AN APPLICATION OF MULTICRITERIA EVALUATION

METHODOLOGIES TO AUTO RESTRICTED ZONE POLICIES

by

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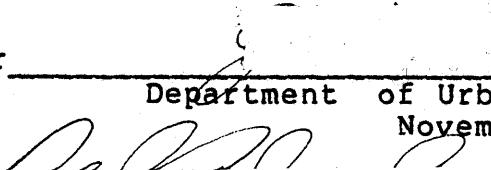Requirements for the
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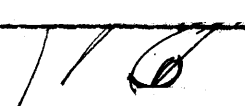DOCTOR OF PHILOSOPHY

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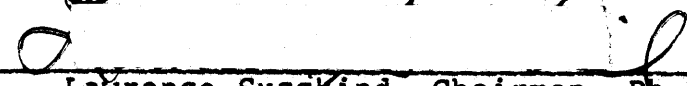© Massachusetts Institute of Technology 1983

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ABSTRACT

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This thesis applies the three multicriteria evlaution methods
- Concordance   Analysis,   Goal-Achievement-Matrix   and
Compromise Solution - to auto restricted zone policies. This
thesis has two major objectives: (1) to discuss the concept
and practice of the auto restricted zone policies in general
and the rationale behind restricting auto traffic in central
cities both in developed and developing countries; (2) to
compare the three multiciteria evaluation methods through the
application to auto restricted zone(ARZ) policies   in
specified case in order to assess their usefulnesses and
limitations.

        In the first part of the thesis, the concept and
        types of ARZ policies are examined, along with the
        experience with ARZs of the U.S., West Europe and
        developing countries. The discussion also relates
        to the objectives and relevant ARZ   schemes.
        Generally, the desirability of closing off streets
        or   areas   is   determined by   the   underlying
        characteristics of a specific urban areas.   The
        objectives and ARZs are distinct for .different
        types   of   areas.   The major reasons of the
        differences seem to be because each region has
        different perceptions and attitudes toward   the
        transportation problems themselves. Thus decision
        making for ARZ selection is different.   The key
        factor is that each of the cities has different
        goals which greatly affect the ARZ objectives.

        In   the   second   part   of   the   thesis,   the
        characteristics of transportation systems in Seoul,
        Korea are presented.   Seven feasible ARZ policies
        and twelve criteria are selected through interviews
        and ranking techniques. For selected ARZs and
        criteria, the implementation of the three methods
        is performed.   The results of the implementation

show that the three methods are very effective in applying to Transporation System Management types of strategies. The area license schemes turn out to be the most preferred ARZ polies by the methods examined.

The third and final part of the thesis assesses the three multicriteria evaluation methods in terms of several criteria. The criteria seen as essential in the assessment of these methods include computational burden, degree of interaction with the decision maker, ease of sensitivity tests, real-world applicability and applicability to developing countries. The comparison receals that the results obtained from the three methds are similar but they differ in general in terms of criteria described. The three methods have counterbalancing strengths and weaknesses.

Thesis Supervisor: Ralph Gakenheimer
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CHAPTER I: INTRODUCTION

1. Objectives of the Thesis

This thesis has two major objectives: (1) to discuss the
concept and practice of the auto restricted zone policies in
general and the rationale behind restricting automobile
traffic in central cities both in developed and developing
countries; (2) to compare the three multicriteria evaluation
methods through the application to auto restricted zone
policies in specified case in order to assess their
usefulnesses and limitations.

2. Auto Restricted Zone(ARZ) Schemes

The increasing attention being paid to the automobile
restriction in central cities is a relatively recent develop-
ment in the evolution of conceptual thought in urban
transportation planning. The point of departure for this
development was characterized by an approach which assumed
that automobile restriction would, by itself, eventually
improve the traffic conditions of the urban areas.

There   has been a growing application of the   auto

restricted zone policies in central cities of developed and developing countries. The increasing interest in restricting auto traffic within the city center is mainly fostered by the deteriorating environmental quality in urban areas. The concept has been most significantly advanced in European cities. Over 130 European citeis have implemented a large variety of ARZ policies to reduce congestion and negative effects on the environment. The application of this concept to U.S. cities appears limited in scope. The pedestrian malls which have been built during the last two decades represent a typical ARZ scemes. At present, more than 70 U.S. cities of varying size have instituted some form of auto restriction. Experience in developing countries has been more limited in scope. The Singapore area license scheme is the only well-document case in the context of developing countries. It is, however, fair to say that various types of ARZ schemes may exist in major cities in developing countries.

Despite the growing interest and application, there is still considerable controversy regarding what apporpriate area restricted zone schemes are appropriate in a given urban environment and what they might accomplish. Thus it seems appropriate to address several issues regarding the ARZ schemes. The issues to be addressed in this thesis are as follows:

(1) The first issue to be addressed is with regard to the kinds of ARZ schemes. The schemes available for restricting automobile traffic are numerous and may be applied to whole

ranges of different urban sizes and transportation situations. It seems, therefore, necessary to explore ARZ schemes by classifying them according to the degree of restriction and types of measure exerted by different strategies.

(2) The second issue to be addressed regards the objectives of restricting auto traffic in central cities in both developed and developing countries. The objectives of ARZs vary in intensity from one city to another, depending upon individual circumstances and are tailored to to the specific urban areas. The relationship between the objectives and the ARZ schemes, therefore, deserves an examination.

(3) The third issue to be addressed concerns with the relevant ARZ schemes and their associate techniques by the types of city and region. Question can be raised as to what the relevant ARZ schemes are in central cities of both developed and developed countries and what kinds of supportive techniques are appropriate for these regions.

3.Multicritertia Evaluation Methods

The transportation facilities result in multiplicity and sometimes unidentified arrays of consequences as the transportation facilities cut accross the many parts of the socio-economic and environmental systems. In recognition of

the need to acount for social, economic and environmental factors, transportation planners and analysts have devoted much effort to improving the evaluation methodology. Although some progress has been made in the development and refinement of evaluation methods for dealing with social, economic and environmental factors, a common feature of the transportation analyses is that the evaluation is mostly based on a single criteria - economic efficiency.

Traditionally, most transportation evaluation has centered around criterion such as travel time saving and cost minimization. Criteria other than above-considerations have been largely overlooked as important decision criteria. There seems to be three reasons for this tradition. First, there is a lack of a conceptual or theoretical evaluation framework which is suitable for the transportation systems involving multicriteria. Secondly, criteria other than travel time or investment cost were considered less important. This was true for both transportation analysts and decision makers. Lastly, it was difficult to get the information on various criteria.

The multicriteria evaluation methods are generally designed to accomodate the social, economic and environmental factors. Although some of the criteria are not measurable in an "absolute" sense, the very fact that multidimensional factors are entering the evaluation process through quantitative and qualitative analysis reflects the attraction of these methods. The insight provided by the multicriteria

evaluation methods can also lead to a better communication between the analyst and the decision maker, thus allowing the decision maker a more active and understanding role in the decision making process.

The emergence of multicriteria concerns in the transportation field has its root in the observation of multiple impacts of transportation systems. The attempt to incorportate multicriteria into an evaluation framework was a response to the widespread use of conventional cost-benefit analysis in transportation project evaluation. There has been a growing recognition of the inadequacies of conventional cost-benefit analysis in capturing the full range of social values that are relevant in transportation decision making. Academicians and decision makers alike have pointed to the need to consider intangibles such as social, economic and environmental concerns in choosing from a given set of alternatives.

Despite the relative lack of attention, several writers have advanced and applied multicriteria evaluation methods to transportation situations. There have been several worthwhile contributions to the rationalization of the multicriteria concern in conjuction with evaluaiton and decision making.

An early suggestion regarding the need for a broad framework for evaluation was made by Lang and Wohl (1960). They essentially stressed the need for a more rigorous definition of "impact", suggesting a classification into four

types - economic, social, aesthetic and political.

Faced with the need for incorporating multidimensional concerns, Manheim (1967) has contributed a set of considerations which clearly delineate the task of the transportation systems analyst. The considerations are contained in nine elements called "The Principles of Transportation Sytems Analysis". The major significance of the principles for evaluation is the oderly, explicit presentation of those elements which the analysts must consider in developing the information necessary for the definition and evalaution of alternative systems and their effects.

Manheim (1969) further points out that transportation choices can be described as essentially socio-political choices where differing interests of the various groups are considered and balanced. The inclusion of socio-political choices appears to represent a clear advance over conventional models (or methods) in its abandonment of the search for only single dimensional choice.

In a similar vein, widespread fuzziness about what the goals of transportation systems should be has created controversy, particularly in urban areas where public interests or value systems often conflict. In response to this, Hill (1967) has created a framework in which a great number of goals for transport systems can be listed and their relationships specified. This work provided a basis for developing the concept of the Goals-Achievements Matrix to be

evaluated latter in this thesis.

The multicriteria evaluation method was developed in explicit form largely through the work of Morris Hill (1973) and applied to a transportation plan in Cambridge, England. Later, Manheim (1979) made an attemt to apply the multicriteria evalaution method called "impact tableau" to the effects of alternative alignment for the Los Angeles freeeways. Rietveld (1978) applied interactive programming methods to the rerouting of commuter traffic. Using integer programming, the subjective and provisional nature of the objective function is fully recognized in the method, which calls for an interactive exchange in which constraints and preferences are gradually defined. Friezs and others (1980) proposed a constraint method, which is generally attributed to Marglin (1967), and the interactive preference-incorproated method of Zions and Wallenius (1976). They applied these methods to hypothetical rural transportation projects.

The broadened objectives are an attempt not only to assist decision makers in evaluating alternative transportation projects but also to educate the affected public regarding the various effects associated with transportation facilities. Perhaps the most important result of a broader range of considerations is the explicit recognition of the interrelationships between transportation and other facts of life.

Despite several contributions to multicriteria considera-

tions in the trnasportation field, little attempt has been made either to improve multicriteria evaluation methods available in the transportation field and other fields or to empirically test these methods in the context of transportation projects.

The three methods chosen for this research include the Concordance Analysis, the Goal-Achievement Matrix and the Compromise Solution. They are generally capable of encompassing multiciteria problems. Strengths of these methods lie in their ability to use many measures of costs and benefits usually excluded from conventional economic analysis. By reflecting social, economic and environmental factors that are not easily quantifiable, the use of the methods can provide adequate justification for transportation projects not defendable previously by economic analysis alone.

With the background of deficiencies in conventional evaluation methods and because of the scant attention being paid to multicriteria evalaution methods in the transportation field, the particular issues to be addressed in the latter part of the thesis are as follows:

(1) The first issue to be addressed regards the manner in which ARZ schemes are currently evalauted. Such evaluation It can provide a basis for not only assessing the advantages and limitations of conventional methods but also for examining the extent to which multicriteria (or multiobjective) are taken into account in current assessment

of transportation plans.

