Long-Term			
Green Line Extension to Medford Hillside	√	√	$88.0m
Blue Line - Red Line Connector	√	√	$137.5m
Arborway Restoration/Replacement	√		$56.6m
Subtotal Long-Term			$282.1m
Total: Short-Term + Long-Term			$1,594.8m+

[24] Boston No. 9, p. F-9.

[25] Boston No. 8, p. 5-7, table 5-2.

Table 3.7-4: Summary of Capital Costs of Recommended Program (all figures in 1993 dollars)[26]

	Short-Term (1994-2000) Total Cost	Long-Term (2001-2020) Total Cost
Category		
System Maintenance	$1,700m	$6,000m
ADA-Related Capital Costs	$266m	$322m
SIP and CA/T Mitigation	$1,311m	$282m
Additional Expansion	$254m	$6,004m
TOTAL	$3,531m	$12,608m

Table 3.7-5: ADA-Related Capital Costs (all figures in 1993 dollars)[27]

	Total Cost	FY 1993-FY 1997	Beyond FY 1997
Key Station Plan	$242.9m	$42.5m	$200.4m
Other Red Line Access	$3.6m	$3.6m	$0.0m
Other Orange Line Access	$11.8m	$9.7m	$2.1m
Commuter Rail Accessibility	$2.7m	$2.7m	$0.0m
Green Line Vehicles	$319.5m	$105.8m	$213.7m
RIDE Vehicles	$1.8m	$0.8m	$1.0m
Misc	$5.6m	$0.4m	$5.2m
Total	$587.9m	$165.5m	$422.4m

Note: Blue Line accessibility costs are included in the Blue Line Modernization project, and all bus accessibility costs are included in the purchase of new buses.

[26] Boston No. 8, p. 5-9, table 5-4.
[27] Boston No. 8, p. 5-4, table 5-1.

Table 3.7-6: Additional Expansion Projects (all figures in 1993 dollars)[28]

	Capital Cost
Short-Term	
Commuter Rail Express Service	
Rockport/Ipswich Line	$18.6m
Haverhill/Reading Line	$39.1m
Lowell Line	$17.1m
Franklin Line	$45.8m
Attleboro/Stoughton Line	$20.8m
Inner Circumferential Bus Service	$2.3m
Expansion of Existing Park & Ride Lots (beyond SIP & CA/T requirements)	$60.4m
New Park and Ride Lots on Express Bus Routes	$2.6m
Intercept Stations along Major Highways	$30.1m
New/ Improved Express Bus Services (Newton, Waltham, Burlington, Lynnfield)	$11.0m
Better Downtown Boston Bus Distribution	$6.1m
Total Short-Term	$253.9m
Long-Term Tier 1	
Expansion of Existing Park & Ride Lots (beyond SIP & CA/T requirements)	$51.2m
Intercept Stations along Major Highways	$30.1m
Rockport/Ipswich Commuter Rail/Blue Line Connection	[illegible]
Inner Circumferential Transit Line	$1,400.0m
South Boston Piers: South Station to Boylston	$180.0m
North Station - South Station Rail Link	$3,633.0m
Needham Commuter Rail Improvements/New Stations	TBD
Green Line Improvements	TBD
Subtotal Long-Term Tier 1	$5,303.6m
Long-Term Tier 2	
Blue Line Extension to Lynn	$275.0m
Red Line to Mattapan	$54.8m
New Bedford/Fall River Commuter Rail Service	$288.0m
Commuter Rail to Millis	$66.7m
Fairmount Commuter Rail/Red Line Connection	$8.2m
New Connections to Logan Airport	TBD
Route 128 Bus Service	$7.9m
Subtotal Long-Term Tier 2	$700.6m+
Total Long-Term + Short-Term	$6,258.1m+

[28] Boston No. 8, p. 5-8, table 5-3.

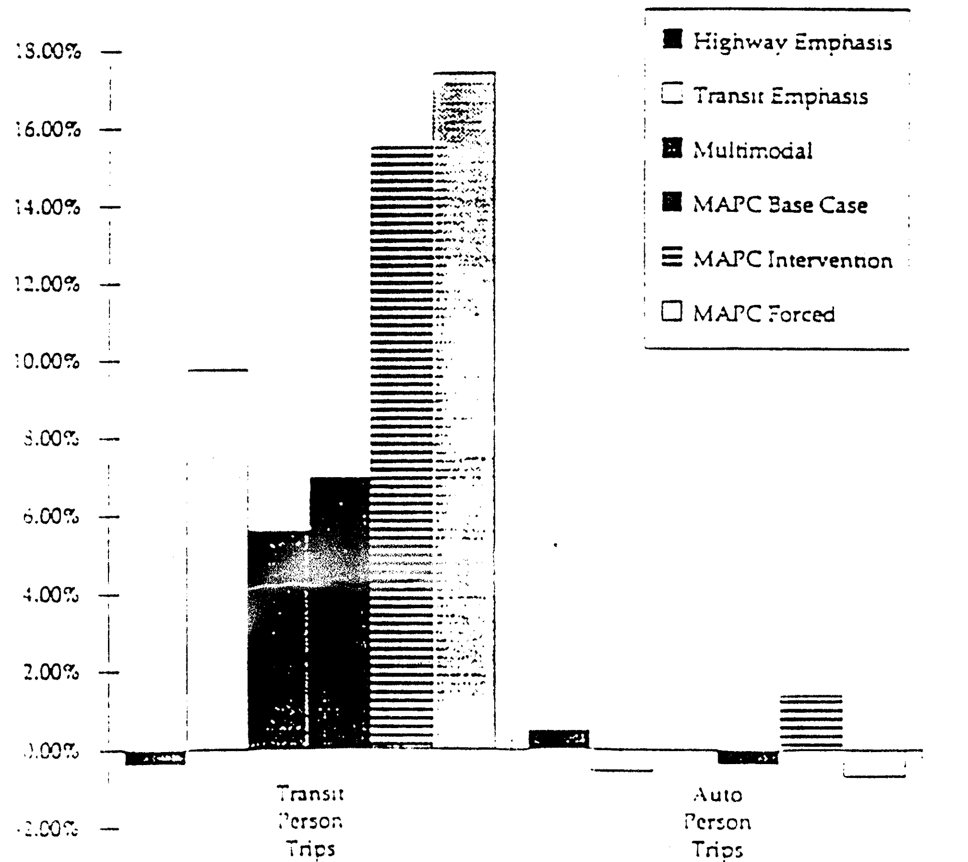
Figure 5.?-?: Network and Land-Use Assumptions Used in Transportation Model Runs[33]

	2020 Base Case Model Run	Highway Emphasis Model Run	Transit Emphasis Model Run	Multi-modal Model Run	Metroplan Base Model Run	Metroplan Intervention Model Run	Metroplan Forced Model Run
Highway							
Central Artery/Third Harbor Tunnel	X	X	X	X	X	X	X
I-93 Industriplex Interchange	X	X	X	X	X	X	X
Beverly-Salem Bridge	X	X	X	X	X	X	X
Rt. 128 Add-a-lane		X		X			
Rt. 3 North Add-a-lane		X		X			
Rt. 3 South Add-a-lane		X		X			
Rts. 1/114 Corridor Improvements		X		X			
I-495 Marlboro Interchange		X		X			
13 More Highway Projects		X					
Commuter Rail							
Old Colony Rail Restoration (3 Branches)	X	X	X	X	X	X	X
Commuter Rail to Worcester			X	X			
Commuter Rail to New Bedford / Fall River			X				
Commuter Rail to Nashua			X				
Commuter Rail to Milford			X	X			
Commuter Rail to Newburyport			X	X			
Commuter Rail to Millis			X				
Commuter Rail to Foxboro				X			
Commuter Rail Run-Time Improvements			X	X			
Commuter Rail Frequency Improvements			X	X			
Rapid Transit							
S. Boston Piers Transitway (S. Station to Piers)	X	X	X	X	X	X	X
RTIS (Lafayette Loop)	X	X	X	X	X	X	X
Red / Blue Line Connector			X	X	X	X	X
Inner Circumferential (Partial Loop)			X		X	X	X
Orange Line S to Rt. 128					X	X	X
Orange Line N to Rt. 128					X	X	X
Green Line to Oak Square			X		X	X	X
Red Line to Mattapan			X				
Green Line to Medford Hillside			X	X	X	X	X
Restore Green Line to Arborway			X				
Blue Line to Lynn			X	X			
Blue Line to Riverside			X				
HOV, Parking, and Bus							
Bus/HOV Lanes on Turnpike & SE Expressway			X				
More Parking for Commuter Rail Lots (5 lines)			X				
New Bus Service to Logan			X				
Route 128 Circumferential Bus Service			X				
New Express Bus to Cambridge & Boston			X				
Additional Commuter Boat Service			X				
Land-Use Assumptions							
Extended Trends	X	X	X	X	X		
MetroPlan Intervention						X	
MetroPlan Forced							X

X means assumption was included in the transportation model run. Model runs were developed to inform the Plan's recommendations, which are presented in Chapter 8.

[33] Boston No. 1, p. 7-21, figure 7-4

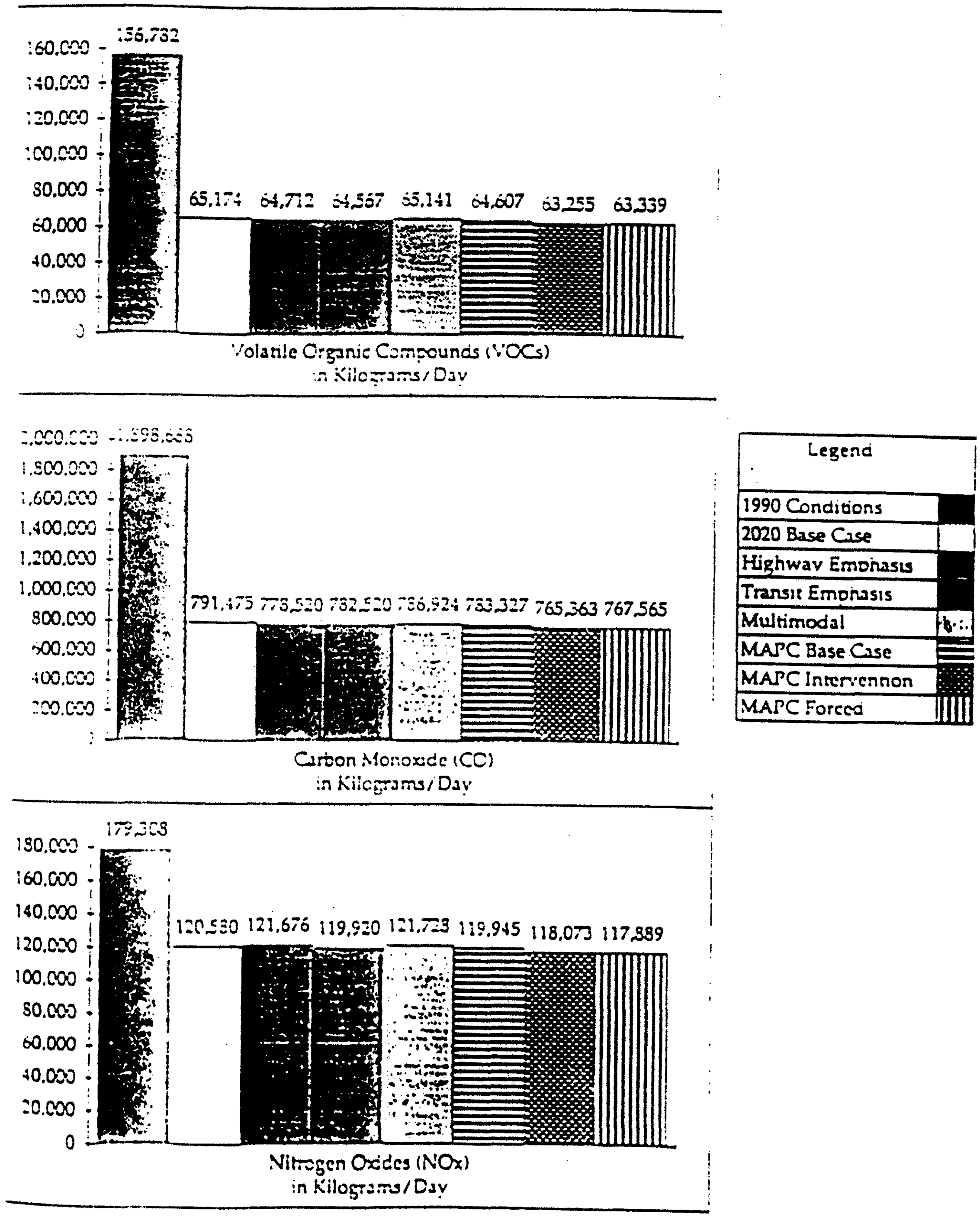
Figure 3.7-16: Travel Behavior Under Alternate Scenarios, Percent Change from 2020 Base Case[34]



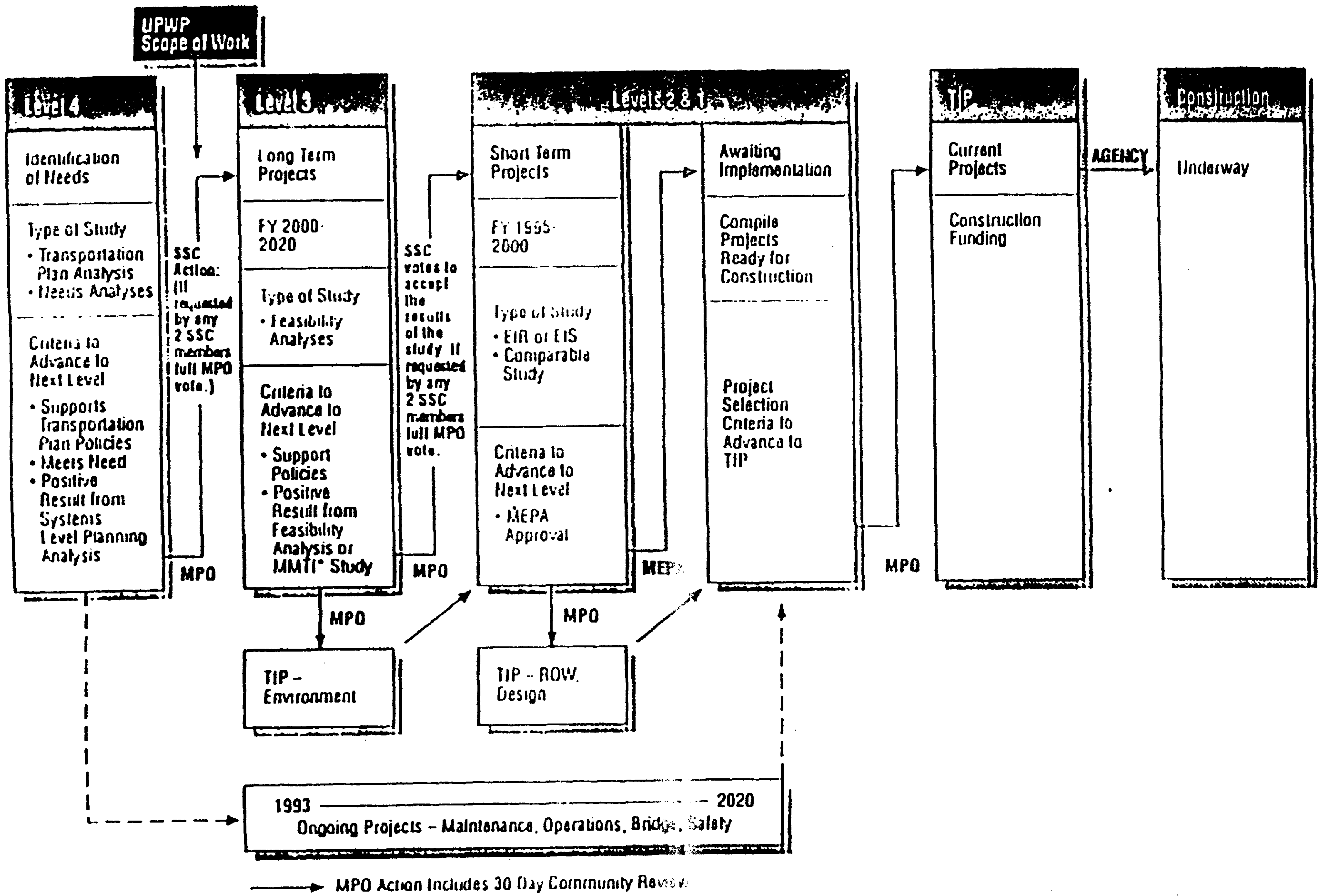
Scenario	Transit Trips	% Change	Auto Trips	% Change
1990 Existing	650,438	N/A	8,298,738	N/A
2020 Base Case	721,554	N/A	9,207,435	N/A
Highway Emphasis	718,605	-0.41%	9,253,857	0.50%
Transit Emphasis	792,055	9.77%	9,155,123	-0.57%
Multimodal	761,960	5.60%	9,205,778	-0.02%
MAPC Base Case	771,928	6.98%	9,169,643	-0.41%
MAPC Intervention	833,635	15.53%	9,333,152	1.37%
MAPC Forced	847,399	17.44%	9,142,754	-0.70%

[34] Boston No. 1, p. 7-27, figure 7-5

Figure 3.8-17: Emission Levels Under Alternate Scenarios[35]