(2) The second issue to be addresed regards the way in which qualitative criteria are handled. How are the weights for qualitative criteria obtained?

(3) The third issue to be addressed concerns whether information on criteria and ARZ alternatives are sufficient and adequate for implementing the three methods - Concordance Analysis, Goal-Achievement-Matrix and Compromise Solution. This issue can be addressed by examining the process and results of an empirical analysis. This serves a basis for whether the three methods are successfully applicable to such transportation systems management strategies as ARZ schemes.

(4) The fourth issue to be addressed is concerned with the best ARZ policies in the context of Seoul. The best policies are to be chosen by each of these methods examined. A related issue concerns with whether the best ARZ policies selected by the three methods turn out to be same or different.

(5) The final issue to be addressed regards the major usefulnesses and limitations inherent in the three methods in terms of several criteria. The criteria seen as essential for assessing these methods include: computational burden, degree of interaction with the decision maker, ease of sensitivity tests, real-world applicability and applicability to developing countries.

4.Organization of the Research

Chapter I introduces the objectives of the thesis and briefly discusses the auto restricted zone policies and multiciteria evaluation methods in the transportation field. Chapter I also presents the·organization of the thesis.

Chapter II begins with a discussion of auto restricted zone in general: the philosophical rationale behind restricting automobile traffic in central cities, a cursory examination of ARZ application in the U.S., Europe and cities in developing countries, and a taxamony of these and other examples. This discussion continues with a comparison of the objectives and underlying characteristics of ARZ application between developed and developing countries. Relevant ARZ schemes with regard to deveoped and developing countries are explored.

Chapter III examines conventional evaluation methods usually applied to transportation projects. These include: cost-benefit analysis, impact analysis and weighting technique. These evaluation methods are discussed, along with their drawbacks and usefulnesses. Posing the problems associated with these approaches directs attention to alternative methods. This is followed by the review of the multicriteria evaluation methods with reference to transportation plans or projects. The attempt is made to discuss the multicriteria evaluation methods as well as an

empirical application of these methods to transportation cases.

Chapter IV begins with the description of the central business district in Seoul and describes the characteristics of the transportation systems with an emphasis on mode shares and trip patterns in Seoul.

In Chapter V, feasible auto restricted zone schemes are described. Discussion is also made of twelve criteria relevant to feasible ARZ schemes. The development of feasible ARZ alternatives and criteria is built upon the Chapter II where relevant ARZ schemes and objectives are described in detail.

Chapter VI begins with a discussion of the underlying theoretical structure of the three methods - Concordance Analysis, Goal-Achievment Matrix and Compromise Solution - and conducts an empirical analysis of the three methods using the information on criteria and alternatives. This chapter also discusses the results of the empirical analysis and its findings.

Chapter VII assesses the usefulnesses and limitations of the three methods in terms of several criteria. The criteria to be considered include: computational burden, degree of interaction with the decision maker, ease of sensitivity tests, real-world applicability and applicability to developing countries.

Chapter VIII summarizes the thesis and presents a conclusion. This chapter also suggests directions for

further research.

CHAPTER II: AUTO RESTRICTED ZONE (ARZ)

1. Introduction

This chapter presents the concept and types of auto restricted zone (ARZ) schemes. It also examines the experience with ARZs of the U.S., Europe and developing countries. The discussion also relates·the objectives and ARZ schemes in these regions. The appropriate ARZ schemes with respect to each region are presented. This chapter provides a basis for developing the feasible ARZ schemes and criteria for Seoul, Korea, in Chapter V. The feasible ARZs and criteria formulated for Seoul's CBD serve as a vehicle for conducting an empirical analysis in Chapter VI. The Appendix to Chapter II gives a detailed description of the characteristics of widely-used ARZ schemes.

The increasing attention being devoted to the auto restriction is a relatively recent development in the evolution of conceptual thought in urban transportation planning. The point of departure for this development was characterized by an approach which assumed that auto restriction could, by itself, eventually improve the traffic

conditions of the urban areas. Despite the growing interest, there is still considerable controversy regarding what the appropriate area restricted zone schemes are in a given urban areas and what they might accomplish.

A review of the literature and experience with ARZ schemes shows a wide variation of concepts and applications (Herald, ed., 1977; Thomson, 1972; Koffman and Edminster, 1977; Loudon, Pecknold and Kern, 1979; Thomson, 1977; Gomez-Ibanez, 1980; Heaton and Goodman, 1980). The increasing interest in restricting auto traffic within the city center is mainly fostered by the deteriorating environmental quality in urban areas, especially central business distrcits.

In developed countries, it is probably fair to say that the interest in the ARZ schemes which developed in the late 1960's was generated by the recognition that the private automobile is the primary source of traffic congestion in the city center. The interest in this concept was heightened in the mid-1970's by growing concerns regarding energy consumption, air pollution, and mobility needs of persons without access to automobiles.

This concept has been most significantly advanced in European cities. Over 130 European cities have implemented a large variety of auto restricted zone schemes to reduce congestion and negative effects on environment. Various types of traffic restriction schemes are quite common and

successful throughout the European countries.

In contrast to European cities, the application of this concept to U.S. cities has been on a limited scale. Most of the U.S. experience is centered around the closure of the downtown shopping street and its conversion to a pedestrian zone with a high degree of emphasis on the urban design element. Some of the reasons for the current ARZ interest in American cities stem from the energy crisis, air pollution and continued deterioration of the economic base of cities. Also of importance has been an interest in giving public transit an operational advantage in central business districts and the current Federal policy of encouraging transportation system managerment (TSM) actions. In effect, successful implementation of ARZ schemes in European countries has awakened widespread interest and acceptance both in the context of American cities and major cities in developing countries.

2. The Kinds of ARZ Schemes

The schemes available for restricting automobile traffic are numerous and may be applied to whole ranges of different urban sizes and transportation situations. Many such schemes

represent time-worn ideas such as one-way streets or turn prohibitions and assignment of a price for parking. Other methods represent more radical or innovative ideas such as area license schemes, as yet seldom attempted. Because of the great variety of appicability and effect of similar ARZ strategies, it seems appropriate to begin the discussion of such strategies by classifying them according to the degree of restriction and types of measure exerted by different strategies.

ARZ classifications are usually based on the general restriction pattern. The first type of categorization is credited to Thomson(1974) who identifies three sets of automobile restriction methods in central cities:

1. **traffic restriction**, in which people are prevented by physical and/or legal means from fulfilling certain travel desires;

2. **traffic restraint**, under which people are discouraged, but not prevented from fulfilling such desires;

3. **traffic avoidance**, in which actions are taken which serves to preclude the development of travel desires in the first place.

The second type of categorization covers a broad range of measures. This classification of ARZ schemes is based on the nature of the traffic restriction. Wagner and Gilbert(1979) identify four groups of restriction methods:

1. physical measures, which utilize the design, location and capacity of facilities to control traffic;

2. operational measures, which utilize signs, signals, or mechanical devices to control traffic;

3. regulatory measures, which utilize enforcement of regulations to control traffic;

4. economic measures, which utilize monetary disincentives as tools to control traffic.

Table II.1 shows the variety of techniques relevant for each ARZ scheme. Some of the techniques listed in Table II.1 play a supplementary role for ARZ schemes.

Table II-1   ARZ Schemes

Physical Measures	Regulatory Measures
Street closing	Area permit
Street barricade	Loading/unloading
Low design speed	Parking restriction
Cul-de-sac	Vehicular regulation
Placement of parking lot	Staggered work hours
Number of parking space	Land use regulation
Ring road/bypass	Regulation of ownership
Operational Measures	**Economic Measures**
Signalization system	Area license
Ramp metering	Parking price/tax
Variable route signing	Toll
Turn restriction	Congestion pricing
Special use lane/street	Full tax
One-way street	Gas rationing

Source: Wagner and Gilbert(1979)

In addition to these categorizations, the characteristics of widely-used ARZ schemes are discussed under the following headings in Appendix to Chapter II:

1. concept
2. mechanism
3. variations
4. possible changes in commuter travel
5. side effects
6. factors which may influence success

.

3. Traffic Restriction Experience

a. European Experience

Generally speaking, the development of ARZs has its roots in the fact that most European cities underwent a similar development pattern and therefore were experiencing similar environmental and traffic problems. Throughout Europe, the transition from the the old to the modern city has been characterized by the built-up areas first reaching and then spilling outside. Cities became organized around a system of radial routes convering on the center.

The growing congestion in the city center caused by rapid urbanization reached the point where remedial action was unquestionably necessary. Controls, such as one-way streets and restricted parking, were introduced. But these strategies proved only partially effective. Thus more comprehensive auto restriction actions emerged along with the above-mentioned strategies. The trend gained momentum, and by the late 1970's, nearly every major city had banned cars from significant portions of its historic central district and retail areas.

The ARZ scheme was one of several actions trying to reduce congestion and conserve historic areas. The scheme most

widely-used to date has been that of cell-type restriction measures, generally for reasons which relate to reducing the congestion in the city center. Cell-type restrictin techniques have been employed in the center of Gothenberg, Besancon, Dijon, Bremen, Delft, and Groningen. Gothenberg's CBD was divided into five cells, with boundaries created by surface tramways. Similarly, four cells were created in Bremen, Groningen and Besancon. Copenhagen, Dijon, Delft and Upsala adapted essentially single-cell ARZ measures where such techniques as parking restriction, turn prohibition, bus street and pedestrian streets were included. In this way, these cities attempt to control automobile traffic and enhance the quality of the environment.

The experience with traffic cells indicates that they are relatively low cost and very efective in controlling traffic both in the city center and residential areas. In some situations total traffic volume may not be reduced and vehicle miles may be increased. While through traffic was reduced by 50 per cent in Besancon and 40 per cent in Gothenberg in the areas encompassed by the traffic cells, in most cases the total traffic volume for the entire central area has essentially remained constant or slightly increased. But in Besancon, Gothenberg as well as Geneva, the indications are that the redistributed traffic has resulted in both increased efficiency and improved operating

conditions and level of service for other modes (OECD, 1979).

The other type of ARZ scheme widely implemented is that of pedestrian streets (or pedestrian areas). More than a hundred city centers have implemented a pedestrian streets. The city centers where the pedestrian streets had been adapted are generally characterized by the congestion during the peak period or most of the day. The reasons advanced by European planners have ranged from strictly functional ones aiming at reducing congestion to humanistic ones aiming at protection of the environment in historical cores. The broad acceptance of pedestrian streets has been rooted primarily in addressing these reasons.