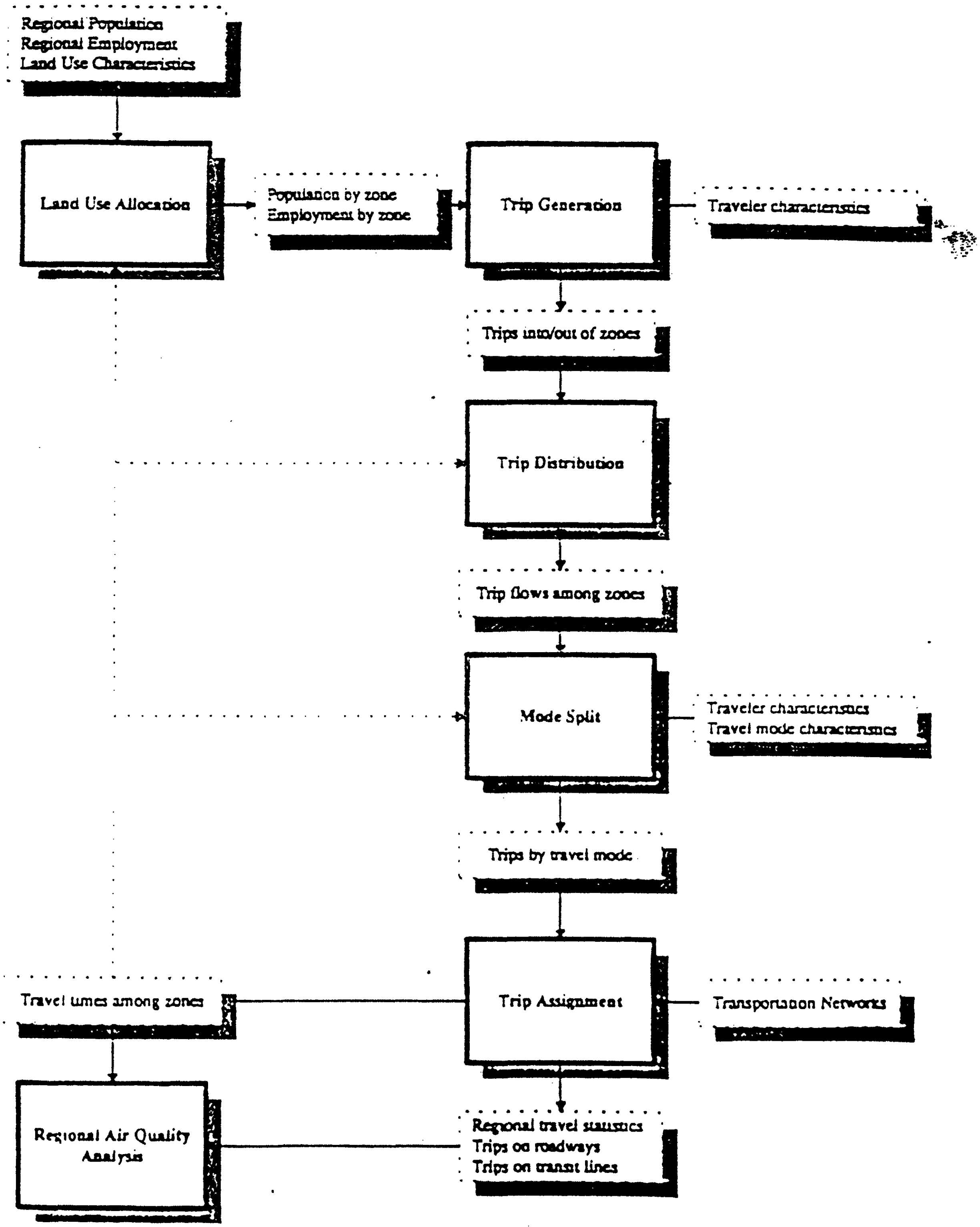
[35] Boston No. 1, p. 7-29, figure 7-6



*MMTI - Major Metropolitan Transportation Investment

[14] Boston [illegible] 1, p. 8-7, figure 8-1.

Figure 3.7-19: Integrated Land Use/Transportation Model Process[40]



[40] Boston No. 2, p. B-5, figure B-1.

APPENDIX S

FY 94 RTIP and 1995 San Francisco Bay Area
Transportation Improvement Program (TIP)
Surface Transportation Program (STP)
and
Congestion Mitigation / Air Quality (CMAQ)
Scoring Criteria

Source: San Francisco No. 6, attachment C..

Date: February 24, 1993
W.I.: 903-40-01
W.A.: 1242r
Referred By: WPC
Revised: 04/28/93-C

Attachment C
MTC Resolution 2526

FY 1994 RTIP AND 1995 SAN FRANCISCO BAY AREA

TRANSPORTATION IMPROVEMENT PROGRAM (TIP)

SURFACE TRANSPORTATION PROGRAM

and

CONGESTION MITIGATION AND AIR QUALITY

(STP and CMAQ)

SCORING CRITERIA

Scoring Criteria

The Scoring Criteria are described in the following table. The Scoring Criteria were originally formulated, and were revised, with the following objectives.

- o Projects on or with significant benefits to the MTS are given priority throughout the point system.
- o Projects that meet a documented need or solve an identified problem are rewarded. Specifically, projects that are the outcome of Management Systems mandated by ISTEA are encouraged, and projects that meet the greatest need or solve the biggest problems are rewarded through the point system.
- o Cost-effective projects, particularly those that fit optimal replacement cycles or demonstrably improve the efficiency and effectiveness of the MTS, are rewarded.
- o Projects that improve multiple modes are encouraged through the point system.
- o Projects are based on adopted plans and programs.
- o The Criteria are applicable to all modes and enable the direct comparison of projects of different modes with equivalent measurements wherever possible.
- o The 15 factors established by ISTEA are all considered within the Screening, Scoring and Programming Criteria as required by law.
- o The program which is established using these criteria based on an evaluation of technical merit must also be in conformance with the Federal Clean Air Act. This conformity evaluation includes documentation of the expeditious implementation of TCMs.

Scoring Criteria by Category

30		Maintain/Sustain the Metropolitan Transportation System (MTS)
		The following scores are for the STP-CMAQ project evaluations.
		A project can score on one line item only in this category. The two exceptions to this are for seismic retrofit as part of a larger project, and for prevention of unacceptable breakdowns in the MTS.
		Rehabilitation and replacements based on Management Systems
		Pavement Management System - Normal pavement rehabilitation cycles are to be determined using the MTC PMS rating system (for an existing facility on the MTS). If a PMS other than MTC's rating system was used, or if another management system was used, a comparable interpretation is acceptable.
	30	Optimal Rehabilitation - Poor to very poor, PMS rating 50 to 25
		Rehabilitation is the entire project.
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score. (For example, if Rehabilitation is 50% of a project, on a cost basis, a project would score 15 points here).
	20	Replacement of Failed Road - Very poor to failed, PMS rating < 25
		Rehabilitation is the entire project.
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
	10	Rehabilitation of Road that prolongs Good Condition - Good to poor, PMS rating 70 to 50
		Rehabilitation is the entire project.
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
		Public Transit Management System - Normal replacement cycles are determined by FTA Circular 9030.1A and the MTC Bay Area Transit Finance Plan as justified in the operator's Short Range Transit Plan (SRTP). Normal replacement cycles are listed in Guidance Section A.
		Normal Replacement or Rehabilitation - Capital asset is at the end of its useful life in the program year.
	30	Replacement is the entire project.
	30	Rehabilitation is the entire project,and useful life is extended at least 40%
		Urgent Replacement or Rehabilitation - Capital asset is beyond its useful life in the program year. (Urgency is defined as an asset that is 20% older than the normal replacement cycle in Section A).
	30	Replacement is the entire project.
	30	Rehabilitation is the entire project, and useful life is extended over 50%.
		Port/Intermodal Rehabilitation - Normal roadway projects are scored accordning to the PMS scale above. Rail or intermodal facilities are scored according to the transit scale above, using the FTA replacement cycles for like assets.
		Rehabilitation and replacements NOT based on Management Systems
		Roadway Support Infrastructure projects - For support infrastructure such as drainage, retaining walls, or obsolete signal controllers, the project receives the following points (using the standards in Caltrans Highway Design Manual):
	20	Optimal Rehabilitation - Poor to very poor condition
		Rehabilitation is the entire project
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
	15	Replacement of Failed Road Section - Very poor to failed condition
		Rehabilitation is the entire project
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
	5	Rehabilitation of Road Component - Good to poor condition
		Rehabilitation is the entire project.
		If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score

30		**Maintain/Sustain the Metropolitan Transportation System (MTS) (Continued)**
		Publicly owned pedestrian and bicycle facilities - For transportation uses as opposed to purely recreational trips.
	20	Optimal Rehabilitation - Poor to very poor condition Rehabilitation is the entire project. If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
	15	Replacement of Failed Element - Very poor to failed condition Rehabilitation is the entire project. If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
	5	Rehabilitation of Facility - Good to poor condition Rehabilitation is the entire project. If Rehabilitation is a portion of the project, the Rehabilitation portion of total project costs is multiplied by "entire project" score.
		Normal transit replacements, like pavement rehabilitations, must be based on management systems and the SRTP.
		Seismic Retrofit Caltrans has evaluated potential seismic retrofit projects, and has categorized the projects by risk and need. Other acceptable studies have been done for components other than bridges on the highway system, thus, other modes and facilities are not excluded. (Some transit facilities are on the Caltrans list).
	30	Entire project is seismic retrofit, and project is included in Tier 1 of Caltrans Seismic Retrofit list, or project corrects an identified high risk.
	20	Entire project is seismic retrofit, and project is in lower tiers of Caltrans Seismic Retrofit list, or project corrects an identified lower risk.
	10	Identified seismic retrofit need is included as part of a larger project.
		Prevention of unacceptable breakdowns in the MTS This is an emergency safety-valve criterion.
	10	Project is for rehabilitation or replacement necessary to prevent unacceptable breakdowns in the MTS.
30		**Improve the Efficiency and Effectiveness of the MTS**
		This scoring category has several parts. While the maximum score for the category is 30 points (for STP-CMAQ and FCR), a project can score in each of the parts of the category. A project can score on only one line item in the first part, "Safety and Security." A project usually scores on only one line item in the second category, "Congestion Relief," but a project with demonstrated congestion relief or service improvement benefits to other modes, can receive points for the affected modes. **Safety and Security** - The first part of the Improve Efficiency and Effectiveness of the MTS category is Safety and Security. A project earns a multiplier - based on the magnitude of the problem - which is then multiplied by the impact score - based on the degree to which a project can solve a problem. Safety and Security Multiplier The existing safety or security problem is defined across modes. The multiplier indicates the severity of the safety or security problem. The score of a project in the Safety and Security part is the product of the Multiplier and the Impact points. Roadway Safety Multiplier — Multiplier If the accident rate is average for the facility type: 0.5 If the accident rate is 25% above average: 0.8 If the accident rate is over 25% higher than ave: 0.9 or 1.0 If the accident rate is 25% below average: 0.2 If the accident rate is more than 25% below ave: 0.1 or 0 For intersections, the multiplier is based on the 3-year total accidents. The accident rates and multipliers by facility type are: Number of Accidents Total for 90, 91 and 92 — Multiplier More than 75 accidents: 1.0 50 to 75 accidents: 0.8 40 to 49 accidents: 0.6 20 to 39 accidents: 0.4 10 to 19 accidents: 0.2 5 to 9 accidents: 0.1 0 to 5 accidents: 0.0

30 | | **Improve the Efficiency and Effectiveness of the MTS (Continued)**

For highways and arterials, accidents per million vehicle miles is the measure that will be used. If data are not given in ACC/MVM, it can be calculated by the project sponsor as:

$$\frac{\text{Number of accidents (avg. for 90, 91, 92) X 1,000,000}}{\text{Ave Daily Traffic (Veh/Day/Yr) X 365 X length of project in miles}}$$

The accident rates and multipliers by facility type are:

		Accident Rate			
Facility Type	CA Avg	125% of CA Avg.	> 125% of CA Avg.	75%of CA Avg.	< 75% of CA Avg.
Freeway	0.69	0.86		0.52	
Expressway- 2 lane	0.89	1.11		0.68	
Exprswy- Multilane	1.00	1.25		0.75	
Conventional-2 lane	1.69	2.11		1.27	
Convntnl- Multilane	2.72	3.40		2.04	
Multiplier:	0.5	0.8	0.9 to 1	0.2	0.1 to 0

Note: Similar tables will be provided for injuries/fatalities. A project sponsor can use actual accident or injury/fatality data to determine the safety multiplier

Transit/Intermodal Safety Multiplier The multiplier is based on the 3-year total of incidents that the project will address. These multipliers can be adjusted to reflect the severity of the incidents.

Number of Incidents Total for 90,91 and 92	Multiplier
More than 24 incidents	1.0
20 to 24 incidents	0.8
15 to 19 incidents	0.6
10 to 14 incidents	0.4
5 to 9 incidents	0.2
2 to 4 incidents	0.1
0 to 1 incidents	0.0

Bicycle and Pedestrian Safety Multiplier The multiplier is based on the 3-year total of incidents that the project will address. These multipliers can be adjusted to reflect the severity of the incidents.

Number of Incidents Total for 90,91 and 92	Multiplier
More than 10 incidents	1.0
8 to 10 incidents	0.8
6 to 7 incidents	0.6
4 to 5 incidents	0.4
2 to 3 incidents	0.2
1 to 2 incidents	0.1
0 incidents	0.0

Safety and Security Impact Values The existing safety or security problem is defined across modes. The score of a project in the Safety and Security part is the product of the Multiplier and the Impact points. The multiplier indicates the severity of the safety or security problem, and the impact values indicate the impact the proposed project would have in solving the safety or security problem.

Roadway Projects Safety Impact Points

16 to 20 — High Safety Impact

HOV enforcement areas.
Grade separations.
Conversion from expressway to freeway or median barrier, when crossover median accidents are the issue.
Geometric improvements, shoulders, curve corrections.
New signals that meet (Caltrans (state highway) or HCM) warrants.

8 to 12 — Medium Safety Impact

Widenings, auxiliary lanes, left turn pockets
Signal interconnect
Interchange modifications.
Bike lockers or racks

<table>
<tr><td>30</td><td></td><td>Improve the Efficiency and Effectiveness of the MTS (Continued)</td></tr>
<tr><td></td><td>0 to 4</td><td><u>Low Safety Impact</u>
New interchanges.</td></tr>
<tr><td></td><td>16 to 20</td><td><u>Transit/Intermodal Projects Safety Impact Points</u>
<u>High Safety Impact</u>
Passenger or employee safety/security project, such as:
Lighting in high security area.
Handrails.
Rail Switches.</td></tr>
<tr><td></td><td>8 to 12</td><td><u>Medium Safety Impact</u>
Equipment or assets safety/security project, such as:
Lighting in low security area.
Bus turnouts/bulbs.
Maintenance yard fences.
Emergency communication systems.</td></tr>
<tr><td></td><td>0 to 4</td><td><u>Low Safety Impact</u>
Revenue collection security project.</td></tr>
<tr><td></td><td>16 to 20</td><td><u>Pedestrian and Bicycle Projects Safety Impact Points</u>
<u>High Safety Impact</u>
Significant Class 1 bike path or Class 2 bike lane.
Sidewalks with curb cuts where none exist.
Curb cuts.
Resolves conflict between bikes or pedestrians and cars or trains, such as traffic signal actuations.
Grade separations.</td></tr>
<tr><td></td><td>8</td><td><u>Medium Safety Impact</u>
Minor Class 1 bike path or Class 2 bike lane.
Sidewalk improvement.
Signage.</td></tr>
<tr><td></td><td>0 to 4</td><td><u>Low Safety Impact</u>
Class 3 bikeway or Class 2 bike lane.
Signage.</td></tr>
<tr><td></td><td></td><td><u>Congestion Relief</u> The second part of the Improve Efficiency and Effectiveness of the MTS category is Congestion Relief. Congestion Relief is based on an assessment of the existing congestion problem and the impact of the proposed project on reducing such problems. Existing congestion is evaluated across modes by looking at the volume of traffic/number of people affected by the congestion. A project earns a multiplier - based on the magnitude of the problem - which is then multiplied by the impact score - based on the degree to which a project can solve a problem. Multimodal projects may score under more than one mode (where each modal feature is weighted by the proportion of that mode to the total project) but a project's congestion relief score is capped at 20 points.
<u>Congestion Relief Multiplier</u> The existing congestion problem applies to all modes. The score of a project in the Congestion Relief part is the product of the Multiplier and the Impact points.
<u>Roadway Congestion Relief Multiplier</u> The multiplier for roadway projects, or the severity of the congestion problem, is the level of service (LOS) for the affected roadway segment. LOS is peak average, and must be calculated according to the CMA adopted method (HCM - 1985, Circular 212, Caltrans for freeway segments LOS).
<table>
<tr><th>Peak Average LOS</th><th>Multiplier</th></tr>
<tr><td>LOS = F</td><td>1.0</td></tr>
<tr><td>LOS = E</td><td>0.8</td></tr>
<tr><td>LOS = D</td><td>0.6</td></tr>
<tr><td>LOS = C</td><td>0.2</td></tr>
<tr><td>LOS = B</td><td>0.1</td></tr>
<tr><td>LOS = A</td><td>0.0</td></tr>
</table>
</td></tr>
</table>

30		Improve the Efficiency and Effectiveness of the MTS (Continued)

Transit/Intermodal Congestion Relief Multiplier The transit/intermodal multiplier, or severity of the congestion problem, may be calculated using one of two standards, depending on the type of congestion the proposed project is to address. For transit projects designed to relieve transit loading, the multipliers relating to peak load factors would apply. For transit/intermodal projects designed to relieve corridor congestion, the roadway LOS factors above, for the corresponding route, would apply.

Peak Load Factor	Multiplier
>1.25	1.0
1.00	0.8
0.75	0.5
0.50	0.2
0.25	0.1
<0.25	0.0

Peak Ave. Corresponding Roadway LOS	Multiplier
LOS = F	1.0
LOS = E	0.8
LOS = D	0.6
LOS = C	0.2
LOS = B	0.1
LOS = A	0.0

Bicycle and Pedestrian Projects Congestion Relief Multiplier The multiplier, or severity of the congestion problem, may be calculated using one of two standards, depending on the type of congestion the proposed project is to address. For bicycle and pedestrian projects designed to relieve congestion on a particular facility (separate from road or transit congestion), the multipliers relating to the facility would apply, in terms of bikes/week. These are relative to other facilities in the region. For bike and pedestrian projects designed to relieve corridor congestion, the roadway LOS factors, below, for the corresponding route, would apply.