A rather unique type of ARZ scheme was developed in Nottingham, England. A system called "zone and collar" was implemented in Nottingham in connection with a new central plan focusing on one-way street networks designed to encourage through traffic. This scheme involved imposing time delays on private automobiles during the morning peak – essentially metering traffic passage with demand-responsive signals at two locations. Although intrazone circulating traffic was reduced 50 per cent, this scheme was abondoned in 1976 after eleven months because it failed to achieve a substantial modal shift from automobile to public transit.

b. American Experience

Experience in the U.S. appears limited in scope. The
pedestrian malls which have been built during the last two
decades represent a typical ARZ scheme. Increased concern
over traffic congestion and environmental improvement in the
1970s has fueled an explosion in pedestrian mall building.
The concept of pedestrian malls was originated from the need
to revitalize the downtown area as a commercial and activity
center. The urban renewal program provided an impetus for the
downtown shopping area to become more competitive with the
newer suburban shopping centers by offering much the same
convenience and attractiveness: pedestrian access to a
variety of business, unobstructed traffic and clean
surroundings.

At present, more than 70 U.S. cities of varying sizes have
instituted some form of automobile restriction (Loudon,1979).
As shown in Table II-2, the ARZ schemes most frequently
implemented have been the closure of the downtown shopping
street and its conversion to either a pedestrian mall or a
transit mall. Most of the malls constructed to date have been
quite modest in size compared with European examples. The
average U.S. mall is about three blocks; almost all are
single streets. The effort is generally to improve the

pedestrian movement on major streets with only a minimal effect on automobile traffic.

A different, yet similar, type of mall in America is the so-called "transitway" whose definition is given in Table II-2. Transitway is a compromise between a completly traffic-free zone and the need for shopper's transportation system on the mall. The transitway was generally motivated by the renewed interest in public transit in conjuction with the effort to revitalize the city center in the early 1970's. The Nicollect mall, Chestnut street transitway and Portland are typical of the transitway schemes developed in American cities. Transitways in several other cities are in either the planning or construction stage, notably in Madison, Chicago, St. Louis, Cleveland, Denver, and Brooklyn and New York.

Table II-2   American ARZ Schemes and Definitions

Pedestrian Shopping Mall (More than 70 cities)	This is usually developed in the core of retail and commercial area and structured to clear separation between traffic and pedestians.
Transitway (Nicollet mall, Chestnut street, Transitway in Philadelpia)	A street for which has been restricted largely to pedestrian use but retains road reservered for transit vehicles intergrated with the city-wide or regional transit system (Koffman,1977).

The effects of transitways have mostly been favorable. The best evidence of which is both the increasing number of cities instituting such schemes as well as the continuous expansion of ongoing schemes (or plans). In the Nicollet mall case, surveys of merchants reported that the predominant attitude was that the mall had been a good investment. Similar responses were observed at the Chestnut transitway. Accordingly, the transitway is judged to have been successful in accomplishing the goals of improving the commercial vitality and environmental quality of the area.

c. Experience in Developing Countries

Experience in developing countries has been more limited in scope. The Singapore Area License Scheme (ALS) is the only well-documented case in the context of developing countries. The Singapore ALS represents the first ever systematic attempt to use a road pricing policy to control downtown congestion in a major city. Thus it seems appropriate to discuss the experience of the Singapore ALS in terms of its characteristics and effects.

The primary motivation for the Singapore ALS has been to relieve the traffic congestion occuring during the peak hours. Under this scheme, which was put into effect in June 1975, vehicle entering the designated restricted zone during certain hours must purchase and display on their windshields a special area license. The boundary of the area is delineated so as to include zones with congestion problems but exclude two circumferential bypass routes for motorists with destinations beyond the zone.

Area license restrictions apply to all automobiles and passenger vehicles (including taxis) with capacities of 12 persons or less. Residents of the central area are exempt from the requirement, as are police, military and emergency vehicles. To provide an alternative for motorists destined

for the central area, a system of 19 fringe parking lots outside the restricted zone was implemented with shuttle bus service between the lots and the zone. Parking charges were also raised in the central area when the ALS was put into effect to provide added discouragement for automobile users.

The overall effect of the ALS seems to have been favorable. The government of Singapore set a goal of reducing the vehicular traffic entering the restricted area by at least 25 per cent and, at least by this criterion, the ALS has been success. The effect of the ALS on evening outbound traffic was disappointing, however, with little noticeable change in vehicular counts. Also congestion on the inner and outer ring roads also increased substantially because of diverted through-traffic.

While information on traffic restriction schemes in the context of developing countries is either nonexistent or a fairly recent development, it is fair to say that various types of ARZ schemes such as turn restrictions, one-way streets and parking restrcitions may exist in major cities in developing countries. In fact, cities like Lagos, Bogota, Teheran and Singapore, one-way streets are in abundance, with lane markings, parking restrictions and copious use of traffic signals (Thomson,1977).

Most Latin American cities have instituted pedestrian streets in their old city centers. For example, pedestrian

streets (or areas) were implemented in the city centers of Puerto La Cruz, Porlamar and Caracas. About 800 to 1000 meters of streets called Sabana Grande in Caracus and Jiron De La Union were colsed to vehicular traffic. Zones such as Ginza, Shinzuku and Asakusa in Tokyo were designated as an automobile-free zones in the early 1970's. Similar scheme can be found in the Myungdong area in Seoul where vehicular traffic is prohibited during the weekend. These ARZ schemes are aimed at relieving the congestion at the city center (informal survey conducted by auther in 1983).

The work of Migley and Watson(1981) shows that the city of Curitiba in Brazil regulates street parking in the city center through no parking areas, loading/unloading areas and restricted waiting areas. Similarly, parking charges were employed that increase with the number of hours parked in Recife in Brazil. The city of Recife has also introduced a number of pedestrian streets in the city center to make the city center less attractive to motorists and more attractive to pedestrians.

Apart from the widely-used ARZ schemes, odd-even plate numbers of automobile are used to relieve congestion in the city center in Lagos, Nigeria. Under this scheme, the automobiles with odd numbers are allowed to drive into the city center on three days per week (Monday, Wednesday and Friday) while the city center is closed for those automobiles

with even numbers on these days and vice versa. The same type of ARZ scheme is currently being implemented in Athens, Greek. In Mexico city, delivery vehicles are prohibited from operating in the city center from 6:00 a.m. to midnight (informal survey conducted by auther in 1983).

4. General Objectives and Related Issues of ARZ

Having discussed the ARZ experience in developed and developing countries, this section focuses on the definition of a set of generalized objectives and examines the relation of each of these objectives to various ARZ schemes. Clearly, different objectives will vary in intensity from one city to another, depending on individual circumstances and will be tailored to the specific urban areas.

Six general objective categories have been selected for discussion as a background to the comparison of motives, types and features of ARZ in developed and developing countries. These are:

    1.Reduction of congestion.
    2.Improvement of noise and visual quality.
    3.Reduction of conflict between pedestrian and auto.
    4.Enhancement of stability of economy and activity.
    5.Preservation of cultural attractiveness.
    6.Encouragement of transit usage.

The objectives, relevant ARZs and techniques are presented
in Table II-3. While a distinction between developed and
developing countries is not attempted in the table itself,
the classification is designed to focus on the context of
both developed and developing countries. One of the
difficulties commonly encountered in attempting to classify
the ARZ schemes and their associated techniques is that many
schemes and techniques are versatile and can be designed to
accomplish different objectives. This table provides a basis
for discussing the objectives, relevant ARZs and techniques
in detail.

a.Reduction of Congestion

This objective generally appears to be a fundamental
rationale behind instituting the ARZ schemes in developed and
developing countries. The objectives of reducing traffic
congestion is constrained by the need to maintain a high
level of assessibility to ARZ areas.

The major objective for cell-type traffic restrictions is
to reduce the traffic congestion generated by automobiles.
For example, The Gothenberg plan was developed to handle the
acute traffic congestion that developed in the CBD after
completion of two new cross-river links. Similarly, the
Nottingham case was based on a strong policy objective of

"balanced transportation" voiced by local political officials.

As discussed previously, most American experience was based on economic revitalization. Auto restriction by itself was not regarded as an objective. The immediate objective of the Singapore scheme was specified in terms of a reduction in the volume of traffic entering the central area in the morning, with such a reduction expected to achieve the more general objective of changing people's travel habits so as to prevent congestion from becoming a severe problem in the future.

As shown in Table II-3, the effective ARZs for achieving reduction-of-congestion objective appear to be area licensing, cell-type and street closing. Such techniques as one-way streets, turn restriction and Cul-de-sac are generally supportive means to these ARZ schemes.

b.Improvement of Environment (Air, Noise and Visual Quality)

Untill recently, the environmental objective has received less attention in transportation policy both in the U.S. and in Europe. By the 1970s, with the growth in the number of automobiles, their environmental effects had given rise to

protest everywhere except in developing countries. Air pollution had become the overriding concern for the American public whereas noise become the principal source of complaints in Europe. Generally speaking, the environmental objective sems to have received more attention in Europe While similar conditions can be observed in developing countries, developing countries generally believe that they cannot afford to pay particular attention to the environmental quality of their cities. This objective appears to be second order of priority.

In American cities, the environmental objective tends to be more directly addressable by the concept of ARZs than was the original objective of revitalization of the CBD as a retail center. In most of the recent ARZ plans in the U.S., the environmental objective is included. The inclusion of the environmental objective reflects the current philosophy of transportaiton policy in the U.S. cities with regard to ARZ schemes.

As to the effectiveness of ARZ schemes toward achieving the environmental objective, the cell-type of measures are likely to have only a limited effect on reducing environmental problems. Many techniques such as turn prohibitions, one-way streets and transitways are so localized in nature that their environmental improvement potential is even more narrowly confined to specific points

or streets.

By contrast, an ARZ scheme such as Singapore's ALS appears
to have a great potential for achieving this objective, since
it covers a wider area and induces a modal shift from auto to
other mode of transportation. It was reported that the
Singapore ALS has been successful in improving environmental
quality.

c. Reduction of Conflict between Pedestrian and Automobile

Improved pedestrian mobility has been regarded as a
separate objective unrelated to traditional transportion
policy. The fact that walk trips can be substitutes or
complements to vehicular trips has been largely neglected. In
American cities, the nature and magnitude of past
transportation investment has forced continued reliance on
the automobile, thereby neglecting pedestrian-oriented
transportation policy. Pedestrian mobility has received more
attention in European countries than in the U.S.

In most cases, the creation of pedestrian and shopping
malls in U.S. cities has resulted in increased pedestrian
volumes. For example, the volume of pedestrians on streets
within the Boston ARZ increased by 5 per cent overall on

weekdays and Saturday: weeknight pedestrian traffic increased by 17 per cent (NCHRP, 1981). Increased pedestrian volume is commonly associated with exclusive pedestrian areas or streets which enable pedestrians to travel throughout the CBD without the conflict with auto travel. This reduction of conflict between pedestrians and vehicles can result in improved travel speed for pedestrians since delays due to sidewalk crowding and traffic signals are the primary negative factors on walking speed.