Facility loading	Multiplier
Above regional average	0.8
Regional average	0.5
Below regional average	0.1

Peak Ave. Parallel Roadway LOS	Multiplier
LOS = F	1 0
LOS = E	0.8
LOS = D	0.6
LOS = C	0.2
LOS = B	0.1
LOS = A	0.0

Congestion Relief Impact Values The existing congestion relief problem is defined across modes by the multiplier values. The score of a project in the Congestion Relief part is the product of the Multiplier and the Impact points. The multiplier indicates the severity of the safety or security problem, and the impact values indicate the impact the proposed project would have in solving the congestion problem

Roadway Projects Congestion Relief Impact Points Impact values are given in ranges. The particular value a project receives within this range depends on the degree of congestion relief provided by the proposed design.

16 to 20 — **High Congestion Relief Impact** - Project must be on or significantly benefit the MTS:

- HOV lanes.
- CMP Deficiency Plan Measure.
- Ramp metering with HOV bypasses.
- Signal interconnect with 8 or more signals.
- Gap closure with system-wide benefit.
- Interchange that upgrades to freeway standards (grade separation).
- Traffic Operations System (TOS)

30		**Improve the Efficiency and Effectiveness of the MTS (Continued)**
	8 to 12	<u>Medium Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS: Auxiliary lanes (on-ramp to off-ramp) - on or significantly benefit MTS. Left turn pockets or other intersection improvements - on or significantly benefit MTS. Park and ride lots - on or significantly benefit MTS. Signal interconnect of 2 or more signals - on or significantly benefit MTS. New signal where none currently exists and meets warrants - on or significantly benefits MTS. Ramp metering without HOV bypass - on or significantly benefits MTS. Other high impact project type (above) connecting to MTS.
	0 to 4	<u>Low Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS: New local interchanges. Gap closure that only moves bottleneck condition. Any high or medium impact project type not on or connecting to MTS. Roadway rehabilitation or resurfacing.
	16 to 20	<u>Transit/Intermodal Projects Congestion Relief Impact Points</u> Impact values are given in ranges. The particular value a project receives within this range depends on the degree of congestion relief provided by the proposed design. <u>High Congestion Relief Impact</u> - Project must be on or significantly benefit the MTS: Reduces transit load factor by 10% or more. Increases service capacity by 10% or more. Increases service reliability by 10% or more. Major interconnect, or fare coordination project. Bus turnouts/bulbs. Major intermodal facility. Reduces transfer time by 10% or more.
	8 to 12	<u>Medium Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS Minor improvement (less than 10%) in load factor, service capacity, ease of transfers, or service reliability on the MTS; improvement in load factor, service capacity, ease of transfers, or service reliability off the MTS. Minor interconnect, or fare coordination project
	0 to 4	<u>Low Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS: Increases passenger comfort and convenience Bike lockers or bike racks. Intermodal facility with unknown level of transfers. Transit rehabilitation or replacement.
	16	<u>Bicycle and Pedestrian Projects Congestion Relief Impact Points</u> Impact values are given in ranges. The particular value a project receives within this range depends on the degree of congestion relief provided by the proposed design. Some impact values have been reduced to reflect the potential mode split for these projects <u>High Congestion Relief Impact</u> - Project must be on or significantly benefit the MTS: Class I or Class II bike path/lane or sidewalk necessary link for journey to work.
	8 to 12	<u>Medium Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS. Bike path/lane or sidewalk that will primarily serve commuters (i.e., parallel reliever route). Sidewalks where none exist- gap closure connecting to transit center. Projects to interconnect across jurisdictional boundaries.
	0 to 4	<u>Low Congestion Relief Impact</u> - Project must be on the MTS, significantly benefit the MTS, or connect to the MTS: Bike path lane with mixed commuter and other non-recreational uses, on or connecting to the MTS Useable sidewalk segments, including upgrades and new installations Sidewalks where none exist- connecting activity centers Signage Bikeway or sidewalk rehabilitation or resurfacing

30 **Improve the Efficiency and Effectiveness of the MTS (Continued)**

Cost-Effectiveness The third part of the Improve Efficiency and Effectiveness of the MTS category is the Cost-Effectiveness criterion. It has been revised to measure the ratio of annual benefits (in terms of total travel time savings and operating cost savings for the project) to annualized total project costs. The ratios of all projects submitted will then be adjusted to the median in the 0-10 scale; in other words, if the most number of projects have a cost-effectiveness ratio of 0.5, this value will be assigned 5 points, and the other values will be assigned accordingly by number of projects in each quartile.

Cost - Effectiveness Measure:

$$\frac{\text{Annual Time Travel Savings} + \text{Annual Operating Cost Savings}}{\text{Annualized Total Project Costs}}$$

Numerator:

Annual travel time savings are total for the entire proposed project. It is the annual average over the life of the project expressed in 1992 dollars. For the travel time savings calculations, the value of time assumptions in the MTC model should be used. These are $7.50 for work trips, and $3.50 for non-work trips (these values are in 1992 dollars). If the MTC assumptions are not used, justifications must include defense for alternative assumptions.

(Worksheets for calculating travel time savings can be obtained from MTC).

Annual operating cost savings are the annual average over the life of the project, as compared to the "no-project" alternative. The calculation of the operating cost savings must be shown on the application.

Denominator

The annualized total project cost = the total project cost times the capital recovery factor.

The formula for the capital recovery factor is:

$$\frac{i}{1 - \frac{1}{(1+i)^n}}$$

Where "i" is assumed to be 5%

Where "n" is the useful life of the proposed project

For ease of calculation, the following table provides the capital recovery factors for different types of projects. To calculate the annualized total project cost, just multiply the total project cost by the capital recovery factor for the appropriate project type in the table below.

Project Type	Useful Life (Yrs)	Capital Recovery Factor
New road or highway facility	40	0.05827816
Road reconstruction	40	0.05827816
Bikeway	40	0.05827816
Pedestrian walkway or bridge	40	0.05827816
Transit maintenance facility	40	0.05827816
Transit transfer facilities	40	0.05827816
Bus stops or turnouts	40	0.05827816
Transit extensions, track, or overhead lines and support	40	0.05827816
Light rail vehicles	25	0.07095246
Heavy rail cars/locomotives	25	0.07095246
Ferry	25	0.07095246
Trolley bus	18	0.08554622
Signalization equipment	15	0.09634229
Bus	12	0.11282541
Bike lockers	10	0.12950457
Transit maintenance tools	10	0.12950457
Service vehicles	7	0.17281982
Vans	4	0.28201183

Weight	Points	Criteria
30		**Improve the Efficiency and Effectiveness of the MTS (Continued)**
		Freight: The fourth part of the Improve Efficiency and Effectiveness of the MTS category is the Freight Movement and Freight Facilities criterion. Project which improve the movement of freight on a truck route:
	20	Heavy trucks are more than 25% of the traffic flow.
	10	Heavy trucks are 10% to 25% of the traffic flow.
	0-5	Heavy trucks are less than 10% of the traffic flow.
		Intermodal Freight Facilities
	25 to 30	Major facility that serves the MTS (i.e., makes a major (>25%) reduction in the amount of time required for a freight container to travel through the region).
	15 to 20	Minor facility that serves the MTS (i.e., reduces the amount of time required for a freight container or other cargo to travel through the region).
	5 to 10	Significant activity not tied to the MTS.
15		**System Expansion**
		The following scores are for the STP-CMAQ project evaluations. A project can score on one line item only in this category. Projects with multimodal aspects are scored as the primary mode of the project. This category is for expansion projects only. System expansion projects will first be evaluated as to whether or not they meet demand. Current demand will be given a higher priority than projected demand. Examples of how demand can be demonstrated include, but are not limited to, LOS data, volumes, or load factors for transit. Support in established planning documents such as Short Range Transit Plans, Congestion Management Plans, ADA plans, or other applicable plans or studies will be given the most credence. Then, points will be assigned up to a maximum of 15 to different project types according to mode. System Expansion Demand Multiplier This is a combination of the Volume Average Daily Traffic (ADT) and Level of Service (LOS). This applies to all roadway projects. This roadway measure is also used as an indication of demand within the corridor for other modes. If demand is to be demonstrated by other means, it must be in according to a similar rationale, i.e., by corresponding volumes and levels of service - with LOS C corresponding to the industry or modal average, and ADT 30,000-50,000 corresponding to the industry or modal average.

LOS

ADT	F	E	D	C	B
>50,000	1.0	0.9	0.6	0.4	0.1
30-50,000	0.8	0.6	0.4	0.2	[illegible]
10-30,000	0.6	0.4	0.2	0.1	[illegible]

Weight	Points	Criteria
		System Expansion Impact Values The multiplier indicates the demand for expanded service, and the impact values indicate the impact a project type would have in meeting that demand. The score in this part of the category is the product of the multiplier and the impact value. Roadway Project Impact Values (Note, these can be additive).
	5	HOV lanes.
	0-2	Mixed flow capacity, including arterials.
	1-5	Supporting features such as ramp metering, park and rides, bus routes, bicycle and pedestrian facilities.
	5	On or significantly benefits the MTS.
	2-3	Minor benefit to the MTS.
		Transit Project Impact Values:
	15	Significant expansion on or significantly benefits the MTS, including supporting features.
	2-10	Minor expansion, on or benefits the MTS supported by the SRTP.

15		**System Expansion (Continued)**
		Intermodal Freight Facilities Expansion Project Impact Values:
	15	Access to major freight distribution facilities.
	2-10	Access to minor freight distribution facilities.
	10-15	Access to containerized cargo port as defined by Seaport Plan.
	4-6	Access to other seaport as defined by the Seaport Plan.
	10-15	Access to air carrier airport.
	4-6	Access to airport with more than 100,000 operations per year.
	0-2	Access to other airports.
		Bicycle/Pedestrian Commuter Expansion Project Impact Values:
	10-15	Bike path/lane or sidewalk that will primarily serve commuters (i.e. parallel reliever route).
	4-6	Bike path/lane with mixed commuter and other non-recreation use or connects to MTS.
	0-2	Bike path/lane or sidewalk that is primarily for recreational travel or not on MTS.
		Corridor Preservation: A project can score under the System Expansion multiplier and impact value OR the Corridor Preservation, but not both.
	15	Right-of-way for major endangered transportation corridor, including station sites or future maintenance facilities.
	10	Right-of-way for major transportation corridor, including station sites or future maintenance facilities.
	0-5	Right-of-way for minor transportation corridor.
25		External Impacts
		Air Quality
		Projects which will produce an **improvement in Air Quality** over the life cycle of the project will be awarded points according to the following system:
	5	Adopted federal Transportation Control Measures (TCMs) required to bring the MTC region into compliance with the region's current federal State Implementation Plan (Clean Air Act) receive 5 points
		Projects with demonstrable air quality improvement impact based on analysis performed for the 1991 Clean Air Plan (includes both federal TCM (FTCM) and state TCM (STCM) measures). Projects may score under several subcategories if multiple TCMs are included in the project, up to a cap of 20 points for TCM inclusion.
		Most Effective TCMs (Group 1): Signal timing (FTCM 24 and 25); Market based measures (STCM 22); Ozone Excess "No Drive Days" (STCM 23).
	20	Entirely a TCM.
	15	Includes a TCM as a significant part
	8	Includes a TCM as a minor part.
	5	No significant air quality impact in certified environmental document.
	0	Unknown air quality impact.
		Highly Effective TCMs (Group 2): Incident Management (FTCM 26); Employer based Trip Reduction Rule (STCM 2); Install Traffic Operations System (STCM 11); Implement Revenue Measures (STCM 21).
	15	Entirely a TCM
	12	Includes a TCM as a significant part.
	8	Includes a TCM as a minor part.
	5	No significant air quality impact in certified environmental document.
	0	Unknown air quality impact.

25		External Impacts (Continued)
	 10 8 5 2 0	**Moderately and Marginally Effective TCMs (Groups 3, 4 and 5):** Regional Transit Coordination (Translink and regional 800 transit phone number)(FTCM 21); Expand and Improve Public Transit (rail station improvements/intermodal stations, purchase of clean fuel buses for fleet expansion)(FTCM 3); Improve transit Service (STCM 3); Expand Regional Rail System (STCM 4); Improve Arterial Traffic Flow (STCM 12); Indirect Source Control Program (STCM 16); Upgrade CalTrain service (FTCM 19); Regional HOV System Plan (FTCM 20); Park and Ride lots (FTCM 7, 8); Employer Audits (FTCM 23); Local TSM Initiatives (FTCM 28); all other FTCMs, all other STCMs. Entirely a TCM. Includes a TCM as a significant part. Includes a TCM as a minor part. No significant air quality impact in certified environmental document. Unknown air quality impact.
		Land Use Criteria The Subcommittee agreed to adopt Planning Principle #6, the land use elements as the new Land Use criteria. If a project meets all three of the new elements, the project would receive eight (8) points; if a project meets two of the new elements, the project would receive six (6) points; if the project meets only one of the new criteria, the project gets four (4) points. The project can also get two (2) additional points if SIGNIFICANT, immediate, and direct land use impacts can be shown. The three elements of Land Use criterion are: 1. Transit investment that complements transit oriented land use plans and strategies (e.g., high density development around rail stations). 2. Improvements that make existing developments more pedestrian and bicycle friendly, that support HOV and transit use, and that improve passenger safety and convenience. 3. Investments that support land use policies that minimize the use of freeways for local trips (e.g., transportation investments that support infill and mixed use development).
	 8-10 4-6 4-6	**Energy Conservation/Modal Shift** Directly promotes modal shift away from the single occupant vehicle, such as rail, bus, HOV or bicycle/pedestrian projects. Indirectly promotes modal shift, such as TOS, park and ride lots. Signal interconnection projects.
	 20 5 2	**Americans with Disabilities Act (ADA)** Entire project is for ADA. ADA is a significant component of project. ADA is a minor component of project.
		TOTAL POINTS

II. Overall Multipliers for Planning Projects

All planning projects are first evaluated as if the project defined for the study were to be built. This is done according to the Screening and Scoring Criteria above. Second, the total score for the planning project is scaled down by the following multipliers. The particular multiplier used for a given project depends on the nearness and necessity of the planning project to direct and immediate transportation improvements.

Planning Activity	Multipliers
Preconstruction Activities such as Alternatives Analyses and project design	1.0 to 0.8
Priority Setting Studies such as county-wide bike plans or Deficiency Plans	0.6 to 0.4
Long-Range Feasibility Studies and general planning activities	0.2 to 0.0

Scoring Criteria Guidance

Section A

Asset	Normal Replacement Cycle
Bus	12 yrs
Van	4 yrs
LRV	25 yrs (or FTA approved cycle)
Trolley Bus	18 yrs
Heavy Rail Car (CT, BART)	25 yrs
Ferry	25 yrs
Tools and Equipment	10 yrs
Service Vehicles	7 yrs
Track/OverheadWire/Facilities	40 years - Components can be replaced earlier based on industry standards (case-by-case determination)

APPENDIX T

TCMs To Be Considered for Testing and Evaluation by Washington, DC.

Source: Washington No. 1, pages 183 - 193.

LIST OF TRANSPORTATION CONTROL MEASURES TO BE CONSIDERED FOR TESTING AND EVALUATION

Developed by the
Traffic Mitigation Subcommittee

The following document is a list of transportation control measures that are under consideration for testing and evaluation. The list was developed by the Traffic Mitigation Subcommittee, for the Transportation Planning Board Technical Committee at COG. It is considered a "working document". As such, measures may still be added or deleted. Once the list has been reviewed by the TPB Technical Committee and received public input, the measures will go through an initial screening process to determine which TCMs warrant further testing and analysis. The goal of the list (and the subsequent analysis) will be to identify the most promising TCMs, for inclusion in a regional air quality plan to attain clean air standards.

TCMs to be Considered for Testing and Evaluation

* = Measure to be scored

1.0 Mobility Improvements

1.1 Public transit

1.1.1 New transit services

1.1.1.1 New transit improvements, as coded in the PFT2 Network along with land use patterns and densities to support them (Decision to be made in conjunction with LRP update process).

*1.1.1.2 New transit amenities, including bus shelters with benches at all bus stops (where in compliance with ADA regulations

1.1.1.3 (TMA Group will provide)

*1.1.2 Increase frequency of existing transit (especially bus) and improve transfer --connections, including the construction of Transit Centers or similar up-graded transfer facilities. Provide peak period headway of all bus and transit to not more then 10 minutes.

*1.1.3 Add timed transfer service with extensive suburban route coverage to:

- Germantown
- Gaithersburg
- Rockville
- Bethesda/Chevy Chase
- Silver Spring
- North Bethesda
- Wheaton
- College Park/Hyattsville/Riverdale
- Greenbelt/Lanham
- Greenbelt/Beltsville
- Laurel
- Largo
- Camp Springs/AAFB
- Cameron Valley
- Merrifield
- Tysons Corner
- City of Fairfax/Oakton
- Fairfax Center
- Fairfax Dulles
- Herndon/Reston
- PW Regional Employment Dist.
- Springfield Transportation Center
- Bowie
- Crofton
- Mitchellville
- Suitland
- Upper Marlboro/Melwood
- Clinton
- Fort Washington/Oxon Hill

*1.1.4 In high volume bus corridors, reduce bus passenger travel time and improve schedule adherence, using such techniques as queue jumpers, HOV lanes, signal priority or other priority treatments.

*1.1.5 Increase the application of technology, such as APTS/AVL terminal displays at transit centers, automated fareboxes or ticket and transfer modules

*1.1.5.1 Implement combined transit info database.

*1.1.5.2 Place information kiosk in suburban employment sites, downtown core and transit/commuter rail stations.

*1.1.5.3 Implement real-time transit passenger information systems

*1.1.6 Increase frequency of commuter rail service in both directions.

1.1.7 Improve transit access, safety and ease of use.

*1.1.7.1 Construct missing sidewalks/other pedestrian facilities, street lights, pedestrian signs and pedestrian activated traffic signals to complete pedestrian systems within 1 mile of all rail transit stops.

1.2 Parking

1.2.1 Provide more park-and-ride facilities that would serve car/van pools and public transit

*1.2.1.1 Expand all Park-and-Ride lots that are now full, by 50%.

*1.2.1.2 Build new Park-and-Ride lots, associated with new HOV facilities, based on PFT1 Network.

*1.2.1.3 Provide preferential treatment for HOVs at transit Park-and-Ride facilities.

*1.2.1.4 Provide Park-and-Ride facilities at intersections of major commuter highways in the region.

1.3 HOV lanes (including bus lanes)

1.3.1 Build HOV network, based on PFT1 Network and LRP update process, with limited access right-of-way. Evaluate diamond lane vs. separate row.

1.4 Bicycle/Pedestrian Improvements

*1.4.1 Construct transit and pedestrian malls

*1.4.2 Designate areas of bicycle, pedestrian, transit priority with traffic calming procedures.

*1.4.3 Construct missing sidewalks and other pedestrian facilities, street lights and pedestrian activated traffic signals to complete pedestrian/bicycle systems with all schools, public facilities, shopping and employment centers.

*1.4.4 All new, widened, reconstructed or repaved arterial roadways should include sidewalks and bicycle/pedestrian lanes or paved shoulders/wide outside lanes (in accordance with state law).

*1.4.5 Develop a fine-grained network of calmed streets linked to a comprehensive network of separated bicycle lanes and paths along higher speed/higher volume traffic arterials.

*1.4.6 Construct the bicycle and pedestrian facilities identified in the Bicycle Element of the Long-Range Transportation Plan.

*1.4.7 Provide bicycle parking racks or lockers at all transit stations and park-and-ride lots.

*1.4.8 Develop guarded bicycle check-rooms or garages and service counters at selected high-volume transit centers.

*1.4.9 Reduce lease fee for bicycle lockers.

1.5 Car and Vanpool Programs

*1.5.1 Upgrade COG Ride Finders Program computer services: Upgrade software for full regional address recognition, corridor searching, graphic display matching, self-walk up matching potential, integrated transit information, and parking database integration.

1.5.2 Increase the availability of employer and residentially based ridesharing matching services.

*1.5.2.1 Implement satellite ridesharing or TMA offices at all major employment centers (Federal, State and Private), with inter-connection through the regional COG ridesharing program.

*1.5.3 Implement regional "Guaranteed-Ride-Home program".

2.0 Policy/Legislative Instruments

2.1 Public Transit

2.1.1 Transit subsidies

*2.1.1.1 Implement a Regional Voucher Program with travel allowance and parking charge ($60/mo. for all employees)

2.1.2 Reduced fares

*2.1.2.1 Single price all public transit services ($1.00/trip) with free transfer.

*2.1.2.2 Mandatory employer transit pass program - equity with free parking.

*2.1.2.3 Develop monthly, quarterly or annual transit passes.

*2.1.2.4 Develop regional transit fare media.

*2.1.2.5 Free rail use (all), 10-3pm weekdays

*2.1.2.6 Reduce cost of all rail use by 50%, 10-3pm weekdays

*2.1.2.7 Introduce fareless transit square in major CBDs.

2.1.3 Promote diverse paratransit

*2.1.3.1 Allow jitney, shared ride taxi and user side subsidy taxi service to all sites not serviced by public transportation.

*2.1.4 Establish regional vanpool service insurance pool.

2.2 Bicycle/Pedestrian

*2.2.1 Require, through zoning ordinances, that secure bicycle parking racks or lockers are provided at a ratio of 1 space per 20 employees for all employment sites.

2.3 Parking

2.3.1 Increase parking costs.

*2.3.1.1 Each suburban workplace parking space outside Metro core, to be taxed at rate of $50/mo., revenues to support transit operations.

*2.3.1.1.1 Tax all parking in the Metro Core at a rate of $75/month, revenues to support transit.

*2.3.1.2 Tax new parking spaces that exceed code minimum (up to $5,000 annually) and phase in charges 1996, 1999 and 2010

*2.3.2 Increase Meter Parking costs in the Metro Core.

*2.3.3 Restrict new parking construction

- 1 space per 5 employees for building within 1/4 mile of transit stations.
- 1 space per 3 employees for buildings in D.C., Arlington and Alexandria.
- 1 space per 2 employees for building inside the beltway.
- 1 space per 1.5 employees for buildings outside the beltway.

*2.3.4 Provide free spaces for all carpools (2 or more) and all vanpools.

*2.3.5 Increase marketplace understanding of parking costs by requiring fully allocated costs for all parking to appear as a separate charge on all commercial and residential leases, and require on a phased in basis - separate leases for parking, with an option to decline all.

*2.3.6 Require market-based parking charges for all federal facilities in the region.

2.4 Land use

2.4.1 Establish new and enhanced current means of creating better jobs-to-housing balances within subareas in the region.

*2.4.1.1 Require all new office development within 1/2 miles of a Metro station to be accompanied by sufficient residential units for all employees of the office development.

*2.4.1.2 Eliminate all prohibitions against residential units above retail establishments in commercial districts

*2.4.1.3 Eliminate on-site parking requirements in commercial districts within 1/4 mile of Metro stations.

*2.4.1.4 Eliminate prohibitions against accessory dwelling units throughout the region.

2.4.2 Develop higher densities at transit stations and along transit corridors

*2.4.2.1 Increase density in the District of Columbia at parcels adjacent to Metro stations.

*2.4.2.2 Set a regional goal for the number of dwelling units at each Metro station by overlaying local zoning and seek enabling legislation from the District of Columbia and the states to implement the goal.

*2.4.2.3 Institute residential parking permit programs in transit corridors.

*2.4.2.4 Require all shopping centers and strip malls to develop or allow development on their parking lots the same number of residential units as there are employees in the retail establishments.

*2.4.2.5 Require construction of a range of housing types in higher-density configurations in the air rights of all transit operator parking lots.

2.4.3 Require mixed-use development

*2.4.3.1 Eliminate prohibitions against neighborhood-serving retail establishments in residential zoning districts.

*2.4.3.2 Eliminate prohibitions against home occupations, including home businesses with employees, in residential districts.

*2.4.3.3 Eliminate single-use zoning districts which segregate permitted land uses into mutually exclusive areas, and replace them with districts permitting a mix of uses in a range of densities, while prohibiting the co-location of residential and noxious land uses to ensure protection of health, safety and welfare.

*2.4.3.4 Eliminate off-street parking requirements for commercial land uses and replace them with on-site housing requirements.

2.4.4 Plan for more urban and suburban in-fill development

*2.4.4.1 Implement taxation changes that severely penalize owners of vacant housing, abandoned housing and vacant lots.

*2.4.4.2 Establish an urban growth boundary to contain the outward force of development in the region and to redirect growth inward.

*2.4.4.3 Transfer ownership of vacant, public housing buildings to churches and others with the resources to renovate and manage them.

*2.4.4.4 Construct mixed-use development on the air rights of most surface parking lots, and severely limit the construction of new surface parking lots.

2.4.5 Require all new development site plans for employment, shopping centers and residential dwellings to include site layouts and facilities that accommodate bus, pedestrian and bicycle access in the most convenient and safest manner.

*2.4.5.1 Require new building to front arterial roads to provide shorter distances between bus stops and building entrances.

*2.4.5.2 Require secure bicycle parking in all new developments.

*2.4.5.3 Require pedestrian and bicycle circulation plans as part of required application materials in all jurisdictions receiving state or federal transportation capital improvement funds.

*2.4.5.4 Publish a handbook on improved site planning techniques jointly prepared by local governments and the development community.

*2.4.5.5 Encourage transit operator joint development and system interface policies that link projects to transit stations.

2.4.6 Develop ancillary services (shops, ATMs, dry cleaners, child care) at suburban employment centers, transit stations and park-and-ride lots

*2.4.6.1 Require through zoning and site plan review processes the provision of ancillary services in exchange for density bonuses and other incentives.

*2.4.6.2 Require transit operator to include commercial operations within transit stations.
*2.4.6.3 Replicate the development of the Shady Grove elderly and child-care facility at all terminal and other transit stations including Park-and-Ride lots.
*2.4.6.4 Work with the District of Columbia and the states to develop employment counseling and training centers at selected transit stations which would provide child care for those being counseled/trained.

2.4.7 Locate public facilities so as to minimize the amount of travel necessary to reach them; sites are to served by transit.

*2.4.7.1 Replace aging schools and libraries with new facilities designed for current requirements as part of mixed-use developments at transit stations. The sale of the replaced facilities would provide funding for recreation areas for schools that would serve as open space for the mixed-use center.
*2.4.7.2 Require new Federal, Regional, State and Municipal services be accessible by transit.
*2.4.7.3 Provide density bonuses and other incentives to developers of transit-oriented buildings with components provided to assist the public, such as visitors centers, job counseling offices, health clinics, elderly and child care facilities, libraries, municipal permit centers and the like.

2.4.8 Zoning changes, such as zoning that encourages development in areas already well served by transit.

*2.4.8.1 Rehabilitate 10,000 vacant dwelling units in the District of Columbia.
*2.4.8.2 Establish clearly defined transit station overlay districts (as exist in Prince George's county and other jurisdictions) on a uniform basis regionwide so as to make a consistent set of regulations apply in these areas to give them a competitive edge over other areas.
*2.4.8.3 Establish urban growth boundaries as required in Oregon to limit the outward growth of the urban area and to focus development on areas that can be provided transit and other urban services.
*2.4.8.4 Reduce barriers to the subdivision of single-family dwelling units.
*2.4.8.5Eliminate prohibitions against Single Room Occupancy.
*2.4.8.6 Encourage adaptive reuse of warehouse and industrial space in transit accessible areas.
*2.4.8.7 Encourage reinvestment in CBD areas through incentives such as free-enterprise zones.

2.4.9 Auto restricted zones

*2.4.10 Establish auto-free zones on streets with crowded or constrained pedestrian movement patterns on sidewalks in Silver Spring, Bethesda, Downtown and Alexandria.

*2.4.11 Develop traffic cell system in CBD (A system which makes auto trips between the cells circuitous, but shortens trips by transit, bicyclists and pedestrians.

*2.4.11.1 Award density bonuses and other incentives to developers of buildings abutting auto-free zones.
*2.4.11.2 Establish auto-free zones linking the Monumental Core to most downtown transit stations.
*2.4.11.3 Replicate the auto-free zones around the Jefferson and Lincoln Memorials at other National Park Service reservations such as Dupont and Washington Circles.
*2.4.11.4 Trip reduction ordinances, as in the Montgomery County TRO, in local jurisdictions

2.4.12 Design new areas for transportation efficiency. Measures include provisions for non-vehicular routes, and layout of streets that discourage motor vehicle use for short trips where other more energy-efficient means of transportation are available.

*2.4.12.1 Forbid construction of cul-de-sacs in the urbanized area.
*2.4.12.2 Require grid patterns of streets to serve all new subdivisions.

*2.4.12.3 Construct a system of footpaths and bikeways throughout the metropolitan area.

*2.4.12.4 Require all new highway and transit construction to be matched by trail construction funding on a formula basis, such as $10 for trails for every $100 spent on highway and transit.

2.4.13 Tax incentives to encourage development in the urban core and inner suburbs along corridors well served by transit.

*2.4.13.1 Enact value-capture taxation methods that favor development and redevelopment while discouraging under-investment and speculation. This technique is used extensively in Pennsylvania and in other countries.

*2.4.13.2 Implement regional tax-base sharing to provide compensation to areas not in the urban core and inner suburbs along corridors well-served by transit which would be expected to forgo potential development that would expand their tax base. This technique is used in the Minneapolis-St. Paul region for several reasons.

2.5 Financial Incentives/Disincentives

*2.5.1 Increase state/regional/local gas taxes ($0.25/yr. for 10 years), with rebates to transit operators and trucking services. Proceeds from tax to go to fund for regional transit operations and capital. Intent is to reduce auto travel without adversely impacting commerce.

*2.5.2 Institute highway tolls, including congestion pricing of roads and travel facilities to achieve minimal level-of-service E., Network to be priced is identical to HOV Network in PFT1. HOVs are not charged. (Toll increases should be greater than that of transit increases). Funds would be used for facility improvements and travel demand management activities.

*2.5.3 Institute area pricing of peak period of travel to CBD's and other designated centers between 6-10 a.m.

*2.5.4 Impose a tax on vehicle milage, graduated according to the milage operated (annual budget of 10,000 free miles, avg. of $0.05/mile charge for each mile driven over 10,000/year with credit for low-emitting vehicles) graduated according to air pollution emission rate of the vehicle.

2.5.5 Institute a graduated vehicle registration fee.

*2.5.5.1 (1st auto @ $50, 2nd auto @ $50 + $25, 3rd auto @ $50 + $40. etc. phased in over a 10 year period.)

*2.5.5.2 (1st auto @ $500, 2nd auto @ $500 + $250, 3rd auto @ $500 + $400. etc. phased in over a 10 year) period.

2.5.6 Provide bicycles for free use by employees.

*2.5.6.1 Employers must provide at least 1 bicycle per 50 employees for mid-day employee business or personal use.

*2.5.7 Tax on people who purchase cars that do not meet minimum fuel efficiencies or that exceed certain size and/or weight restrictions (similar to California standards).

*2.5.8 Institute toll-free travel on toll facilities for all carpools, vanpools, and buses.

*2.5.9 Rebate gasoline taxes to registered vanpools.

*2.5.10 Abolish licensing fees for registered vanpool.

*2.5.11 Abolish personal property taxes on all vehicles used primarily for vanpooling and buspooling.

*2.5.12 Property tax incentives for businesses operating in pedestrian areas.

*2.5.13 Accelerate depreciation or investment tax credit for employers providing vanpool vehicles.

2.6 Bicycle/Pedestrian

*2.6.1 Permit bicycles to be carried on all suburb to suburb and suburb to city public transit bus routes, and expand hours of the Metro bike-on-rail program to include 10am to 3pm on weekdays.

- *2.6.2 Eliminate bike-on-rail permits.
- *2.6.3 Easier access to bike-on-rail permits.
- *2.6.4 All local and state jurisdictions should hire/designate a pedestrian coordinator to manage projects and market and promote pedestrian travel.
- *2.6.5 Employers should provide pedestrian and bicycle commuters with free access to shower and locker facilities.
- *2.6.6 Develop pedestrian/bicycle paths that access commercial/retail centers.
- *2.6.7 All local and state jurisdictions should hire/designate a bicycle coordinator to manage projects and market and promote bicycle travel.

2.7 <u>Restrictions on private auto use and fuel consumption</u>

- *2.7.1 Programs to limit or restrict motorized vehicle use in congested areas, particularly during periods of peak use.
- *2.7.2 20 Miles per hour speed limit on all local streets.
- *2.7.3 Programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use (both as to time and place)
- *2.7.4 Mandate minimum fuel efficiencies for all cars (federal CAFE standards)
- *2.7.5 Programs to control the extended idling of vehicles
- *2.7.6 Programs to reduce motor vehicle emissions caused by extreme cold start conditions
- *2.7.7 Programs to encourage the voluntary removal from use and the marketplace of pre-1980 model year cars
- *2.7.8 Adopt California emissions standards.
- *2.7.9 Retrofit existing vehicles: Require installation of energy conservation equipment on existing vehicles, including installing ignition and carburetor devices and fuel-efficient tires.
- *2.7.10 Inspect vehicles to ensure that they are achieving fuel efficiency

- *2.8 Weekly radio, TV, and newspaper advertisements to promote alternative modes.
- *2.9 Regulate commercial trucks travel to non-peak periods.
- *2.10 Establish Kindergarten - 12th grade bicycle education safety programs (School education curriculum materials on environmental/transportation options).
- *2.11 Establish telework friendly state and local regulations.
- *2.12 Levy substantial 'pollution fee' on gasoline-powered motor vehicles (similar to California).
- *2.13 Allow each household to register no more than one gasoline-powered motor vehicle; additional vehicles must be powered by alternative fuels or electricity.

3.0 Employer Programs

*3.1 Employer-based transportation management plans (including incentives)
*3.2 Flexible work schedules
*3.3 Four-day work week/proportionately staggered over the entire work week.
*3.4 Staggered work hours
*3.5 On-site trip reduction programs, requiring employers/building owners to provide all of the following measures for employees of work sites:
- Telecommuting
- Bus shelters at bus stops adjacent to work sites.
- A discount on transit fares and vanpooling fees, subsidized at least to the level of the employer/landlord subsidies for the fully allocated cost of parking.
- 75% fuel discount for carpoolers and vanpoolers.

*3.6 Establish an area-wide program to assist employers in providing company cars, taxi fares, or other transportation as appropriate for a universal 'Guaranteed Ride Home' program.
*3.7 Permit greater full-time home occupations.
3.8 Telecommuting
*3.8.1 Establish 12 shared-use telecommuting centers in outlying areas.
*3.8.2 Offer financial incentives for employers to set up telecommuting programs, requiring that employers certify effectiveness as a precondition of funding.
*3.8.3 Create a regional telecommuting advisory center to promote the concept and educate employers.
*3.9 Adopt Maryland ETR requirements.

4.0 Non-Work

*4.1 Raise driving age to 18.

*4.2 Replacement of shopping trips by a combination of tele-ordering and parcel delivery encourage telebanking, any substitution of telecommunication.