In terms of ARZ scheme effectiveness, cell-type ARZs seem most likely to reduce conflict between pedestrians and vehicular traffic. This is particularly true in Europe where cities were originally designed on a scale to accomodate pedestrians and short vehicular trips, and their central areas still contain high proportion of residential commercial land uses which provide a favorable environment for walking trips.

In developing countries where the road system is strongly oriented toward the city center and where the road system for absorbing heavy traffic is inadequate, it is not hard to imagine that there shoud be frequent conflicts between pedestrians and vehicular traffic in the city center. Given the high pedestrian traffic in the city centers in these countries, some ARZ schemes which improve the pedestrian mobility are likely to be preferable to other transporation alternatives.

d. Enhancement of Economy and Activities in the City Center

While reducing traffic congestion is a principle objective of the ARZ, another important objective is to enhance the stability of the economy and activities in the city center. It is, however, naive to assume that the ARZ itself could accomplish this objective. The economic enhancement objective can, of course, be pursued in connection with broad urban development goals. Other contributing factors may include land use policies, public and private investment, metropolitan growth and urban renewal policies.

In terms of the effectiveness of ARZ schemes in achieving the enhanced economy objective, the pedestrian mall and transit mall bear some potential since these schemes were designed to increase retail sales by improving pedestrian mobility and rban design. These types of ARZs have been successful in reversing the decline of economic activity in the city center in American cities. The transit mall may be more effective in fulfilling this objective than pedestrian mall since public transit carries a large number of passengers, thereby increasing the potential patronage of the downtown retail core. The area must be, above all, the commercial center of particular city in order to sufficiently

achieve the economic enhancement objective.

With regard to European experience, ARZ schemes apear to be less often justified in terms of the economic enhancement objective although this objective is both explicitly and implicitly expressed in their ARZ development. European cities contrast sharply with American cities in terms of economic stability of the city center. While American cities have sufffered from the inevitable decline of their city centers, Europe's inner cities have shown a striking capacity to retain their attractiveness as commercial and cultural centers.

While the characteristics of the city center vary from one developing countries to another, the enhanced economy objective may be readily achievable in developing countries. The reasons seem to be because economic vitality through coexistence of variety of activities has always been maintained, either spontaneously or encouraged by deliberate government planning efforts. Where the city center space has been in excess demand, with a number of activities competing for space such as in developing countries, ARZ schemes such as pedestrian streets or traffic-free zone may be effective in achieving the economic enhancement objective.

Whether or not paratransit such as jitney or taxi should be allowed in the city centers in developing countries depend greatly on the specific local situations. Paratransit has

augmented the urban development process in the city center in some countries by improving access to local services. Also some economic activities rely heavily on the paratransit system. Thus elimination of this paratransit may undermine the economic activities of the city center.

Accessibility to the city center has been considered an important factor for achieving the economic enhancement objective. The Boston ARZ, for example, shows an increase in sales volume of 27 per cent from 1977 through 1979 (Cambridge Systematics, Inc., 1981). This trend can be attributed to the existence of a transit system which draws both captive riders and shifted-travelers from automobiles. Thus, with the reduction of automobile accessibility to the area, it seems essential that an alternative transporation system such as public transit be available.

e.Preservation of Cultural Attractiveness and City's Unique Character

This is an objective that is more closely related to urban design and urban form. The achievement of this objective rests directly on the degree of success attained in fulfilling transportation related-objectives such as a reduction in congestion. Traffic congestion along with vehicle pollutants and noise poses a noticeable problem in European cities. Since town centers frequently contain historical sites, there seems to be a strong desire to preserve attractiveness and each city's unique character.

The cell-type of ARZ appears to be productive in achieving this objective. The traffic cell scheme encompasses the entire city center as well as historical sites and open spaces in some cities. For example, the traffic cells created in Gothenberg, Bremen and Uppsala are far more extensive than those in American cities.

While the preservation objective is explicitly mentioned in several reports which study the ARZ scheme in the U.S. context, this objective received less attention than did the transportation and environmental objectives. Preservation of cultural attractiveness and city's unique character seems to

be an objective that draws virtually no attention in developing countries although some countries have tended to address this issue in recent years.

This objective can best be served by radical measures such as congestion pricing over a larger area. Such techniques as one-way streets and parking restrictionn are likely to be less effective in fulfilling this objective.

f. Encougement of Public Transit Use

The encouragement of transit use serves as one of the major objectives addressed in the U.S., Europe and Singapore cases. This objective entails the improvement of public transit accessibility to and within the ARZ area. The public transit mall appears to be the best type of ARZ in accomplishing this objective.

In the U.S., this objective does tend to be more directly addressable by downtown auto restriction than was the original objective of auto restrictionn schemes, namely the revitalization of the CBD as a retail center. This objective can be achieved rather readily in European cities where

transit accessibility to the city center is already high. Besancon experience shows that a 75 percent increase increase in bus ridership was observed within two years (May and Westland, 1979). This increase in transit ridership is significant when compared to a 34 percent increase in transit ridership in the Boston ARZ during 1978-1980. A similar argument can be made for developing countries where public transit use is generally high. High density cities rely more heavily on public transit than less densely-populated ones.

The existence of more than one public transit or paratransit mode needs to be integrated in order to effectively address the public transit encouragement objective. This is particularly important for an area where various types of paratransit modes compete for a limited space. In some developing countries, there are the motorized and non-motorized paratransit modes such as jitneys, trishaws and minibuses which play relatively important roles in providing trips over short and medium distances. A complete ban of paratransit in some urban areas may be necessary to give preferential access to public transit given the slow paratransit speeds and absence of schedules and fixed stops which impede the general traffic flow in congested areas.

5. The Appropriate ARZ in Developed Develoing Countries

Having established the relationship between objectives and ARZ schemes, it seems appropriate to categorize these schemes and their associate techniques by the type of city and region. The ARZ schemes and techniques listed in Table II-4, present the range of approaches a transportation planner might consider in developing ARZ pakages in each region.

Table II-4 Types of City Center and Relevant ARZ Schemes

Region	Types	Schemes	Techniques
Developed countries	Old and small city center	Street closure Cell-type Pedestrian area Transit street Physical barier	Traffic circulation One-way Parking restriction Turn restriction Cul-de-sac
	Medium to large city center	Transit mall Transit Street Parking control Pedesrian street	Signalization One-way Turn restriction Bus priorities Low design speed
Developing countries	Old and small city center	Pedestrian street Parking charge Paratransit street street closing	One-way Turn restriction Low design speed
	Medium to large city center	Area license Parking control Street closing Pedesrian street Transit street	One-way Bus priorities Turn restriction Paratranist contorl Vendor control Traffic circulation

Most actions listed under techniques should be viewed as supportive or supplemental to the associated ARZ schemes. Since the cities in both developed and developing countries differ considerably from one another, categorization of this sort should be considered suggestive rather than definitive. Likewise implementality depends upon a host of external conditions including the role of the city goverment, prevailing attitudes, and existing modal shares.

The types of cities categorized by Thomson (1977) provides a useful basis for discussing relevant ARZ schemes. As shown in Table II-5, three types of categorization were made on the basis of centralization versus decentralization.

Table II-5   The Types of City Structure

City Structure	Cities
Centralized	Paris, Washington, London, New York, Tokyo, Toronto, Hamburg, Stockholm, Sydney, Athens
Less Centralized	Boston, San Fransisco, Copenhagen, Goteberg, Chicago, Vienna, Melbourne
Decentralized	Baltimore, Pittsburg, Milwaukee, Buffalo, Salt Lake City, Denver, Detroit, Los Angeles

Source: Thomson(1977)

Thomson's categorization was based on several factors: population density, employment density and city size. The traffic handling capacity of roads in centralized cities is generally limited due to a high level of employment density. Potential candidate schemes for these cities are: street closure, traffic-cell creation, pedestrian streets and area license schemes. Parking restrictions may also be more applicable for centralized cities.

In decentralized cities like Los Angeles, Detroit and Denver, street closure, pedesrian streets and traffic cells may not be suitable options to consider since these cities are characterized by larger city centers, low density, grid-pattern streets and less conflict between pedestrian and vehicular traffic. A certain zone of the city center in these cities may be, however, closed off to automobile traffic, depending upon the circumstances.

As to transitways or transit malls, transit routes connecting to the CBD seem to be a fairly important prerequisite. Such a prerequisite is most likely to be met in older cities such as Boston, San Fransisco, Chicago and New York. Transitways or downtown shopping malls are hardly applicable to decentralized cities like Los Angeles, Salt Lake City and Denver for the following reasons: (1) public transit sytem, namely rapid transit connecting the suburban residential area to the CBD is quite poor; (2) the trip distance from residential locations to the city center is

relatively long; (3) the downtown has not generally maintain its vitality as a commercial and business center; (4) there are a number of suburban shopping malls located near residential areas.

Area license schemes may produce potential benefits in larger cities in developing countries. In smaller cities in developing countries, however, the license scheme would be too much bother to introduce for the very small returns that could be gained, and similar advantages could be gained from good traffic engineering.

The transit mall may not be relevant for larger cities in developing countries because of the coexistence of various activities in a relatively limited space. It may even make the situation worse. The transit mall may, however, be applicable to the city center in developing countries where such public trasit as a light rail system alteady exists and where streets are less crowded.

In a major city in developing countries, the pedestrian street may be effective as a tool for restricting automobile traffic when there is heavy pedestrian movement. In certain situations, lanes reserved for paratrasit or transit within the pedestrian area may potentially be beneficial. A traffic cell type of ARZ may cause further traffic congestion due to the already severe traffic congestion, lack of boundary roads and enforcement problems.

While few would dispute that parking restrictions help to

maximize traffic capacity and are essential prerequisite of many traffic management schemes, they may have only limited success as traffic restrainer in developing countries because of enforcement problems.

6. Conclusion

The desirability of closing off streets or areas is generally determined by the underlying charactreristics of a specific urban area. Likewise, the objectives and relevant ARZ schemes are distinct for different types of areas. The discussion in this chapter must, therefore, be general.

Examining the ARZ experience with the U.S., Europe and developing countries, each has distinct approaches and solutions to essentially similar transportation problems. Grossly summarizing these experiences, the major reasons for the differences seem to be because each region has different perceptions and attitudes toward the transportation problem itself. Thus decision makings for ARZ selection is different. The key factor is that each of the cities has different goals which greatly affect the ARZ objectives.

The degree to which certain ARZ schemes may be useful in accomplishing particular objectives is rather hard to determine. In most cases, no obvious matrix such as Table II-3 exists between ARZ schemes and objectives. Also a direct

relationship with specific types of ARZ schemes seems difficult to establish because of other forces operating on these objectives.

The conclusion, then, is that each region has distinct philosophical orientations and traditions of government. These led them to differ in their interpretation of transportation problems, recognition of ARZ alternatives and formulation of objectives. Obviously, the differences between developed and developing countries seem to imply that ARZ schemes should be tailored to the specific local situation. Therefore, the exploration of these differences and similarities is a crucial step when applying ARZ schemes to urban areas having different characteristics. Viewed in this way, the extent to which certain ARZ schemes would be appropriate would depend not only on the applicability of these schemes and their experimental confirmation, but also on the local constraints which would be faced in applying these schemes.

CHAPTER III: EVALUATION METHODS USED IN ARZ SCHEMES

1. Introduction

With the background of ARZ schemes and relevant objectives discussed in previous chapters, it is the purpose of this chapter to understand the importance of the multicriteria evaluation methods through the examination of evaluation methods used in ARZ schemes.

The first part of this chapter is aimed at assessing the case for ARZ evaluation in the literature. The second part summarizes the results of the assessment made in the first section. Advantages and disadvantages of ARZ evaluation methods are explored. In orther words, it is intended to identify some of the logical weaknesses in assessment methodology and indicate the areas in which a more relevant and comprehensive framework should be sought. A discussion of these evaluation methods provides a background to the following discussions in which the use of multicriteria

evaluation methods are justified in preference to other approaches. This is followed by a section that discusses the multicriteria evaluation methods used in transportation systems.

2. Assessment of ARZ Evaluation Methods

A review of evaluation mehtods used for ARZ schemes reveals that there are three different methods that have been employed in the studies conducted for cities in developed and developing countries. These methods are: cost-benefit analysis, impact analysis and weighting technique.

Cost-benefit analysis employed in ARZ schemes is directed toward the issue of whether benefits exceed costs for the alternatives considered. In some cases, benefits only are taken into consideration. Cost-benefit analyses are mostly used in preinvestment situations based on before-the-fact (ex ante) estimates of costs and benefits. Ex ante cost-benefit analyses are undertaken on the basis of anticipated estimated costs and benefits of ARZ schemes. Such estimates are not

necessarily empirically based. In the absence of past performance and empirical data, the cost-benefit analysis employed in some ARZ schemes was based on somewhat arbitary assumptions and speculative logic.

Impact analysis is the second type of evaluation method used in ARZ schemes. Impact analysis can be viewed as an impact evaluation in the sense that it is undertaken after an ARZ scheme has been shown to have a significant impact.

The third type of evaluation method used in ARZ scheme is weighting technique. By reflecting values and effects that are not easily quantified, the use of the weighting may provide an adequate justification for projects not defendable by the cost-benefit type of analysis. Weighting technique is generally used on the basis of anticipated outcomes of ARZ schemes. The essential usefulness of weighting technique is that it can handle a significant number of factors including tangibles and intangibles. This weighting tends to oversimplify variables or criteria. Moreover, the entire evaluation process is suffered by subjective weighting and interpretation.

Table III-1 Cases for ARZ Evaluation

Methods	Authors	Titles	Area
Cost-Benefit Analysis	Gomez-Ibanez & Fauth(1980)	Downtown Auto Restraint Policies	Boston
	Thomson(1967)	Two Restraint Policies in London	London
	Kulash(1974)	Income Distributional effects of Road Pricing	Boston Washington Los Anegeles
	Tokunaka (1981)	Study of Congestion Pricing	Los Angeles
	Peat, Morwick Mitchell (1974)	Mannual for Pedestrian Facilities	
	Bhatt(1976)	What can we do about Congestion?	Hypothetical Area
	Bertrand (1978)	Congestion Costs	Bangkok
	Cambridge Systematic (1976)	Internal CBD Travel Demand Modelling	Hypothetical Area
Impact Analysis	Watson&Holland (1978)	Relieving Congestion: Singapore ALS	Singapore
	Delaware Valley R.P.C. (1977)	ARZ in Delaware	Chestnut St. Trenton Common
	TRR(NCHRP) (1981)	Boston ARZ Nicollet Transit Mall	Boston Nicollet
	OECD(1979)	Managing Transport	Gothenberg
Weighting Technique	TRR(NCHRP)	Benefits of Separating Pedestrians & Vehicles	Hypothetical Data

In order to evaluate the cases of ARZ evaluation in a consistent fashion, five criteria are applied to each. First, what is the decision problem? Second, what are the alternatives that will be considered in the evaluation? Third, how was the evaluation designed and implemented? Fourth, what were the findings? And, finally, how should the results be interpreted? Each case will be presented in this manner in order to illustrate how different problems have been addressed.

All the cases of ARZ evaluation have been included. Each may have certain weaknesses relative to an "ideal" study. In some cases real-world data could not be obtained, and in others the studies represent pioneering atempts in their substantive areas of inquiry. However all of the the studies provide a useful basis for examining how evaluation methods can be applied to ARZ types of schemes, and both their strengths and weaknesses enter the discussion. Because the full assessments turned out to be rather lengthy, it was decided place most of their details in Appendix to Chapter III. The summary of these assessments along with methodological issues surrounding three evaluation methods is given in the following section.

3. Overall Assessment and Methodological Issues

The primary emphasis of this section is to highlight the

important methodological issues surrounding cost-benefit analysis, impact analysis and weighting technique. The discussion is based on the assesments of ARZ evaluation listed in Table III-1 and discribed further in this section.

a. Methodological Issues of C/B Analysis

There are seven major methodological issues associated with cost-benefit analysis that deserve some discussion. First, the length of project life and choice of discount rate were largely neglected in most ARZ evaluation cases. Unlike such capital intensive projects as rail lines or highways, these variables may not be particularly relevant for the evaluation of ARZ type of projects. ARZ schemes, however, imply capital and maintenance costs. It is rather naive to assume that an ARZ such as pedestrian streets or shopping malls will have value forever: it is always possible that changes in land use, population density and commercial activities can make the ARZ obsolete.

With regard to discount rates, it seems necessary to take the discount rate into account in evaluating an ARZ scheme in conjunction with the length of the project life for the reasons discussed above. A discount rate is useful when considering the concept of opprotunity. Also dicounting can incorporate the level of uncertainty associated with the expected returns on investment. However, the selection of an

appropriate discount rate and project life is very aften
biased and subjective. High discount rates in conjunction
with long-term planning periods effectively nullify the
consideration of long-term effects.

Second, while distributional effects were briefly touched
in some of the ARZ studies, they were not embeded in the
actual cost-benefit calculation. The choice of
distributional weights can considerably affect which ARZ
scheme is selected or where the ARZ scheme is applied.
Heavily weighting benefits to pedestrians can push the ARZ
toward pedestrian-oriented ARZ schemes. The discussion on
the way weighing can be done with respect to income groups is
beyond the scope of the present study.

Most of the cases of ARZ evaluation contain no explicit
statement about whose interests the ARZ schemes are intended
to serve. There are two main reasons why this is important
to know. Firstly, decision-makers and others concerned in
the process of decision-making will wish to know from whose
viewpoint the ARZ schemes are being evaluated: for instance,
are merchants and new users included? Secondly, it is not
possible to determine the incidence of gains and losses
between different groups unless one knows whose interests are
involved.

Generally speaking, cost-benefit analysis looks at costs
and benefits in efficiency terms, treating equally the cost
or benefit for all users. Different ARZ projects, however,

may have vastly different distributive effects, because population groups to which the cost and benefit accure, and the needs of those groups, may be quite different in each case. If such effects are included, a project with less efficiency may actually be more desirable because of its contribution toward an equitable distribution of income and opportunities.

Third, it is surprising that even in systematic cost-benefit analysis, consumer surplus which has been widely used for transportation evaluation was not considered. The measure of consumer surplus in money terms assumes, as Marshall pointed out in his original description of the concept, that the marginal utility of money varies depending upon the income of users.

Furthermore, when the goal is not only to maximize consumer surplus (efficiency) but also to achieve equitable distribution of income, a tradeoff has to be made between these two often conflicting goals. This is because projects that are most efficient in increasing total benefits may be less efficient in reducing the dispersion of income distribution and vice versa. A resolution between conflicting value judgements then will remain a task for the decision-maker. What is important, therefore, is that all value judgements be made clear, that the value positions of all interested groups be elaborated, and that the decision maker be in a position to make his own judgement on all

relevant issues although in practice this is often difficult.

Fourth, the value placed upon time in the evaluation of benefits is often treated quite loosely (see the cases of Boston (Gomez-Ibanez and Fauth) and London (Thomson)). In the two cited cases, an average time value was applied to all transportaiton users affected by the ARZs. However, the value placed on users' time can vary from person to person in accordance with a number of factors, such as time of day, length of trip and transportation mode used. The underlying assumption in the evaluations was that trips made are homogeneous with respect to the behavior of users, trip purpose and mode used. Viewed in this way, placing a monetary value on time saving in the context of developing countries raises more serious questions as to the taste of users, trip mode, and charateristics. They do not appear as sensitive to time value as those users in developed countries. A similar quesiton can be raised as to whether very small time savings have any value at all.

Fifth, with only a few exceptions, the alternatives were not evaluated directly in relation to the objectives of the proposed ARZ schemes. Objectives were specified in very general terms. In order to assess the effects of alternatives, it was therefore necessary to break down the objectives into more detail. The presence of intangible objectives provided an obvious problem in this respect. There is little doubt that nearly all transportation projects

involve both tangible and intangible objectives. Intangible objectives were largly neglected in most ARZ evaluations.

Sixth, no mention has been paid to the secondary effects of ARZ projects. Economists or public policy analysts have yet to really come to grips with the question of how to deal correctly with secondary effects. These basically refer to Keynesian multiplier effects (both positive and negative) stemming from expenditures and economic activity level changes surrounding the transportation project. In our ARZ situation, these secondary effects might largely concern the local economy in general. They present not only difficulties in correct treatment from a theoretical standpoint, but also entail tremendous measurement problems because of the diversity of effects involved.

Seventh, the way most studies classify the benefits for different users appears to be rather naive. Classes of users for the ARZ are usually not explicitly considered. In fact, there are three different classes of users that should be taken into account - diverted, gernerated, and long-run users, the last category often being assimilated into the second in other writings. The distinction between the two made here is that while both groups are undertaking new trips including modal shifts, long-run users have changed home or job location. All other trips are considered generated. This distinction is made because benefit measurements to the two groups can be made somewhat differently.

b. Methodological Issues of Impact Analysis

Methodological issues surrounding the impact analysis also deserve some discussion. In contrast to cost-benefit analysis, impact analysis has been largely used for demonstration and pilot studies in the transportation field. This method seems particularly suitable for those projects which have noticeable impacts within a relatively short period of time.