*4.3 Prohibit student parking at high schools.

*4.4 Free transit passes for high school and college students, subsidized by the schools or through a student registration fee.

*4.5 Bicycle lockers at park-and-ride lots.

*4.6 Retrofit convenience commercial centers within five-minute walking distance of residences in each neighborhood.

*4.7 Develop penetrator paths that access commercial centers.

5.0 Traffic Operations

- *5.1 Introduce ATMS to provide fully integrated intersection controls, freeway ramp metering and advisory signs, real-time information on traffic conditions, and quick response incident management.
- *5.2 Traffic flow improvement programs that achieve emissions reductions.
  (See TIP)
- *5.3 Optimize traffic signal timing.
  (See TIP)
- *5.4 Upgrade traffic signal systems.
  - US 1, MD 212 to I-95
  - US 1, Laurel Rd. to Contee Rd.
  - MD 4, Forestville Road to Shadyside Ave.
  - MD 5, MD 637 to Marlow Heights
  - Md 197, B/W Parkway to MD 193
  - US 1, MD 500 to Fox St.
  - MD 214, Addison Rd. to Hampton Park Blvd.
  - (See TIP for additional projects)
- *5.5 Remove unwarranted traffic control devices.
  (See TIP)
- *5.6 Put traffic signals on "flashing yellow". Introduce flashing yellow in the predominant direction and flashing red in the minor direction from the hours of 12 midnight to 5 a.m. for all low-volume intersections, where safety and geometrics permit.
- *5.7 Improve streets at traffic bottlenecks.
  (See TIP)
- *5.8 Increase use of right-turn-on-red.
- *5.9 Maintain pavements intensively.
  (See TIP)
- *5.10 Improve horizontal and vertical alignment at selected locations.
  (See TIP)
- *5.11 Travel advisory services (such as via radio).
  - *5.11.1 Introduce regional ATIS to provide travellers with real-time information on travel conditions for all.
- *5.12 Change street circulation.
- *5.13 Highway ramp metering, preferential entry, for HOV and transit.
- *5.14 Traffic signal priority for high-occupancy vehicles.
- *5.15 Increase speed limit enforcement in freeways so that 85 percent is at 55 mph at all times.

APPENDIX U

Three Examples of Analysis Methods Used By Washington, DC
(Sketch Planning, Mode-Choice Model, COMSIS TDM)

Source: Washington No. 1, pages 118-120, 132 - 138.

MEASURE M-32: Increase Bus Speeds in High Volume Bus Corridors

DESCRIPTION: This Transportation Control Measure would decrease the travel time of buses operating in corridors with extensive bus service by making various street-level and transit operational improvements. By providing bus lanes, pre-emption of signals, and increased use of express and limited-stop operations, weekday-peak period bus travel times on major arterial streets would be improved.

ANALYSIS TOOL: Mode-Choice Model

TRAVEL ANALYSIS ASSUMPTIONS: The effect of this measure on work trips was analyzed using the MWCOG Mode Choice model. High-volume bus corridors were identified for any zone-zone pair if they meet the following two (2) criteria:

1) initial wait time is five minutes or less.
2) bus run time is 50% or more then (bus + rail) combined run time.

For the zone-zone pairs that met the above criteria, the bus run times were reduced by 20% for input to the model. The 20% reduction reflected a reasonable potential improvement in running speed from all bus priority treatments. The measure increases HBW transit trips by 4,500 trips along with a reduction of 3,500 vehicle trips. Since few non-work trips occur during the peak period, the relative effect of this measure on non-work transit trips was estimated at 10%. The decrease in non-work vehicle trips was estimated from the increase in non-work transit trips.

Increase in Transit Trips:

4,500	Increase of 0.7% in HBW transit trips
+ 15.5%	Increase by 15.5% to account for work-related trips
5,200	Estimated increase in HBW transit trips
	IMPACT ON NON-WORK TRANSIT TRIPS
0.7%	Estimated increase in HBW transit trips
x 10%	Non-work impact is estimated to be 75% of HBW impact
0.07%	Estimated increase in non-work transit trips
x 274,100	Total base non-work transit trips
200	Total increase in non-work transit trips
5,400	**Total increase in transit trips**

Reduction in VT:

3,184,000	Base 1996 HBW vehicle trips (average weekday)
x 0.11%	Estimated reduction in HBW VT attributable to the TCM
3,500	Reduction in HBW vehicle trips
+ 15.5%	Increase by 15.5% to account for work-related travel
4,000	Total HBW trips reduced

IMPACT ON NON-WORK TRIPS

200	Increase in non-work transit trips
+ 1.5	Non-work Average Vehicle Ridership (AVR)
100	Estimated reduction of non-work trips
4,100	**Total reduction in vehicle trips**

Reduction in VMT:

47,006,000	Base 1996 HBW VMT (average weekday)
x 0.09%	Estimated reduction in VT attributable to TCM
42,300	Reduction in HBW VT
+ 15.5%	Increase by 15.5% to account for work-related travel
48,900	Total HBW VMT reduced

IMPACT ON NON-WORK VMT

66,082,000	Base non-work VMT
+ 10,941,000	Base non-work VT
6.0	Average trip length for non-work trips (miles)
x 100	Reduction in non-work VT
600	Estimated reduction in non-work VMT
49,500	**Total VMT reduced due to implementation of TCM**

Estimated Emission Reduction

Cold start emissions =	4,100 trips X 2.919 grams/trip =	12,000 grams
Running emissions =	49,500 miles X 0.551 grams/mile =	27,300 grams
Hot soak emissions =	4,100 trips X 1.114 grams/trip =	4,600 grams
Total trip cycle =		43,900 grams
	43,900 grams + 907,185 grams/ton =	0.05 tons

COST ANALYSIS ASSUMPTIONS:

Transit capital and operating costs and revenues impacts were estimated on the basis of a 4,100 increase in daily transit ridership. Using the standard transit financial impact procedures for this project, transit capital costs would increase by $194,800 and transit operating costs would increase by $2.73 million. These costs would be offset by $1.85 million in additional revenue. Additional capital costs were estimated for the implementation of certain priority treatments, such as signal pre-emption and bus-only lanes. Of the total change in ridership, 45.5% of trips end in the District, 22.4% of trips end in Maryland and 32.1%

of trips end in Virginia. The assumed number of days for this measure was 250 and the life cycle was one year.

Capital Costs:	\$0.19/trip X 5,400 trips/day X 250 days =	\$256,500
Operating Costs:	\$2.66/trip X 5,400 trips/day X 250 days =	\$3,591,000
Transit Revenue:	\$1.30/trip X 5,400 trips/day X 250 days =	(\$1,755,000)
Net Public Cost:		\$2,092,500

$$\text{Cost effectiveness} = \frac{\$\ 2{,}092{,}500}{250 \times .05} = \$\ 167{,}400/\text{ton}$$

NOTE: This cost does NOT include construction of bus lanes, or signal pre-emption.

EVALUATION RESULTS:

Emission Reduction Potential: 0.05 tons/day
Net Cost/(Revenue): \$2.1 million
Cost Effectiveness: \$167,400/ton

MEASURE M-39: P&R Lots Near Selected Major Highway Intersections

DESCRIPTION:

This Transportation Control Measure would construct new Park and Ride lots in the vicinity of selected intersections of major commuter highways in the region. Such Park and Ride lots were designated as serving either express transit with transit/carpools.

ANALYSIS TOOL: Sketch Planning

TRAVEL/EMISSION ANALYSIS:

The facilities which were assumed are as follows:

Maryland

MD210	@	MD373	Prince George's	200 spaces / mixed use
MD4	@	MD408	Anne Arundel	50 spaces / express transit
MD216	@	US29	Howard	400 spaces / express transit
MD355	@	Montrose	Montgomery	200 spaces / mixed use
MD4	@	MD258	Anne Arundel	70 spaces / express transit
				920 spaces in Maryland

Virginia

Rt. 29 Corridor	Fairfax County	1,000 spaces / mixed use
		1,920 TOTAL SPACES

Data presented in the 1981 FHWA *Traveller Response Handbook* suggests the following characteristics of Park-and-Ride lots to support express transit. Six new Park-n-Ride Lots are assumed to be in place, having a total capacity of approximately 1,920 spaces.

PRIOR TO P&R FACILITY CONSTRUCTION

MODE OF TRAVEL (for every 100 person trips)	SOV Person Trips		38
	SOV Vehicle Trips		38
	HOV Person Trips		12
	HOV Vehicle Trips (12 ÷ 3.2)		4
	TRANSIT	Walk Access	14
		Auto Access	27
	Non-Motorized Modes		9

AFTER P&R FACILITY CONSTRUCTION

MODE OF **ARRIVAL** (for every 100 person trips) for EXPRESS TRANSIT & MIXED USE	Auto Access Person Trips	87
	Average Vehicle Occupancy	1.08
	Vehicle Trips (87 ÷ 1.08)	81
	Kiss & Ride	4
	Walk/Other	9

AFTER P&R FACILITY CONSTRUCTION

MODE OF **DEPARTURE** (for every 100 person trips) for **MIXED USE LOTS ONLY**	Carpool	60
	Vanpool	22
	Transit	18

AFTER P&R FACILITY CONSTRUCTION

MODE OF **DEPARTURE** (for every 100 person trips) for **TRANSIT ONLY**	Transit	100

VT REDUCTION (Express Transit & Mixed Use Lots):

One-Way Vehicle Trips PRIOR to Lot Construction (for every 100 person trips)	69
One-Way Vehicle Trips AFTER Lot Construction (for every 100 person trips)	- 85
Increase in One-Way VT due to implementation (per 100 person trips)	(16)
Number of spaces (assumed to be same as VT)	÷ 85
Increase in VT per space	0.19
	x 2
Increase in Two-Way VT per space	0.38

VT increase due to TCM = 1,920 spaces x 0.38 = 730 trips

VMT REDUCTION (Express Transit Lots Only):

Home to Work VMT PRIOR to Lot Construction (for every 100 person trips) (69 vehicle trips x 2) x 36.5 {ave. trip length}		5,040
Home to Lot VMT AFTER Lot Construction (85 vehicle trips x 2) x 7.9 {ave trip length}	1,340	
Lot to Work VMT AFTER Lot Construction (for every 100 person trips)	0	
Total VMT AFTER Lot Construction	1,340	1,340
Decrease in VMT due to implementation (per 100 person trips)		3,700
Decrease in VMT per space (3,700 ÷ 85)		**44**

VMT REDUCTION (Mixed Use Lots Only):

Home to Work VMT PRIOR to Lot Construction (for every 100 person trips) (69 vehicle trips x 2) x 36.5 {ave. trip length}		5,040
Home to Lot VMT AFTER Lot Construction (85 vehicle trips x 2) x 7.9 {ave trip length}	1,340	
Lot to Work VMT AFTER Lot Construction (for every 100 person trips) (21 vehicle trips x 2) x 28.6 {ave trip length}	1,200	
Total VMT AFTER Lot Construction	2,540	2,540
Decrease in VMT due to implementation (per 100 person trips)		2,500
Decrease in VMT per space (2,500 ÷ 85)		**29**

VMT Decrease in Express Transit Lots = 520 spaces x 44 miles = 22,900 miles
VMT Decrease in Mixed Use Lots = 1,400 spaces x 29 miles = 40,600 miles

Total Decrease in VMT = 63,500 miles

Estimated Emission Reduction

Cold start emissions =	730 trips added X 2.919 grams/trip =	(2,100 grams)
Running emissions =	63,500 miles X 0.551 grams/mile =	35,000 grams
Hot soak emissions =	730 trips X 1.114 grams/trip =	(800 grams)
Total trip cycle =		32,100 grams
	32,100 grams/907,185 grams/ton =	0.04 tons

Increase in Transit Trips:

Increase = (Transit trips after lot construction - Transit trips prior to lot construction)

Mixed-use lots:

Increase = (18-41) = (23) *decrease* in one way transit trips per 100 spaces.

Total for mixed-use lots = $\frac{1{,}410 \text{ spaces} \times 23 \times 2}{100}$ = 650 *decrease* in transit trips

Transit only lots:

Increase = (100-41) = 59 increase in one way transit trips per 100 spaces.

Total for transit lots = $\frac{510 \text{ spaces} \times 59 \times 2}{100}$ = 600 increase in transit trips.

Net increase in transit trips for the measure = (650) + 600 = (50) *decrease* in transit trips

COST ANALYSIS ASSUMPTIONS:

Transit capital and operating costs and revenues impacts were estimated on the basis of an *decrease* of 50 in daily transit ridership. Using the standard transit financial impact procedures for this project, transit capital costs would *decrease* by $2,400 and transit operating costs would *decrease* by $33,300. These costs would be offset by an *decrease* of $16,300 in revenue. Assuming cost per space as $3,500, it would cost Maryland $3.22 million to construct 920 spaces, and Virginia $3.5 million to construct the 1,000 spaces. The cost of 6.72 million amortized over ten years at 6% yields an annual amount = $913,200

Capital Costs:	$0.19/trip X (50) trips/day X 250 days =	$(2,400)
Operating Costs:	$2.66/trip X (50) trips/day X 250 days =	$(33,300)
Transit Revenue:	$1.30/trip X 50 trips/day X 250 days =	$16,300
Construction:	$6,720,000 X 0.1359	$913,200
Net Public Cost:		$893,800

Cost effectiveness = $\frac{\$\ 893{,}800}{250 \times 0.04}$ = $89,400/ton

EVALUATION RESULTS

Emission Reduction Potential: 0.04 tons/day
Net Annual Costs: $893,800
Cost Effectiveness: $89,400/ton

MEASURE M-41: Mandatory Employee Commute Options

DESCRIPTION:

This Transportation Control Measure would require all employers with 100 or more employees to implement measures to achieve a 25 percent improvement in their employees' average vehicle ridership, or a 20 percent decrease in their employees' home-based work trips. These programs would not only include traditional support and promotional programs for transit, carpools and vanpools, but also alternative work schedules, economic incentives and telecommuting.

ANALYSIS TOOL: COMSIS TDM Model

TRAVEL ANALYSIS ASSUMPTIONS:

The COMSIS TDM model was used to identify program groupings of measures that would allow employee trip reduction programs to achieve the necessary trip reduction of 20 percent. The effect is on home-based work trips only. The analysis was restricted to HBW trips only and to only employers of 100 or more. The program would include:

- High level of support and promotion for rideshare
- Application of the $60 travel voucher/parking charge
- Alternate work arrangements offered to 60% of employees

The majority of the vehicle trip reduction that will be achieved as a result of this program is through rideshare, compressed work week, telecommuting and not through transit mode shift.

Reduction in VT:

3,184,000	Base 1996 HBW vehicle trips (average weekday)
x 11.3%	Estimated reduction in HBW VT attributable to TCM
359,800	Reduction in HBW vehicle trips
+ 15.5%	Increase by 15.5% to account for work-related travel
415,600	**Total trips reduced due to implementation of TCM**

Reduction in VMT:

47,006,000	Base 1996 HBW VMT (average weekday)
x 11.3%	Estimated reduction in HBW VMT attributable to TCM
5,311,700	Reduction in HBW VMT
+ 15.5%	Increase by 15.5% to account for work-related travel
6,135,000	**Total VMT reduced due to implementation of TCM**

Increase in Transit Trips:

41,900	Increase in HBW transit trips
+ 15.5%	Increase by 15.5% to account for work-related trips
48,400	Estimated increase in HBW transit trips
48,400	**Total increase in transit trips**

Estimated Emission Reduction

Cold start emissions =	415,600 trips X 2.919 grams/trip =	1,213,100 grams
Running emissions =	6,135,000 miles X 0.551 grams/mile =	3,380,400 grams
Hot soak emissions =	415,300 trips X 1.114 grams/trip =	463,000 grams
Total trip cycle =		5,056,500 grams
	5,056,500 grams/907,185 grams/ton =	5.6 tons

COST ANALYSIS ASSUMPTIONS:

Transit capital and operating costs and revenues impacts were estimated on the basis of a 48,400 increase in daily transit ridership. Using the standard transit financial impact procedures for this project, transit capital costs would increase by $2.3 million and transit operating costs would increase by $32.0 million. These costs would be offset by $15.7 million in additional revenue. The governmental cost to administer this program was based on experience, and was estimated to cost $2,300[6] per employer trip reduction plan. The total number of employers in the Washington region was estimated to be 110,543, of which 3,365 are employers of 100 or more[7]. The estimated number of employees in these firms of 100 or more was assumed to be 1,278,445. The cost and revenue to operate the $60/month voucher/parking charge program (Refer to M-42) was calculated using the regional mode shares for SOVs and HOVs. The assumed number of days for this measure was 250 and the life cycle was one year.

Capital Costs:	$0.19/trip X 48,400 trips/day X 250 days =	$2,299,000
Operating Costs:	$2.66/trip X 48,400 trips/day X 250 days =	$32,186,000
Revenue:	$1.30/trip X 48,400 trips/day X 250 days =	($15,730,000)
Administration:	3,365 employers X $2,300 =	$7,739,500
Net Public Cost:		$26,494,500

[7] 1990 MWCOG Regional Employment Census

Private Costs

Voucher Costs =	1,278,445 X $60 X 12 months =	$920,480,400
SOV Revenue =	1,278,445 X 54.6% SOV X $60 X 12 months =	($502,582,300)
Carpool Revenue =	1,278,445 X 28.5% HOV X $60 X 12 months =	($262,336,900)
Administration =	1,278,445 X $105/employee[8] =	$134,236,700
Telecommuting =	1,278,445 X 1.5% X $350 =	$6,711,800
Net Private Costs:		$296,509,700
Total Cost:		$323,004,200

Cost effectiveness

$$\frac{\frac{\$323{,}004{,}200 \text{ total net cost}}{250 \text{ days}}}{5.6 \text{ tons/day}} = \$230{,}700/\text{ton}$$

EVALUATION RESULTS:

Emission Reduction Potential: 5.6 tons/day
Net Cost/(Revenue): $323,004,200
Cost Effectiveness: $230,700/ton

[8] Ernest & Young Study on Regulation XV, 1992

APPENDIX V

Qualitative analysis conducted for the three projects included in Chapter 6's hypothetical scenario.