With one exception (i.e., Singapore), many studies that have been examined are mostly based on the ad hoc survey and interview. A major weakness of many studies was the failure to systematically examine the various indirect impacts of ARZ schemes. Because of the limited range of effects considered, most studies do not provide much insight. The social groups affected were mostly ignored by all the studies examined except that for Singapore. The consideration of environmental effects was also excluded by most studies. The Singapore and Gothenberg studies however, made an attempt to evaluate pollution and noise.

With regard to the consideration of the sales volume, no formal evaluation of change was attempted beyond a rough comparison of sales figures after implementation. It appears hard to evaluate the degree to which economic viability is to be achieved. Inevitabily, a considerable amount of

subjective judgement was unavoidable in evaluating the objective of downtown revitalization.

There are thus several drawbacks inherent in impact analysis. First, the data and measurement problems before ARZ implementation seem to be serious in some cases. Appropriate data describing conditions at the time of ARZ initiation were not available in sufficient detail at a later date. For the Nicollect Transit Mall and Chestnut Street Transitway, for example, no attempt was made at data and information collection prior to the initiation of the schemes. The case of the Singapore ALS appears to be exceptional since a deliberate effort was made to collect base-line information before implementation. Also the amount of information collected before the implementation of Gothenberg's traffic cell was not eqivalent in scope to that of the information gathered after implementation. Thus impacts on pedestrian activity and behavior were not able to be ascertained.

Second, the before and after situation poses a different type of methodological difficulty. There is a risk of confusing the effects of the project with those effects which would have occured in any case as a result of the evolution of the transportation and urban systems. It is extremely difficult to distinguish other effects which might have some bearing on the ARZ scheme itself. For example, urban development policy related to housing and infrastructure

might have had an effect on transportation and environmental systems in the city center between the inception of the traffic cell scheme and the opportunity to observe results.

Finally, as was recognized in cost-benefit analysis, non-market external effects cause problem of measurement. Similarly, it is difficult for analysts to distinguish the primary from the secondary effects and to appropriately account for the latter.

c. Methodological Issues of Weighing Technique

The weighting technique varies from simple to systematic. method. The simple weighting is often based on arbitary scores and subjective judgements. The systematic weighting, on the other hand, is comprehensive in the sense that it identifies diverse costs and benefits and intangibles. The weighting scheme employed in the ARZ scheme is a kind of comprehensive weighting technique in which 36 variables were identified and rated. However, this study can be faulted for the arbitariness with which weights were assigned and scores derived.

4. Multicriteria Evaluation Methodologies in Transportation

At the outset, it is necessary to discuss the definition of multicriteria. Multicriteria can be used for measuring the degree to which multiobjectives are met. Multiobjectives are multiple values, multiple preferences or multiple desires of decision makers or individuals. Many complex decision problems involve multiple objectives. A decision maker must choose among several alternatives, each of which results in impacts describable in terms of criteria.

It is naive to assume that objectives of a complex project such as transportation systems can objectively be stated and evaluated in terms of a single criterion since transportation systems imply a complexity of interactions between the environment, economics and people. Yet, transportation system objective is defined in terms of a single dimension in many cases.

The multiple criteria approach accomodates conflicting criteria (environment vs. economics vs. social) through recognition of relevant trade-off issues. Although some of the criteria are not measurable in an "absolute" sense, the very fact that multidemensional factors are entering the decision making process through either quantitative or qualitative evaluation reflects the attractiveness of this

approach.

In contrast to the field of water resource and management science where a great deal of effort has been devoted to the development of mulicriteria evaluation methods, multicriteria evaluation methods have received relatively scant attention in the transportation field. Probably a major reason for the relative scarcity of multiobjective formulations and evaluations in the transportation literature is that almost all the solution strategies developed to date involve a single objective function such as the minimization of transportation cost or time.

Despite the generally scarce attention, several writers have advanced and applied multicriteria evaluation methods to transportation situations. There have been serveral very worthwhile contributions to the rationalization of the multicriteria concern in conjunction with evaluation and decision-making.

a. Earlier Development of the Field

The emergence of multicriteria concerns in the transportation field has its root in the observation of multiple impacts which leads to the notion of multicriteria for judging the impacts. The attempt to incorporate

multicriteria into an evaluation framework was a response to the widespread use of conventional cost-benefit analysis in transportation project evaluation. As was stated previously, cost-benefit analysis focuses primarily on the single criterion of economic efficiency. There has been a growing recognition of the inadequacies of conventional cost-benefit analysis in capturing the full range of social values that are relevant in transportation decision making. Academicians and decision-makers alike have pointed to the need to consider intagibles such as economic, social and environmental concerns in choosing from a given set of alternatives.

In general, concern for the multicriteria nature of the transportation system emerged in the early 60's in the U.S. although there were some implications relating to the impacts associated with transportation planning before 1960. This concern mainly came from the methodological problems inherent in the Red Book (mannual for transportation evaluation). The Red Book focuses primarily on benefit-cost ratios, emphasizing the road user benefits related to capital and maintenance costs.

An early suggestion regarding the need for a broader framework for evaluation was made by Lang and Wohl (1960). They essentially stressed the need for a more rigorous definiiton of "impact", suggesting a classification into four types - economic, social, aesthetic and political. While

emphasizing the need to identify correctly the differences in economic efficiency between alternatives, they also established a basis for the evaluation of social gains in terms of required sacrifices in economic efficiency. The foundation was laid for estimating just who will get the benefits of a given project and who will incur its costs.

A suggestion by Kuhn (1961; 1962) is more broad in that various objectives such as the tangible and intangible effects of potential investments in transportation facilities should be aggregated. Tangible items include construction and vehicle operating costs. Intangibles include the quality of transportation service, noise, dirt, aesthetics and the separation of industrial and residential land uses. Although he does not include it specifically in his proposed analytical technique, Kuhn also advocates determining the distribution or incidence of benefits and costs.

Another trend of this time (i.e. early 1960's) has been the concern for the broad spectrum of economic effects of investments in transportation facilities. The following set of economic objectives set forth by Fromm in a Brookings Institution study list this spectrum of effects in terms appropriate to developed as well as to developing countries.

(1) growth in aggregate national income accompanied by an equitable distribution between and within population, business and regional groups;

(2) increase in the kinds and amounts of final goods and services available to consumers, industry and government;

(3) development of a national industrial structure
    capable of earning foreign exchange and of
    supplying domestic markets;

(4) establishment and maintenance of a high level
    of employment (Fromm, 1965).

The implication of these effects is that investments in
transportation facilities call for multidimensional
considerations.

A wide spectrum of objectives was also considered in the
location and design of a new expressway in Chicago in the
late 60's. The objectives included decent housing for every
family, elimination of poverty, elimination of crime, removal
of slums, and adequate recreational facilities (Pikarsky,
1968). Some of the aspects of the expressway location which
were therefore considered are dislocation of people,
reduction in the value of adjacent property, division and
disruption of neighborhoods, and visual blight.

b. Recent Development of the Field

Faced with the need for incorporating multidimensional
concerns, Manheim (1967) has contributed a set of
considerations which clearly delineates the task of the
transportation systems analyst. The considerations are
contained in nine elements called "The Principles of
Transport Systems Analysis". The major significance of the
principles to evalution is the orderly, explicit presentation

of those elements which the analysts must consider in developing the information necessary for the definition and evaluation of alternative systems and their effects.

Manheim (1969) further points out that transportation choices can be described as essentially socio-political choices where the differing interests of the various groups are considered and balanced. It has been suggested that, where transportation is viewed in context with a number of supplementary programs, concerted strategies can be evolved which ensure that no single group is unduly penalized. The need for socio-political choices appears to represent a clear advance over conventional models (or methods) in its abandonment of the search for only single dimensional choice.

In a similar vein, widespread fuzziness about what the goals of transportation systems should be has created controversy, particularly in urban areas where public interests or value systems often conflict. In response to this, Hill (1967) has created a framework in which a great number of goals for transport systems can be listed and their relationships specified. He groups the goals into three major hirarchical levels. The highest level, "ideals", represents those qualities of life for which the members of the community are striving. The middle level, "objectives", provides an operational list of those elements of the environment which are affected by transportation facilities. The objectives are expressed in such a form that the

contribution of a given facility or project to their achievement can be measured. The lowest level, "policies" lists those elements of the transportation system itself which can be altered to produce different levels of achievement of the objectives.

The policies are connected to those objectives which they affect. The objectives are in turn connected to those ideals, the level of achievement of which they express. It should be noted that in this framework, benefits are positive contributions to goal achievement, while costs appear as negative contributions. The measure of effectiveness for any plan or project is thus expressed as the level of achievement of each objective.

Explicit presentation of the effects of design and operating policy decisions on goal achievement in this way can remove much of the fuzziness surrounding goal definition. It provides an especially beneficial framework in which to present to decision-makers the expected consequences of different decisions. One can envision trade-off funcitons showing the relationship between the levels of achievement of two objectives as a function of the value of some policy variable. Also, the incidence of various costs and benefits can easily be shown. The work of Hill (1967) is a very significant step in these regards. Since this "goal achievement matrix' is one of the methods to be examined in this thesis, the method will be discussed in detail in the

next chapter.

Another valuable contribution to the multicriteria concern in the transportation field is the planning Balance Sheet Method developed by Lichfield (1964, 1968). Lichfield applied this method to road proposals for a shopping center of Edgware, a suburb of North-West London in England. A major asset of the method is that it does not insist on the translation of all relevant items into monetary terms, recognizing that this is not technically possible at the present time. It does, however, attempt to take these unquantified items into account in order that they might be viewed alongside the quantified items.

Whereas conventional cost-benefit analysis tends to ignore such unquantifiables, the Planning Balance Sheet method at least incorporates them formally into the analysis, thus making the analyst or decision-maker aware of their existence and relevance and allowing for a trade-off between these items and those which are more easily quantified. Yet the number of intangibles is generally very large, pointing both to the need to quantify as many variables as possible and for a more rigorous method of incorporating the intangibles into the analysis. However, it is inevitable that a certain degree of value judgement will still be necessary in reaching a decision from such an analysis and it seems that the Planning Balance Sheet at least narrows down the area in which value judgements will be necessary.

Another advantage of the Planning Balance Sheet method is that it explicitly attempts to trace the incidence of costs and benefits upon the various groups involved. This method also recognizes that different groups within the community are bound to have different aspirations with regard to particular plans.

Along a similar line of methodological development, Manheim (1975) advanced an evaluation methodology more appropriate to the current transportation planning process. The puppose of this evaluation approach is not to choose the best alternative thorugh a rational process, but to identify issues of concern, the concerns of affected parties, the impacts of each alternative, and those who will gain or be hurt from each action considered. Elaborate techniques. for weighting are not used. Trade-offs are not made by the evaluator, rather the trade-offs involved are made explicit by the evaluator.