Source: Boston No. 9, pages G-155 to G-158, G-197 to G-200. From Boston No. 8, pages 8-19 to 8-22.

Blue Line Extension to Lynn

Existing Conditions

The Blue Line currently runs from Wonderland Station in Revere to Bowdoin Station in the Government Center area of downtown Boston. At six miles, it is the shortest of the MBTA's three high-platform rapid transit lines. The Blue Line has direct connections with the Orange and Green Lines, but not with the Red Line. Headways are currently 3.5 minutes during peak periods.

The Rockport/Ipswich commuter rail line runs from North Station through Chelsea into Lynn and then beyond to other North Shore communities. In Revere, the commuter rail tracks run within about one third of a mile of Wonderland Station. Past proposals for extending the Blue Line have always involved use of the commuter rail right of way from some point north of Wonderland.

Four MBTA express bus routes (426, 441/442, 450, and 455) provide through service between points in Lynn and Haymarket Square in Boston.[38] Three of these operate through Central Square, at the heart of downtown Lynn. This is also the location of the Lynn commuter rail station. Peak-period commuter rail headways at Lynn Station range between 20 and 30 minutes. Each express bus route serving Central Square has peak headways of ten to 20 minutes. The MBTA recently completed construction of a large parking garage at Central Square for commuter rail line and express bus passengers. This project included new commuter rail platforms.

PMT Alternative

The PMT examined a four-mile extension of the Blue Line from its current terminus at Wonderland to Central Square in Lynn (see Figure G-40). The extension would use an abandoned narrow-gauge railroad right-of-way from Wonderland to West Lynn, and then continue to Central Square beside the Rockport/Ipswich commuter rail line. Intermediate stations would be located at Point of Pines, serving a residential community in northern Revere, and at West Lynn, serving the General Electric complex and other employment centers there.

Previous studies of a Blue Line extension to Lynn have assumed a somewhat different routing, joining the Rockport/Ipswich right of way just north of Wonderland and following it all the way to Central Square. Although such a scheme would involve less land-taking, it would require widening the existing rail grade through the environmentally sensitive Saugus Marshes. Therefore, the narrow gauge route to West Lynn was chosen for study in the PMT. A separate consultant study of several North Shore transit improvements is considering both possible alignments. Ridership figures for the two alignments should be similar. The only station not served by both routes would be Point of Pines, where the PMT analysis predicts very low ridership.

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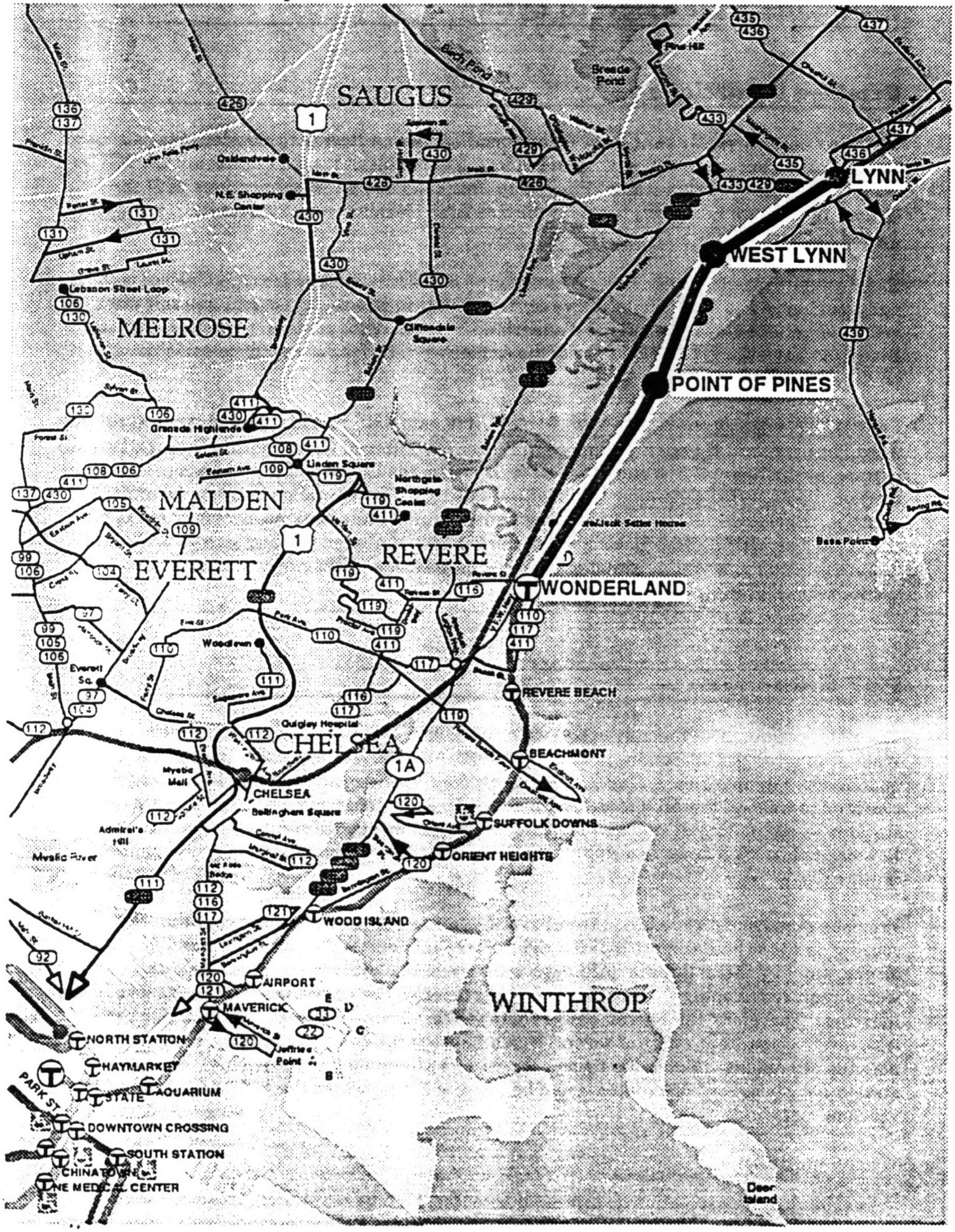
[38]Despite their classification as express bus routes, all four make many stops between downtown Lynn and Boston, and only Route 426 operates for a substantial part of its length on limited-access highways.

Figure G-40
Blue Line Extension to Lynn



Ridership Impacts

The PMT demand forecasts for the year 2020 indicate that the Blue Line extension to Lynn would serve 11,340 weekday riders, of which 4,860 would be new users of the transit system. The rest would be drawn from other transit services such as commuter rail and express bus, or diverted from existing Blue Line stations.

On a station-by-station basis, weekday ridership would be as follows:

Central Square Lynn:	7,140
West Lynn:	4,120
Point of Pines:	80
Total	11,340

At these ridership levels, the Central Square Station would serve more riders than six of the 12 existing Blue Line stations now serve, but West Lynn would rank below all Blue Line stations except Suffolk Downs and Wood Island. The projected ridership for a Point of Pines Station is far below that of any existing MBTA rapid transit station. Consequently, the final design of a Lynn extension would probably omit Point of Pines.

Travel time savings for existing transit riders would be 893 hours per weekday or 273,258 per year. These figures are relatively low among the rapid transit extensions, because the Blue Line would not offer an in-vehicle travel time advantage over commuter rail. The trip from Lynn to Downtown Boston on the commuter rail line currently takes 26 minutes, compared to a projected 30-minute Blue Line trip to Government Center. Blue Line trains would stop 12 times between Lynn and Government Center, compared to the one or two stops now made by commuter rail trains between Lynn and North Station.

The Blue Line would have the advantage of much greater service frequency, resulting in shorter average wait times. Blue Line stations in downtown Boston are more centrally located than either North Station or the Haymarket terminal used by North Shore express buses, so the Blue Line would have lower average access times. For Logan Airport employees and passengers, the Blue Line also has the advantage of providing direct service to Airport Station.

Costs and Cost-Effectiveness

The construction cost of the Blue Line to Lynn would be in the mid-range of PMT projects examined to date (see Table G-72). The initial capital cost would be $275 million for track and power, three stations, a new bridge over the Pines River and 100 Blue Line vehicles. The capital cost per new transit rider would be higher than any other rapid transit or commuter rail extension included in the SIP and CA/T Mitigation and Additional Expansion categories, at $56,600.

It would also be among the more expensive PMT projects in annual operating cost, at $10.25 million. Fare revenue from the extension would be $1.4 million annually (assuming that riders at stations beyond Wonderland would pay the same fare as Red Line riders from Quincy—double fare in, single fare out), resulting in a farebox recovery ratio of only 14 percent. The operating subsidy per passenger would also be fairly high, at $2.54. Because of the relatively low travel time savings, the cost per passenger hour saved would be high, at $75.46.

Table G-72
Costs and Revenues of Blue Line Extension to Lynn

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$10.25m	$1.4m	$275m	$56,600

Air Quality Impacts

The Blue Line extension to Lynn would reduce regional emissions by 0.07 percent, which would be a moderate reduction. The air quality improvements would be among the more expensive to attain among all PMT projects. The capital cost per weekday kilogram of VOC eliminated would be $4.6 million. This is more expensive than any of the commuter rail extensions and the other rapid transit extensions included in the recommended program.

Conclusions

There is merit to the idea of bringing high frequency transit service to densely developed Lynn. The Blue Line extension could be an economic benefit for Lynn, and it would provide a higher level of service for commuters to the urban core. There is strong support for such an extension from the City of Lynn and other North Shore communities.

These improvements in service would come at a high cost, however. By most measures, the Blue Line extension is one of the more costly, and least cost-effective projects. When North Shore transit improvements were studied in the 1970s, the MBTA decided to invest in improvements to the commuter rail service rather than extending the Blue Line (although it did not rule out the latter). Higher frequency, higher speed commuter rail service could offer many of the benefits of the Blue Line at a much lower cost.

The consultant study taking place concurrently with the PMT will provide additional information about a Blue Line extension to Lynn as well several other options for improved North Shore transit, including conversion of the Rockport and Ipswich lines to electrified light rail or rapid transit, enhanced commuter rail service, and enhanced express bus service.

Red Line Extension to Mattapan

Existing Service

The Mattapan High Speed Trolley Line is a 2.6-mile light rail line, running from Ashmont station at the end of the Dorchester Branch of the Red Line to Mattapan Square. It is entirely on private right of way (a former commuter rail route) but has two at-grade road crossings. There are six intermediate stations between Ashmont and Mattapan, mostly serving residential neighborhoods in South Dorchester and Milton.

In 1989 counts, 65 percent of all riders on the High Speed Line transferred to or from the Red Line. The busiest two stations, Mattapan, and Central Avenue, accounted for 82 percent of all inbound boarding. Many of the passengers boarding at Mattapan transfer from feeder buses there, and transfer again at Ashmont to the Red Line. At present, there is no fare for most travel on the Mattapan Line, except that for inbound trips ending before Ashmont a 60-cent fare (equal to a local bus fare) applies.

Present headways on the Mattapan Line are five minutes in peak periods, eight minutes mid-day and 12 minutes at night. Rolling stock on the line consists of President's Conference Committee (PCC) cars built in the 1940s. Present peak schedules require six cars, all operated as single units. These are the remainder of a large fleet of cars used on the Green Line prior to the introduction of more modern light rail vehicles (LRVs).

The main reason for retention of PCC cars on the Mattapan Line is the lack of an on-line carhouse to maintain the electronic systems of LRVs. The PCC cars get light maintenance in the yard at Mattapan, but are trucked to other MBTA facilities for heavy repairs. It will not be cost-effective to operate the Mattapan Line indefinitely with the present cars, and a decision on their replacement will be needed in the near future.

PMT Alternative

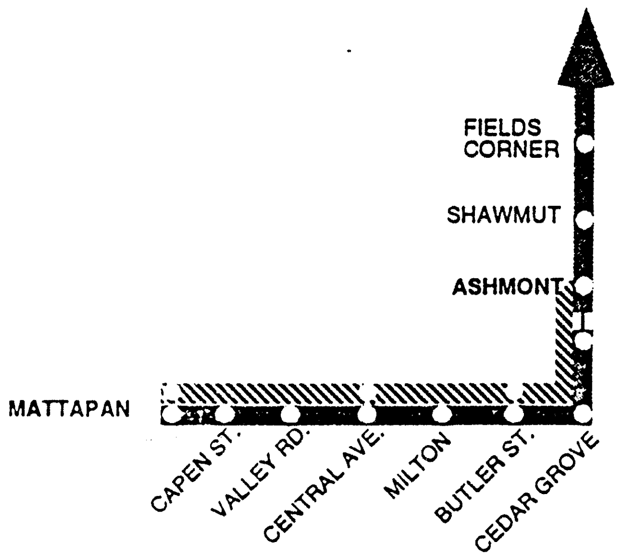
The PMT analysis examined a possible replacement of the Mattapan High Speed Trolley Line with an extension of Red Line service from the present Ashmont terminal to Mattapan. New rapid transit stations would be located only at Mattapan, Central Avenue, and Butler Street. Present stations at Capen Street, Valley Road, Milton, and Cedar Grove would be discontinued.[48]

All Ashmont branch Red Line trains would run through to Mattapan instead of originating or terminating at Ashmont. Frequency would decrease on the Mattapan Line from 4 minute headways to 8 minute headways during the peak, but seating capacity would increase significantly because Red Line trains of four or six cars would replace the single unit PCC cars.

With the smaller number of stops, travel time between Mattapan and Ashmont would be reduced from 9 minutes to 5 minutes. Passengers traveling between points on the Mattapan extension and points on the present Red Line would experience additional time savings from

[48] CTPS counts in 1989 found that of 3,465 inbound daily riders on the High Speed Line, 548 or 15.8 percent used the stations that would be discontinued.

Figure G-50
Existing Mattapan High Speed Trolley and Potential Red Line Extension to Mattapan



elimination of the transfer at Ashmont. These time savings would be partly offset by the additional access time imposed on passengers whose current stations would be closed.

Ridership Impacts

An extension to Mattapan would serve 4,720 Red Line boardings per day in the year 2020. Of these, 1,260 would be new transit trips, and 3,460 would be diversions from other transit services. The largest share of transit diversions would come from the present Mattapan Line. Some of the remainder would come from MBTA local bus routes, especially Route 27, which parallels the High Speed Line between Mattapan and Ashmont.

The projection of 1,260 new weekday transit trips for the Mattapan Red Line extension is among the lowest among all of the rapid transit extensions being studied in the PMT, although it compares favorably with the commuter rail extensions and new express bus routes. Travel time savings for transit riders is estimated to be 338 hours per weekday, which is again the lowest for all of the rapid transit projects in the PMT.

Costs and Cost-Effectiveness

Among the changes needed for rapid transit conversion would be installation of signal and power distribution systems, elimination of grade crossings at Capen Street and Central Avenue, and construction of high-level platforms at stations being retained. Red Line cars could run on the existing tracks.

The most recent capital cost estimate for these improvements and the additional Red Line cars needed to serve the extension is $54.8 million. The average capital cost per new

weekday transit rider would be $43,500. Of the rapid transit projects examined, only a Green Line extension to Medford Hillside or a Red Line-Blue Line connector would have a lower cost per new transit rider. The annual net cost of $27.34 per hour of travel time savings for the Red Line extension would be in the mid-range for all PMT projects.

Because of the age of the PCC cars, the MBTA will have to undertake some improvements to the Mattapan Line in any case to maintain service. As of the summer of 1993, all of the cars used on the line are receiving major overhauls at the Riverside carhouse, but this will not keep them running indefinitely. To run LRVs on the Mattapan Line, the power system would have to be upgraded and some arrangements would have to be made for routine maintenance. Costs for such improvements have not been estimated yet, but it is clear that a portion of the money which would be spent for a Red Line extension would have to be spent anyway just to maintain service.

The Americans with Disabilities Act requires that key stations on the Mattapan line be accessible to people in wheelchairs no later than 2020. The high platforms needed for a Red Line extension would solve the accessibility problem, while some other solution would be necessary if LRVs were used.[49]

Table G-84
Costs of Red Line to Mattapan Extension

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$1.3m	$0.24m	$54.8m	$43,490

The Red Line extension to Mattapan would result in an increase of $1.3 million in annual operating costs, compared to an increase of $24,400 in annual revenue. (The calculations assumed eight-minute peak-period headways and six-car trains.)

The majority of riders that would use a Mattapan Red Line extension now use the existing Red Line by transferring at Ashmont. Currently the Ashmont branch is served by a mix of four and six-car trains during peak periods. In the future, peak-period service will consist of all six-car trains. With time distribution similar to that of present ridership, new trips attracted by the extension should not cause serious crowding problems on the Red Line.

Operational Impacts

Operationally, an extension to Mattapan would have limited impact on the Red Line. The number of trains passing over the existing line would be unchanged. Increased loads could result in slightly longer dwell times, causing increased running times.

[49]One plan is to shift the Boeing LRVs from the Green Line to the Mattapan Line as the new low-floor cars are purchased for the Green Line. Accessibility would be achieved through the construction of mini-high platforms in conjunction with adjustments to the entryways of the vehicles to allow for level access.

Through-routing of Red Line trains to Mattapan would eliminate the logistics problems entailed in maintaining a small isolated fleet of cars for the High Speed Line. It would also improve passenger flow on the platforms at Ashmont Station, where nearly one third of the Red Line passengers are now transferring to or from the High Speed Line.