The evaluation approach recommended by Manheim consists of four activities. Prior to commencing the four activities, basic data which include information from citizen participation in early planning as well as impact information are organized and reviewed:

> Activity I - the issues are viewed from the perspective of the affected parties. Affected parties are identified and impact information is reviewed to determine the extent to which these parties are affected. When possible, compensation and mitigation measures are proposed. The opinions of

affected parties are also reviewed and when necessary additional information is provided to the public.

Activity II - each action is examined and issues of community concerns, feasibility, equity, and acceptability to the public are examined. At this point modifications are sought to increase desirability.

Activity III - issues are viewed from the perspective of the process as a whole. Compromises between conflicting groups are sought and patterns of conflict or consensus between groups are examined.

Activity IV - the results of the three previous activities are documented and reported to decision makers and other interested parties.

The purpose of this approach is to present evaluation results in a disaggregated form and to solicit community reaction to proposed actions as a whole rather than simply a set of goals. The evaluation system is also ment to be an active component of planning. Rather than merely evaluate alternatives, the evaluation process is used to generate new ideas and possible modifications.

Since then, Manheim (1979) has made an attempt to apply a particular muticriteria evaluation method, an impact tableau, to the effects of alternative alignment for the Los Angeles freeway. The impact tableau contains goal variables and actions. Goal variables can be expressed in both qualitative and quantitative terms (for example, 30 minutes saving in travel time). The actions are the alternative transportation plans being considered.

Rietveld (1980) applied an interative programming method to the rerouting of commuter traffic. Using integer programming, the subjective and provisional nature of the objective function is fully recognized in the method, which calls for an interactive exchange in which constraints and preferences are gradually refined. In contrast to Hill's goal-achievement matrix, however, Rietveld's suffers by abstraction from the heterogeous elements of real world planning, in which concrete alternatives shape the decision makers's thought process, objectives are not fully quantifiable, and impact predictions themselves are often uncertain.

Friezs (1980) proposes a constraint method, which is generally attributed to Marglin (1967) and to the interactive preference-incorporation method of Zionts and Wallenius (1976). Friezs (1980) applied these two methods to hypothetical rural transport projects.

The broadened objectives are an attempt not only to assist decision-makers in evalualing alternative transportation projects but also to educate the affected public regarding the various effects associated with transportation facilities. Perhaps the most important result of a broader range of considerations is the explicit recognition of the interrelationships between transportation and other facets of life.

5. Conclusion

This chapter has summarized the major mehtodological issues surrounding cost-benefit analysis, impact analysis and weighting technique through the examination of ARZ evaluations. In so doing, this chapter has demonstrated the need for a multidemensional consideration in transportation field in general and ARZ evaluations in particular.

CHAPTER IV DESCRIPTION OF TRAVEL CHARACTERISTICS OF SEOUL

1. Introduction

Having discussed the need and attractiveness of the multicriteria evaluation methods, this chapter is intended to 1) describe the characteristics of Seoul's Central Business District in which ARZ alternatives will be applied; 2) discuss the travel characteristics with an emphasis on mode shares and trip patterns.

2. Description of Seoul's Central Business District

This section describes the characteristics of the Seoul environment in which the ARZ schemes are applied. The general characteristics of the Central Business District (CBD) are described followed by travel characteristics. To obtain a basis for exploring the present situation, information on a variety of characteristics is required. However, data are scarce and often inadequate if available. Thus description about transportation characteristics has to be based on the scanty data available.

Seoul is the capital city of Korea; it is located on both sides of the Han River.   Its central business district (CBD) lies in the northern part of Han River.   Seoul metropolitan area has 6,249 km of road, mostly all-purpose roadways used for through traffic, local traffic, freight, and public transport.   As shown, in figure VI-1, the network is essentially radial, with 13 major corridors converging on the central area.

Since World War II, Seoul has rapidly grown in both size and population.   The large population of the city and high rate of growth create a dense and centralized distribution of population.   In fact, economic growth, technological progress, and social transformation have combined to significantly alter the structure of the urban environment and transportation patterns.   Major new development has been occurring on the south of the Han River and a policy of decentralizing both residerntial and employment opportunities has been followed.

Economic activity is heavily concentrated in the CBD. Seoul's city center is a strong regional and national center for government, banking, manufacturing, and education. The CBD is shown in the upper-left map in Figure VI-2. In the metropolitan region of nearly 8.5 million people, the city center is the principal urban area, serving as a regional center for a variety of services.   Traditionally the CBD has served as center for five specific classes of activities –

Figure VI-1   Major Road Network in Seoul Metropolitan Area
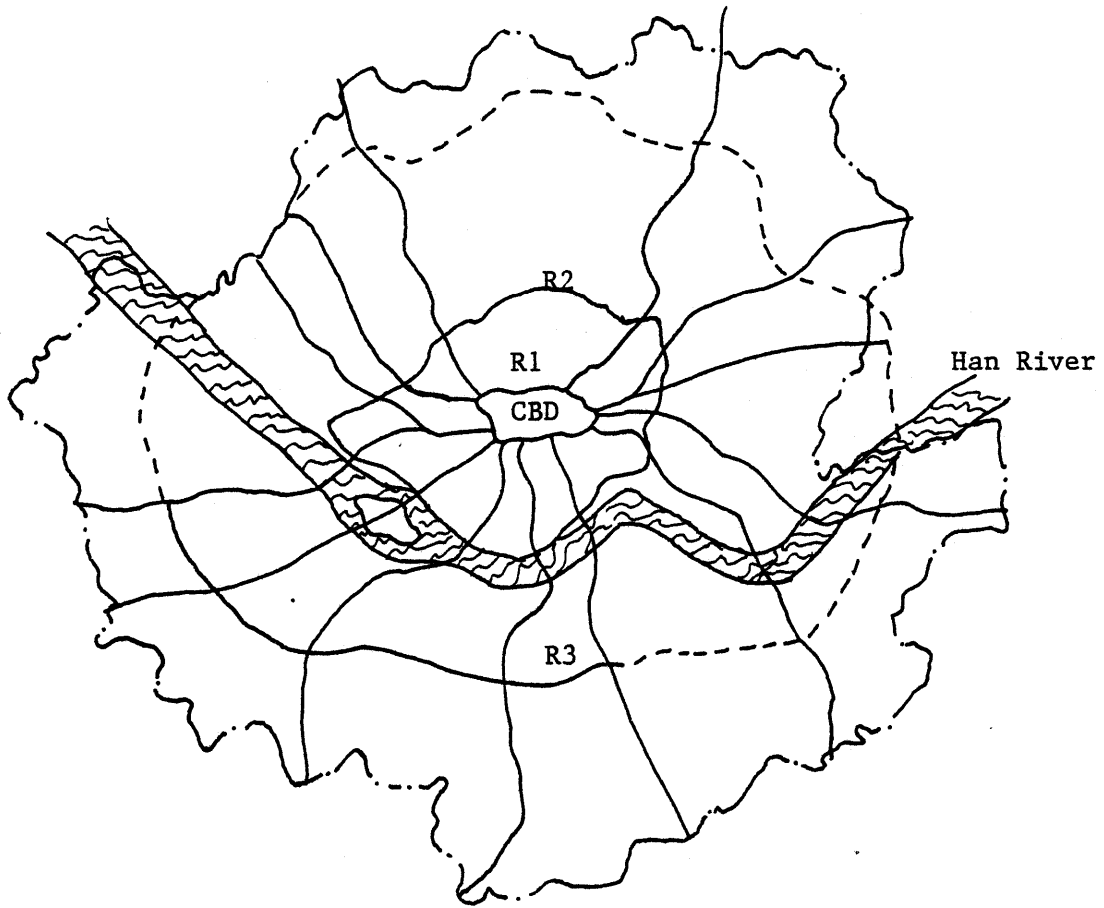
R1 - R3   Ring Roads
- - - -   Ring Roads Planned to be built
-- . --   Metropolitan Boundary

office employment (both government and private sectors), retail shopping, professional services, entertainment, and schools.

Government offices are heavily concentrated on the North Western part of the CBD and are also scattered throughout the CBD. There is a cluster of offices relating to insurance, stock market, and finance in the middle part of the CBD. In the retail shopping category, the focal points lie in the east and south of the CBD, where two major enclosed retail and wholesale shopping markets lie within the area of approximately 200 m. There are lots of small shops located along the corridors to take advantage of pedestrian flows. Jewelry and bakery shop are typical example of this type of shop.

Dining and entertainment establishments are widely dispersed throughout the area, with the core areas such as Myong-dong, Sogong-dong and Moogyo-dong occupying a particularly prominent role. The same holds true in the lodging industry with several major hotels. The area near Lotte Hotel, located near the Seoul city hall, has shown new vigor in these categories in recent years. The number of buidings and shops are located in these areas. These areas are heavily used by different groups of people for shopping, working and various types of entertainments. The other significant space occupiers within the CBD are schools including elementary, highschool and college. Many of the

Central Business District

Figure VI – 2 Central Business District in Seoul

SCALE = 1 : 40000

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schools are located in the Northwest and the North of the CBD.

Apart form these functions, the CBD contains a wide variety of other uses that reflect both its historic nature and its location in the heart of Seoul city. The midestern part of the CBD is the major foci of theaters.

While the central area of the city has a substantial network of wide streets, the conflict between the various road users combined with very high trip generation rates leads to considerable problems of traffic congestion, accidents, and environment. These problems are growing rapidly due to the increase in vehicle ownership and usage. Conflict exists between pedestrians and vehicles and between vehicles and vehicles.

As shown in Figure IV-1, the main radial routes provide access to the CBD from most areas of Seoul. The areas along these radial roads are the major trip attractors. In addition to the concentration of important commercial areas along these corriders, government offices and buildings are mostly located within the CBD. Among these radial roads, Yulgokro, Jongro, Ulgiro, and Thegero are the major east-west arteries entering into the CBD. The existing street network pattern in the CBD reflects these major flows of movement. Circling the central business district is a ring road that has continued to function as an important cicular road. This ring extends approximately 2.5 km from the center of Seoul.

There is also an outer ring road, bordering the Han River and which extends 5 km from the center of Seoul. Because most trips are directed toward the city center, the downtown street network has become heavily congested. In addition, the Han River which is crossed by few major arterials creates pockets of highly congested entrances to the CBD area.

As shown in Table IV-1, the five major east-west arterials in CBD suffer from serious congestion. Volume on these roads far exceeds the design capacity except for Yulgokro. Therefore, traffic volumes approaching the core from all directions are exceeding capacity limitations.