Air Quality Impacts

A Red Line extension to Mattapan is projected to reduce regional emissions by 0.01 percent. This is the lowest reduction among all of the rapid transit and commuter rail extensions examined in the PMT. The capital cost per kilogram of VOC eliminated per weekday would be relatively low, at $5,141,700. (Only the Green Line to Medford Hillside, the Blue Line extension from Wonderland to Lynn, and the Blue Line-Red Line connector would be less costly in this measure among the rapid transit projects.)

Conclusions

A Red Line extension from Ashmont to Mattapan would attract fewer new riders than most of the other PMT projects examined [illegible]. It would also be among the less expensive projects, with a capital cost of $54.8 million. Most passengers now using the Mattapan High Speed Line would experience faster travel times with a Red Line extension, and the majority would be relieved of one transfer per trip. Passengers not transferring to the Red Line would experience longer average wait times in peak hours.

Without a Red Line extension to Mattapan, substantial capital improvements will be required to maintain service on the High Speed Line. These will include upgrading the power system for compatibility with modern light rail vehicles, construction of an on-line vehicle maintenance facility, and modification of key stations for wheelchair accessibility.

It is important to note that the Red Line extension to Mattapan was examined by the MBTA in 1968. This plan was withdrawn because of [illegible] from the town of Milton, which would have lost all of its station stops. It is unknown whether local residents would be in favor of such an extension today.

The MBTA will have to make a significant investment in the Mattapan Line in the next five to ten years. At that time, it would be prudent to consider the Red Line extension as one of the options, given its benefits from an operational and systems standpoint.

Air Quality Impacts
The Newburyport extension would reduce regional emissions by 0.04 percent. The capital cost per kilogram of VOC eliminated per day would be $1.6 million for the extension. This cost falls within the middle of the range of the same costs for other PMT projects.

Two Commuter Boat Facilities

Five different ferry services that could utilize new commuter boat facilities were examined as part of the PMT Update. These were:

- North Station to Fan Pier and World Trade Center
- North Station to Navy Yard Pier 4 and Logan Airport
- South Station to Long Wharf and Navy Yard Pier 4
- Navy Yard Pier 4 to Long Wharf and World Trade Center
- South Station to Navy Yard Pier 11

The PMT analysis indicated that, without supporting transit services to feed the docking terminals, nearly all of the ridership on each route would consist of existing transit riders that would shift from rapid transit and buses to the ferries. As a result, the air quality and downtown traffic benefits would be very small.[5]

Massport and the CA/T project have recently initiated a study of ferry services that will be more comprehensive than the PMT analysis. If that study is successful in determining a more effective manner of operating new ferry services, the new commuter boat facilities may be warranted. If not, a substitution should be considered. Better downtown bus circulation and/or improvements to commuter rail service (on the Rockport/Ipswich, Haverhill/Reading, Lowell and Franklin Lines) would be potential alternate projects that would remove traffic from downtown Boston streets.

[5]For additional information on the PMT analysis of these services, see Appendix G.

Long-Term (after 2000)

Green Line Extension to Medford Hillside (near Tufts)

A Green Line extension to Medford Hillside would provide rapid transit service through Somerville to Medford Hillside in the vicinity of Tufts University. The extension would run from Lechmere Station 3.9 miles along railroad rights-of-way to Medford Hillside. There would be stations at Washington, School, and Lowell Streets in Somerville, at Ball Square (Broadway) on the Somerville/Medford border and at Medford Hillside (see Figure 8-6). The School Street and Lowell Street Stations would each include 50 parking spaces. The Medford Hillside Station would have 200 spaces.

A Green Line extension from Lechmere to Medford Hillside would serve an estimated 11,560 riders a day; of these, 3,660 would be new transit users. This extension would be among the better projects examined for the PMT in terms of capital cost per new weekday transit rider ($24,000), annual cost per hour of travel time saved ($11.02), and capital cost per weekday kilogram of VOC eliminated ($1.9 million). The extension would provide a moderate reduction in regional emissions of 0.06 percent.

The capital cost of the extension would be approximately $88.0 million. It would cost $2.1 million per year to operate and generate $1.1 million in new fare revenue. This would represent a farebox return of 52 percent, which is significantly higher than the 34 percent generated by the existing Green Line.

Note that the PMT also examined a Blue Line extension from Bowdoin to Medford Hillside along the same alignment between Lechmere and Medford Hillside, which would also include the Red Line - Blue Line Connector. A Green Line extension to Medford Hillside and a Red Line - Blue Line Connector together would attract more new transit users than a Blue Line extension to Medford Hillside at a much lower cost.

In more detail, the impacts of this project would be as follows:

Ridership

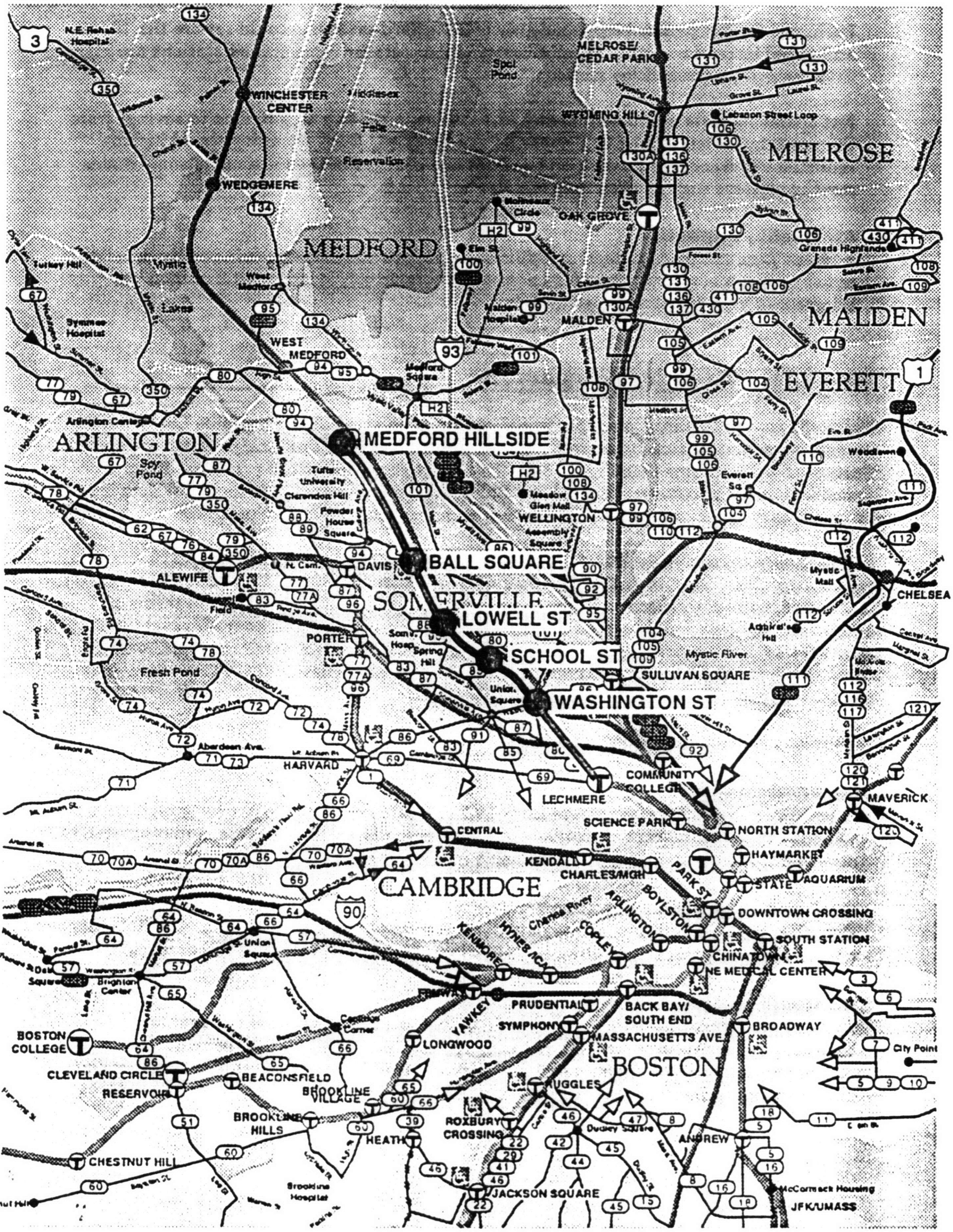
A Green Line extension from Lechmere to Medford Hillside would serve an estimated 11,560 riders a day. Of these, 3,660 would be new transit users, and 7,990 would be diverted from other MBTA services—primarily Somerville bus routes.

Costs

The estimated capital cost of a Green Line Medford Hillside extension is $88 million. By comparison, capital costs for the Blue Line extension to Medford Hillside would be $548 million (which would include $138 million for the Red Line - Blue Line Connector). The Charles–Medford Hillside segment alone would cost $411 million, or $323 million more than a Green Line extension to Medford Hillside.

The largest component ($140 million) of the difference in cost between the Blue and Green Line extensions is the additional 0.8 mile length of the Blue Line extension, all of which would be in a tunnel under the Charles River. Another $55.5 million is attributable to the purchase of 50 new Blue Line cars for the extension, compared to only 10 new LRVs for a Green Line extension. The Blue Line extension also includes a related cost of $37.5 million for a new equipment maintenance facility near Lechmere, because the present Blue Line shops could not accommodate an additional 50 cars. Existing Green Line shops and a new

Figure 8-6
Green Line Extension to Medford Hillside



Lechmere facility planned independently of a Medford extension could service the 10 additional Green Line cars. Finally, construction costs for rapid transit stations are higher than for surface Green Line stations.

Net operating costs would increase by $2.1 million, including $1.3 million in savings from the rerouting of bus service in Somerville and Medford. Such rerouting would include reductions in frequency on parallel bus lines and changes in the terminal of some routes serving stations such as Lechmere and Davis.

Air Quality Impacts

A Green Line extension to Medford Hillside would provide moderate air quality benefits, reducing regional emissions by 0.06 percent, at a relatively low cost ($1.9 million per kilogram of VOC eliminated per weekday).

Blue Line - Red Line Connector

The Red Line - Blue Line Connector would consist of an extension of the Blue Line from its present inner terminal at Bowdoin Square via a subway under Cambridge Street to Charles Station on the Red Line (See Figure 8-7). This short extension would provide a direct transfer connection between the Red and Blue Lines, which would provide better distribution for trips starting on both lines, including improved travel to Logan Airport.

A Blue Line extension from Bowdoin to Charles would attract an estimated 19,210 new riders to the Blue Line, including 4,970 new transit riders. The Red Line - Blue Line Connector is one of the better rail expansion projects examined for the PMT in terms of capital cost per new weekday transit rider ($27,700), annual cost per hour of travel time saved ($4.73), and capital cost per weekday kilogram of VOC eliminated ($3.2 million). It would also provide a moderately high reduction in regional emissions of 0.05 percent. The capital cost of the extension would be $137.5 million.

In more detail, impacts would be as follows:

Ridership Impacts

A Red-Blue Connector alone would carry 19,210 total riders and 4,970 new transit trips per weekday. This represents a relatively large increase in new transit trips, and compared to other PMT projects, would be exceeded only by significantly larger rail projects.

Costs and Cost-Effectiveness

Capital costs for a Red Line - Blue Line Connector would be $137.5 million. Capital costs per new weekday transit rider would be $27,700. This cost is low for a rail extension.

Air Quality Impacts

The Red Line - Blue Line Connector would provide moderate air quality benefits considering the size of the project, reducing regional emissions by 0.05 percent. The capital cost per kilogram of VOC eliminated per weekday would be low for a rapid transit project, and in the mid-range of all PMT projects, at $3.2 million.

APPENDIX W

Quantitative methods used to estimate travel and emission impacts of the three projects included in the hypothetical scenario discussed by Chapter 6.

Source: Boston No. 9, Appendix E and Appendix H.

Appendix E
Demand Forecasting Process

When demand forecasting for the PMT began in September 1992, the best available projections of population, employment, and travel were for the year 2010. Therefore, initial ridership estimates were produced using those projections and the then-current CTPS regional travel model. Concurrently, CTPS was in the process of updating its model set using newly collected travel data and new MAPC projections of 2020 population and employment. This effort led to the development of an "Interim Model" set, which was used to analyze highway and transit strategies for the Transportation Plan. So that the PMT and Transportation Plan would be consistent, a decision was made to update the PMT projections to reflect the most recent 2020 projections, and improvements in travel projections included in the Interim Model.

This appendix describes the demand forecasting process, and the method used to update the PMT ridership estimates from 2010 to 2020. This includes:

- An overview of the nature and role of the Boston Metropolitan Planning Organization's regional model set.
- A discussion of how the model set was recently updated for use in the draft Transportation Plan.
- A description of the steps in the model set.
- Information about how the model set will be further improved in the future.
- A description of the technical procedure used to update the 2010 ridership forecasts to 2020.

Overview of the Regional Model

A regional land use/transportation model set is composed of several models that together simulate intra-regional passenger transportation supply and demand for the current and future years. Supply enters the model set in the form of a computerized representation of the region's highway and transit systems. All express highways and major arterials, most minor arterials and many local roadways are included. All transit lines, both public and private, are included. Demand enters the model in the form of weekday trips that are generated from population, employment and land use.

A regional model set is used to forecast changes in regional travel patterns that would result from certain actions. Historically, those actions have focused on major new or widened roadways and new or extended transit lines. Also, regional models have been used to estimate the systemwide travel effects of changes in such things as transit fares, parking price or supply and fuel prices. Recently, regional models have come to be used in forecasting the impacts of transportation system changes on air quality.

Travel forecasting models used at a regional level are appropriate for developing regional transportation plans, but are not necessarily the best tool in all planning situations. Precise and accurate forecasts of roadway traffic volumes and transit line volumes are often obtained by using these same models, but at a corridor or subarea level, where supply and demand variables can be represented with more detail and where relationships in the models can be calibrated more precisely. Even more fine-grained forecasts, such as those of intersection levels-of-service must be obtained from operations-level traffic forecasting models.

The Intermodal Surface Transportation Efficiency Act of 1991 and the Clean Air Act Amendments of 1990 have placed new demands on travel forecasting models and on those who develop and use them. These models are being relied on for guidance in how transportation investments inter-relate with land use patterns, air quality and livable communities. Neither this region's nor any other region's models can provide all of the guidance being sought, but the models used in the PMT were recently updated and are more responsive to some of these issues than they were before.

Model Update Process

Travel models need to be updated periodically. At a minimum, they must be recalibrated with new data as it becomes available. In addition, their structures must be updated to maintain currency with evolving research and the state-of-the-practice. The Boston Metropolitan Planning Organization regional model set, which is maintained by the Central Transportation Planning Staff (CTPS), is in the process of being updated for these reasons and in order to make it more responsive to the recent federal mandates referred to above. It will be another year before the update process is complete, but that process yielded an "interim" model for use in the Transportation Plan and the PMT.

Steps in Model Update Process

The process of developing a new interim model set involved several steps, the first of which was to acquire a new data base. Early on, some new computer software, notably a land use allocation model, was also acquired. After these acquisitions, many months were devoted to modifying some elements of the model process and completely revamping others. All elements of the process were then connected to one another and implemented on a mainframe computer.

Model calibration was then undertaken. Calibration refers to repeatedly running the model set and adjusting certain of its components until it replicates current regional travel patterns at an acceptable level of accuracy. Once the model set was calibrated to current conditions, it was used to forecast future conditions associated with the various scenarios described in this PMT.

New Data Used in Model Update

Acquiring new data was crucial to the model update process. Several types of data, including the following, were obtained:

- Characteristics of region's travelers and of their trips
- Current and forecast regional population and employment
- Community land use and zoning information
- Traffic and transit counts

Among the more important data sources was a travel diary, used to collect information from 3,900 of the region's households. Descriptive data about households and their members was obtained, as was detailed information about the trips they make each day. This information was expanded to represent all of the region's residents and used to refine and reformulate certain portions of the model set. Socio-economic data from the 1990 U.S. Census supplemented the survey data.

CTPS developed a comprehensive file of current population and employment from various sources, including the Metropolitan Area Planning Council (MAPC), the 1990 U.S. Census, the Massachusetts Department of Employment and Training and a commercial vendor. Forecasts of future-year population and employment were obtained from the MAPC. Community land use and zoning information was collected from the MAPC and individual towns and used in the land use allocation model.

Current traffic and transit ridership counts were acquired from the state transportation agencies and other sources and used in model calibration.

New Interim Model Versus Old Models

The new interim model differs from those previously used at CTPS in several key respects. First, it is a single comprehensive regional model, used for highway, transit and high-occupancy vehicle (HOV) forecasting. In the past, three separate sets of models were used for each of these travel modes. The new model set is based entirely on new data, as described above, and incorporates many modified and brand-new steps. Because of these features, the new model is more accurate and sensitive to a wider array of policy variables than were the old ones. In short, it can do more things and do them better than the old models.

The integration of a land use allocation model with the transportation models radically changed the nature of the regional model process. In the past, population and employment forecasts input to the transportation models were always pre-determined and they remained unchanged in the modeling process. Now the land use allocation model allows us not only to forecast the impact of population and employment on transportation, but also to test how transportation might, in turn, shift the patterns of those variables across the region.

Regional employment forecasts used in the new model set are different from those used in the old models. The differences in employment projections between the old and new models translate into differences in the future trips that are generated, in part, from those projections. The old forecasts implied a central Boston employment growth of about 30 percent between 1987 and 2010. The new MAPC forecasts imply a central Boston employment growth of only seven-to-eight percent between 1990 and 2020. In consequence, the forecast of central Boston-bound trips is now lower than before. In particular, since most transit trips are made to and from that area, systemwide transit ridership forecasts output from the new model are lower than before.

Step by Step Description of Model Steps

The transportation model used in the PMT is similar to those used in most large North American cities. It is commonly referred to as the four-step urban travel demand forecasting process or simply as the four-step process. There are actually several more steps to the process; the four steps refer to the major ones. The four steps are: trip generation, trip distribution, mode split and trip assignment. With the addition of a land use allocation model, there are five major steps in the model process.

In the course of constructing a model set, the region was subdivided into small geographic areas called traffic analysis zones or simply zones. These zones, many of which are similar in size to census tracts, serve as the basic geographic units for which trips are forecast. Also in the model development stage, the region's transportation supply, in the form of roadways and transit lines, was represented in computerized networks. These networks are used to derive travel times by travel mode from each zone to every other one. These times are then used in the trip distribution and mode split steps. The networks themselves are used in the trip assignment step. The zone system and the networks are connected to one another to allow for interaction between demand and supply.

Land Use Allocation Model

The land use allocation model spatially allocates forecasts of total regional population and employment among traffic analysis zones. Employment for a given forecast year is allocated to a given zone on the basis of historical levels of employment and population in that zone, total land area in the zone and the accessibility of that zone from other zones where people live. Population is allocated to a given zone based on its historical population, forecast employment level, amount of residential land, vacant developable land and the accessibility of that zone to other zones where people work.

Use of an integrated land use/transportation model allows for a linkage between the locations of activities and transportation system accessibility. Land use models used alone ignore the effects of spatial activity allocation on the transportation system. Transportation models used alone ignore the effects of transportation systems on the spatial allocation of activities.

Trip Generation

The trip generation model takes the allocated population and employment from the land use allocation model and translates that to trips into and out of each zone. It does so for several different trip purposes (work, school, shopping, social, personal business). This is an extremely important step because it yields the basic number of trips in the regional transportation system. Subsequent steps simply allocate those trips spatially, modally and temporally. Completely new trip generation equations were developed in the model update process.

Trip Distribution

Trip distribution spatially allocates the trips generated in the previous step. Trip generation deals solely with how many trips begin or end in a given zone, without reference to where the other ends of those trips are located. Distribution links trips among zones: it deals with where all trips begin and end. Trips that start in a given zone are forecast to end in another given zone as a function of how far apart the two zones are from each other and how many trips each zone generates in total. The longer the travel time between two zones, the fewer trips will flow between them, all other things being equal. On the other hand, the more total trips a zone generates, relative to all zones, the greater the "pull" it will have on a given origin zone; hence, the more of that origin zone's trips it will attract to itself. Distribution results in a matrix of trips among zone's for each trip purpose. This model was modified somewhat in the update process, but its basic structure remained unchanged from previous model versions.

Mode Split

In the mode split (or mode choice) step, the matrices of trips by purpose output from distribution are allocated to competing travel modes. The model that does this considers the times and costs associated with the competing modes and certain characteristics (e.g., auto ownership, forecast with one of the sub-models in the model process) of the travelers being modeled. Work trips are split among the transit, drive alone, 2-person carpool and 3-or-more person carpool modes. Non-work trips are just split between transit and automobile, irrespective of automobile occupancy. This model is critically important for the PMT because it predicts shifts from the auto to the transit mode that could be expected to occur as a result of implementing various transit projects. The model update process resulted in a brand-new work trip mode choice model.

Trip Assignment

The final step in the model process is trip assignment. In this step, the trips split by mode from the previous step are assigned to the appropriate computerized networks in order to predict which routes those trips will choose in the highway and transit networks. It is from this step that we produce statistics such as regional vehicle-miles-traveled, vehicle-hours-traveled and average operating speed. From this procedure, we also produce predicted traffic volumes along specific roadways and transit ridership on specific lines. Trip assignment procedures were modified in the model update process.

Also output from trip assignment are highway travel times under congested conditions and transit travel times. These are combined and input back into the land use model in order to forecast how transportation system accessibility, measured by travel times, might lead to a reallocation of population and employment. These times are also input back into the trip distribution and mode choice steps as well, and for any given model scenario, those steps and trip assignment are run through a second or even third time in order to reach a rough equilibrium state among all steps of the land use/transportation model set.

After the travel models are run, regional air pollution emissions can be calculated. This is done by combining information from Environmental Protection Agency (EPA)-approved emissions models with the results from the trip assignment procedures.

Future Model Development

As stated previously, development of the travel demand model for the Boston region is not complete. The model used for the Transportation Plan is termed "interim"; a final model will be available in 1994. It will differ from the interim model in three broad respects. First, CTPS will have completely redone certain steps in the model that, for now, have simply been modified or left alone. The trip distribution model will, for instance, probably be completely reformulated to make it responsive to travel cost as well as to time.

Second, CTPS will have collected and used additional data to refine the model further. This will, for example, include some survey work to obtain information on unique trip generators such as sports complexes and military installations. Trips to and from these kinds of facilities are not well represented in the standard model process described above. Getting better information about them will enhance the accuracy of the forecasts.

Finally, by next year, CTPS will have tied the individual model steps together more tightly and calibrated the entire land use/transportation model set more precisely. At present, the land use allocation model, being brand-new in the process, does not yield results as satisfactory as will be required in the future. The trip assignments must be further refined in order to enhance their accuracy at the level of individual roadways and transit lines.

Update of 2010 Forecasts to 2020

As mentioned earlier, the 2020 Person Triptable (resulting from Trip Distribution step) used in the Interim Regional Model was developed using more recent population and employment forecasts produced by the MAPC. These forecasts indicate that the growth in downtown employment would be only eight percent from 1992 to 2020 and that regional employment would grow by about 15 percent during the same period. The population for the entire region was assumed to grow at an average rate of 1.7 percent. However, some cities were expected to grow more rapidly than the others. The percentage growth assumed for each city in the Interim Model differs significantly from what was assumed in the 2010 model.

Though the recently forecasted employment growth for downtown Boston between 1992 and 2020 is much less than had been previously projected, the total number of trips entering the CBD in 2020 is projected to be only slightly less than with the previous 2010 projections. This is largely a result of a more sophisticated method being used for the 2020 triptable than had previously been used for the 2010 triptable. The 2010 triptable was developed by factoring 1987 triptable based on projected employment and population growth, with the total number of trips and their distribution dependent on the 1987 triptable. As a result, in the development of 2010 triptable, the proportion of downtown bound trips for different trip purposes was assumed to stay the same between 1987 and 2010. The 2020 triptable was developed independent of prior trip tables, used better trip generation models, and was based on more recent population and employment projections. The implied trip generation rates and the proportion of non-work trips destined to downtown Boston in the new model set are slightly higher than the old models.

Method Used to Update PMT Ridership Forecasts

The differences between the 2020 ridership projections and 2010 projections are largely due to the differences between the 2020 and 2010 triptables. Within the amount of time available for the PMT update, it was not possible to rerun all of the PMT alternatives using the 2020 triptable. Instead, a simpler yet technically sound method involving rerunning a sample of projects was used to develop a set of factors that was then applied to other alternatives. This method consisted of the following steps.

- Determine changes in travel to the core area from each corridor.
- Group similar transit projects.
- Select representative projects by category and geographical area.
- Rerun the entire model for the representative projects using the new 2020 triptable.
- Compare the 2020 ridership results with the previous 2010 estimates and calculate the percentage difference.
- Apply the appropriate factor to the 2010 ridership estimates of all the other projects within the same category and geographical area to obtain the year 2020 estimates.

To determine changes in travel by corridor and transit mode, the base case alternative was rerun using the new 2020 triptable. Transit trips were aggregated by corridor and transit sub-mode. These results were compared to the base case estimates for the year 2010. This comparison highlighted several differences in the way trips will be geographically distributed from the outer suburbs to downtown Boston between the two horizon years, 2010 and 2020 (see Table E-1).

Table E-1
Projected Trips to Boston Central Business District

From	2010 Projections	2020 Projections	Difference Factor
North Shore	42,780	67,030	1.56
North	72,840	78,450	1.08
Northwest	74,880	77,580	1.04
West	107,050	100,350	0.94
Southwest	49,960	39,850	0.80
South Shore	137,770	85,590	0.62
CBD	46,090	72,770	1.57
Total	**531,370**	**521,620**	

In general, regardless of mode, the 2020 projections indicate that there will be more trips from northern suburbs to Boston proper than had previously been projected for 2010. However, from the southern suburbs, there will be fewer trips to Boston proper in 2020 than had been previously estimated for 2010. Although the southern suburbs are expected to experience a higher employment and population growth than the rest of the region, a high proportion of the new trips generated in this area will be attracted by the employment and retail centers within the same areas. As a result, a lower proportion of the new trips from the south will be made to the core area.

The distribution of transit trips also differed by mode. To take this into account, the PMT alternatives were broadly grouped under nine categories, and several representative projects from each category were rerun using 2020 inputs. The nine categories were:

- Commuter rail extensions
- Rapid transit extensions
- Improved run times on commuter rail lines
- New commuter rail stations
- New express bus services
- Circumferential transit service
- Ferry services
- Logan airport related improvements
- Parking expansions

Based on the 2020 results for the sample projects that were rerun, update factors were developed for different combinations of transit mode and geographical area. These factors, which are shown below, were then applied to the 2010 estimates for projects that were not rerun.

Transit Service	Update Factor
Green Line extensions	1.13
Red Line north-related projects	1.20
Red Line south-related projects	0.70
Blue Line-related projects	1.50
New MBTA bus options	1.15
Route 128 circumferential bus	0.90
MBTA express bus improvements	0.95
All Parking expansion-related	0.90
All Ferry-related projects	0.95
Blue-Red connector	1.13
All Logan-related improvements	1.13
Inner Circumferential Transit	1.25
Orange line extension, south	0.86

Appendix H
Air Quality Methodology

Air quality impacts of transportation related projects are based on two components: emission rates and vehicle miles traveled (VMT). Emission rates are estimated using Environmental Protection Agency software called Mobile5A; VMT estimates are an output of the regional model described in Appendix E. This appendix describes the way these factors are developed and how they have been used for air quality analysis of PMT projects.

Major Components of Vehicle Emissions

Vehicle emissions are made up of both exhaust emissions and evaporative emissions (see Figure H-1). Exhaust emission is the by-product of burning gasoline or diesel fuel, and is dependent on operating mode (hot start, cold start, stabilized), the speed at which the engine is running, and the air temperature.

Figure H-1
Emission Components

Emission Component	Primarily a Function of...
Exhaust	Operating mode, speed, and air temperature.
Running Evaporative	Engine temperature, running time.
Resting Evaporative	Age of auto, condition of seals and gaskets.
Refueling Evaporative	Vapor recovery systems and programs.
All Evaporative	Air temperature, and fuel volatility

Evaporative emissions occur when the car is running, resting, and refueling. The amount of running evaporative emissions is a function of the temperature of the engine, which in turn depends on how long the car has been running. The amount of resting evaporative emission is dependent on the age of the car and condition of various seals and gaskets. Refueling emissions are controlled by vapor recovery devices used at filling stations. All evaporative emissions are also dependent on the volatility of the fuel and ambient temperature. The only pollutants in evaporative emission are volatile organic compounds (VOCs). The evaporative and exhaust emissions are combined into "emissions factors" or emission rates that are used in calculating changes in emission burden.

Transit projects that reduce VMT reduce vehicle emissions. Because exhaust emissions are dependent on speed and operating mode, and running evaporative emissions are dependent on length of trip (in time), *all VMT are not equal* with respect to emissions. The rate of exhaust emissions are higher at slower speeds and when the car is operating in cold start mode. Running loss evaporative rates are lower on short trips than they are on long trips. As the engine heats up there is more evaporative loss from the fuel tank, fuel lines, and engine.

Air Quality Analysis for PMT Projects

The PMT air quality analyses involved the use of average emission rates per vehicle miles of travel. As a result, the stated impacts do not fully consider the different emissions rates of each operating mode. However, as described below, the results are valid at the sketch planning level of detail used for the PMT and do provide for valid comparisons between projects.

Impact of Cold Starts

Transit trips that involve automobile access provide lesser air quality benefit than those which entirely involve transit and walking. All or much of the automobile access portion of the trip is in cold start mode; as a result, emission rates for these trips are higher than "normal."

The magnitude of the difference can be seen by comparing emission rates for drive access trips with emission rates for normal (Federal Test Procedure)[1] trips. As described above, Volatile Organic Compounds (VOCs) emission rates from transit drive access trips are higher than normal emission rates due to the fact that the vehicle is operating in cold start mode for most or all of the trip. However, this effect is partly mitigated because drive access trips are shorter than "normal" trips and therefore produce less running loss evaporative VOCs emission per mile. The combined effect of these two factors results in VOC factors that are on average 24 percent higher for transit access trips than "normal" factors.[2]

Because there are no running evaporative emissions associated with NOx and CO, the trip length has no effect on the emissions rate, and thus only operating mode (cold start, hot start, or stabilized) affects the emission factors. Cold start NOx rates are on average 25 percent higher, and CO rates are 143 percent higher for transit access trips than normal emission rates.

Rates of emissions should not be confused with emission reductions. The effect that these higher drive access emission rates have on the reductions of a specific project is completely dependent on the length of the transit trip.

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[1] Federal Test Procedures are a set of standard default values used in Mobile5A. Many FTP values can be adjusted for more specific analysis.

[2] Differences are based on Mobile5A factors for light duty gas vehicles in 1993. They assume a worst case scenario where the whole drive access trip would be in cold start mode. In addition, the VOC analysis assumes that the transit access trip is less than ten minutes.

Examples

Two examples shown below illustrate the impact that automobile access can have on short and long transit trips. For short transit trips, the emissions from an average drive access trip could significantly reduce any emission reduction due to new transit riders; for longer transit trips, the drive access emissions are small compared to the emission reduction due to the elimination of the corresponding auto trip.

Short Trip

A short walk-access transit trip that eliminates 7 miles of automobile travel would save 12.6 grams of VOC from being emitted:[3]

100% Auto Trip = 7 VMT * 1.8 grams of VOC per mile = 12.6 grams of VOC

100% Transit Trip = 0 grams of VOC

Reduction = 12.6 grams of VOC

If the transit trip includes a 3.75 mile automobile access trip, it would produce 10.9 grams of VOC, thereby reducing the savings to 1.7 grams, and negating most of the air quality benefit:

100% Auto Trip = 7 VMT * 1.8 grams of VOC per mile = 12.6 grams of VOC

Auto Access Trip = 3.75 miles * 2.91 grams of VOC per mile = 10.9 grams of VOC
Transit Trip = 0 grams of VOC
Total = 10.9 grams of VOC

Reduction = 1.7 grams of VOC

Long Trip

A long walk-access transit trip that reduced VMT by 25 miles would save 45.0 grams of VOC from being emitted:

100% Auto Trip = 25 VMT * 1.8 grams of VOC per mile = 45.0 grams of VOC

100% Transit Trip = 0 grams of VOC

Reduction = 45.0 grams of VOC

If the long transit trip includes a 3.75 mile automobile access trip, it would produce the same 10.9 grams of VOC as the auto access to the short trip. However, in this case, the transit trip would still provide significant air quality benefits—a reduction of 34.1 grams:

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[3] The calculations of emission assume an average speed of 35 miles per hour for the 1.8 grams/mile factor used for transit trip savings, and 24 miles per hour for the 2.91 grams/mile factor used in the calculation of drive access emissions. The drive access distance is an estimate of regional average distance driven to park and ride lots.

100% Auto Trip = 25 VMT * 1.8 grams of VOC per mile = 45.0 grams of VOC

Auto Access Trip = 3.75 miles * 2.91 grams of VOC per mile = 10.9 grams of VOC
Transit Trip = 0 grams of VOC
Total = 10.9 grams of VOC

Reduction = 34.1 grams of VOC

PMT alternatives were designed so that only relatively long trips would have parking facilities. With a few exceptions—express bus parking and the expansion of existing parking facilities at rapid transit stations—new parking facilities would be located along Route 128 or beyond. Therefore, while some of the emission reduction figures may be somewhat overstated, there are not any cases where automobile access to transit would negate the air quality benefits of the transit trip.

APPENDIX X

LIST OF INTERVIEWS

Interview Label	Person and/or Agency Interviewed
Interview No. 1	Donald O'Cooke from the Boston EPA office, July 14, 1995.
Interview No. 2	Erika Vandenbrande of the Southern California Association of Governments (SCAG), July 18, 1995.
Interview No. 3	Rob Ireson of SAI in the San Francisco Bay Area, July 19, 1995.
Interview No. 4	Kendra Morries of the Los Angeles Metropolitan Transportation Authority (LAMTA), July 19, 1995.
Interview No. 5	Gerry Everett in FHWA's Washington, D.C. office, July 20, 1995.
Interview No. 6	Jackie Lentz of the Houston MPO, July 20, 1995.
Interview No. 7	Paul Davies of the San Diego Air Pollution Control District, July 20, 1995.
Interview No. 8	Nick Roach of the Puget Sounds Regional Council (i.e. Seattle region), July 21, 1995.
Interview No. 9	Jack Henneman of COMSIS, July 24, 1995.
Interview No. 10	Michael Burbank of the North Central Texas Council of Governments (i.e. Dallas-Fort Worth region) , August 3, 1995.
Interview No. 11	Victoria Eisen of the San Francisco Bay Area's Metropolitan Transportation Commission (MTC), September 21, 1995.
Boston Interview No. 1	David J. Mohler and Anne S. McGaham of CTPS on 9-14-95.
Boston Interview No. 2	Chris Skelly of MAPC on 9-14-95.
Boston Interview No. 3	Kreig Leiner of the CTPS
Boston Interview No. 4	Dan Fortier of the MAPC
Other Interviews	Individuals from COMSIS Corporation, JHK & Associates, and Systems Applications International.

APPENDIX Y

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Boston No. 10	Xerox from Commuting in a New Century: the New Program for Mass Transportation, Executive Summary, prepared by EOTC, MBTA, CTPS, and others, approved by MBTA Advisory Board on March 1, 1994.

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