Table IV-1   Peak-hour Volume/Capacity Ratio on Five Major Arterials (1979)

Name of road	Volume per hour	Capacity per hour	V/C
Yulgokro	2,928 (pcu)	3,600	0.81
Jongro	3,649	3,600	1.01
Chunggero	6,227	6,000	1.04
Ulgiro	4,010	3,600	1.11
Thegero	4,945	3,600	1.37

Note: Capacity is the maximum number of vehicles which has a reasonable expectation of passing over a given section of a

roadway.   Capacity is an hourly volume.   Both volume and
capacity
are measured in passenger car unit (pcu).
Source: Seoul City Government, Long-Term and Mid-term
Planning for Seoul: Transportation Sector, 1980.

There are six main overpass roads (elevated roads) each
also connecting the CBD with the rest of the metropolitan
area.   While two-way serivce is possible on these overpass
roads, the width of these roads is narrow and the maintenance
poor.   These roads are heavily used by taxi and automobible
traffic.

The current traffic situation is typified by dense traffic
flows on the major corridors, low driving standards and
driver behavior.   Vehicles are illegally parked in most
congested areas in the CBD.   Car horns sound incessantly
through frustration.   Air becomes extremely polluted due to
the heavy emission level generated by vehicles.

In an effort to improve present traffic congestion, a
subway system was planned in Seoul conneting suburban areas
to the city center.   By 1980, subway line 1 was in operation
and subway line 2 was under construction. Subway lines 3 and
4 were to be completed by 1986.   Ultimately, nine lines with
a total length of 250 km are envisaged to cater to the
expected increase in urban population and to relieve severe
traffic congestion occurring throughout the day.   The subway

system will then absorb most of existing bus riders. By 2001, Seoul will eventually be linked to most satellite cities by 9 subway lines. Hence subways will play the key role in urban transportation in Seoul and will be of paramount importance for work trips in Seoul.

3. Characteristics of Travel

a. Trip Making Shares

The total number of trips made in Seoul is about 11 million per day. The significant portion of trips have their destination in CBD, to the north of the Han River. The average person trips in Seoul in 1977 was 1.4 trip per person per day with 73% by public transit, 19% by taxi, 4% by auto and 4% by other modes.

The morning peak hours generally occur in the period between 6:30 A.M. and 9:30 A.M., representing 37.8% of total trips. The off-peak trips which occur between noon and 5:00 P.M. also appears to be significant. These off-peak trips occupy 24.4% of total trips. Twenty-one point seven percent of total trip is made in the evening peak hours between 5:00 P.M. and 8:00 P.M. The remaining trips which represent 16.1% of the total occur between 8:00 P.M. and midnight.

Table IV-2 shows that the role of the bus in terms of modal shares has been reduced from 88.7 percent in 1970 to 67.7 percent in 1977. Taxi's share has rapidly increased during the same period. In 1977, the taxi represents 18.9 percent of total modal shares, and each taxi carries 130 passengers per day. The information on walking trisp is not available.

Table IV-2   Trip Making Shares in Seoul

Modes (%) Year	1970	1973	1977
Bus	88.7	85.5	67.7
Taxi	3.3	4.6	18.9
Private car	3.2	4.2	4.0
Gov't or company Provided car	-	3.4	3.7
Subway	-	-	4.8
Other	4.8	2.3	1.9
Total (%)	100	100	100

Note: Walking-trips are not included (no data are available).
Source: Korean Institute of Science and Technology (KIST) Survey
        Report for Comprehensive Transport Planning in Seoul, 1978.

b. Characteristics of Trip Makers

In Seoul, three public transit modes are prevalent.
They are bus, subway and microbus. These modes typically
provide for approximately two-thirds of all urban trips.
Buses are used to a greater extent throughout metropolitan
Seoul than any other mode. The subway has been limited to
serving two major corridors and is largely an intra-city
(mostly between city centers) operation. In the region as a
whole, the subway system plays a relatively small role as a
commuting mode except for the Jongro corridor. Microbuses
serve primarily the same routes as do buses, with some
extended services between the CBD and the outlying areas.
The role of buses is principally to provide services to the
middle and low income residents. These groups regresent a
large captive market (groups have no mode choice alternatives
other than bus). In spite of high coverage and an average
headway of around 4-6 minutes, the quality of service is very
poor in terms of comfort and speed.

Except for the subway, all public transport services in
Seoul are provided by the private sector. Present public
transport services are offered by registered companies owning
a number of vehicles. The official public transport routes
are determined by the municipal government. Permits are
issued to operate specific routes in the city, and the

allocation of vehicles to each route is based on a crude assessment of the needs of each corridor. Taxis are widely used for shared rides mostly during the peak hours. The taxi occupancy rate has been estimated to be 2.5 to 3 persons during the peak hours. Each passenger is responsible for paying his share of the taxi fare.

The metered taxis in Seoul are providing two distinct kinds of service: exclusive service for which one or more passengers are carried directly from their origin to their destination without intermediate passenger pick-ups and drop-offs; and shared service for which the driver picks up three or four passengers along the route.

The fare for the exclusive service is typically based on the taxi meter while the fare for a shared ride is generally negotiable. The fare for a shared ride is equally divided between passengers. In most cases, a rate sightly above the equivalent metered rate is considered the base fare from which each passenger's share is calculated. In some cases, informal rules appear to have been worked out between the driver and the passengers. Because different passengers may be going very different distances, driver often intervene to charge a reasonable fare for different passengers. Though taxis contribute to congestion problem in Seoul, they nevertherless play an important role in transporting peak-hour passengers. This service is particulary attractive to many who do not own a car and whose income level is

relatively high (from upper middle to high income group).

The bus, in more than one sense, is the "common carrier" of the Seoul. Every income group except the lowest (who are extremely poor) and the highest (who use autos or employer-provided vehicles) are found in large numbers among its riders. Those in the middle-income and low-income brackets form a significant part of the bus riders, and while the use of the bus by the high income group is not as frequent as for the middle-income groups, the mode is still the one most often used. In fact, the largest part of all income groups ride the bus to work.

The majority of transit riders in Seoul, whether they use bus or subway, own no autos. Auto ownership is extremely low even among those with high incomes. The income of those who use the subway for work trips is relatively higher than for those who use buses. For example, the median income of workers who rode the bus in the Jongro corridor in 1977 was about w18,500 per month while among subway riders it was about w27.646 per month.

The income level of riders using the microbus appears much higher than those using either bus or subway. The reasons for this high income among microbus riders lies in the high level of fare structure, currently three times as high as the fare structure of bus and subway. The level of service for this mode is much better than for the buses and subways in terms of comfort and time delay.

Although a segment of the polulation may perceive the existing bus fares as a significant cost, the large proportion of bus trips is made by people for whom the fare is nominal. This is indicated by the large differential in cost between riding public transit and operating an automobile. Given this situation, a large population must currently exist which can afford more than the cost of bus transit but which cannot afford a car. For these people, the costs of riding public transit are probably small compared to the cost of the time involved in making the trips (waiting, transfer andd travel time) and the discomfort of the crowding on buses.

As stated previously, for most of the population of Seoul, there is no comparable alternative to public transport, and less than 5 percent of trips were made by private car in 1977. For the remaining trips, the modes available are walking, taxi, minibus and motorcycle. Travelling by taxi is much more expensive than public transit, particullarly at the current fares, and walking requires very long travel times. As a result, a large proportion of the market for public transit is essentially captive.

The combined effect of these factors is that the ridership is composed of two roughly defined types. A certain share of trips is essential, including work, school and other necessary trips made by people who have no

alternative means of transport. These people will make their trips in spite of long waiting times and extreme crowding. The remaining trips are optional, often shopping or recreational trips which could be foregone, short trips which could be made on foot, etc. The number of optional trips will decrease as waiting times and crowding increase.

Another important characteristic of travel is the trip purpose. The amount of trips made varies according to trip purposes. Table IV-3 shows average percent of trips by purpose. Work trips account for 69.1 percent of total trips. Next are journey to and from school, representing 19.1 percent of all trips. Recreation and shopping account for 2.6 and 1.2 percent respectively. Recreation and shopping trips made in Seoul appear to be far smaller than those in north American cities. The remaining three purposes account for less than ten percent.

Table IV-3   The Amount of Daily Trips made by Purpose (unit:1000)

	1970		1973		1977	
	Trips	%	Trips	%	Trips	%
School	1,636	24.3	1,872	24.5	2.194	19.1
Work	1.137	16.9	1,563	20.5	2,586	22.4
Shopping	127	1.9	64	0.8	133	1.2
Business	362	5.4	343	4.5	696	6.1
Recreation	64	0.9	113	1.5	295	2.6
Work-Home	3,279	48.6	3,624	47.0	5,367	46.7
Travel	26	0.4	1	0.02	15	0.1
etc.	109	1.6	55	0.7	208	1.8
Total	6,740	100.0	7,635	100.0	11,496	100.0

*Business trips represent trips made for business purposes during
 the working hours.
Source: KIST, Survey Report for Comprehensive Transport
        Planning in Seoul, 1978.

    Work trips have continuously increased since 1970.   In

contrast to work trips, the share of school trips increased

only   slightly   from 1970 to 1973,   and   decreased   by

approximately 5 percentage points from 1973 to 1977.   The

decrease in the share of school trips during this period is attributable to the fact that (1) the relocation of middle and high schools from the CBD to outlying areas, south of Han River, as part of government's decentralization policies; (2) the absolute number of school trips increased. Total trips of all categories have steadily increased. A fifty-one percent increase has been observed between 1973 and 1977. The increase in total trips is due largely to a rise in car ownership.

4. Conclusion

This chapter has described the characteristics of Seoul's Central Business District in which ARZ alternatives are to be applied and discused the travel characteristics with an emphasis on mode shares and trip patterns.

It can be seen from the above discussion that the transportation problems are characterized by:

(1) heavy concentration of a variety of activities in the CBD;

(2) severe congestion occuring in the major arterials in the CBD;

(3) a high degree of dependency on public transit such as buses and subway and other public transit;

(4) rapid increase in taxi ownership.

CHAPTER V: THE DESCRIPTION OF CRITERIA AND ARZ ALTERNATIVES

1. Introduction

Having described the travel characteristics of Seoul's Central Business District, the primary purpose of this chapter is to determine the set of criteria and ARZs for the multicriteria analysis in the context of Seoul, Korea. The advancement of criteria and ARZ alternatives is built upon the chapter II where objectives and ARZs with regard to developed and developing countries are described in detail. The criteria and ARZ alternatives to be advanced in this chapter will be used for empirical anayses in chapter VI.

2. ARZ alternatives

In order to obtain the opinions of public officials engaged in transportation planning concerning alternative ARZ schemes, a survey of objectives and ARZ alternatives in the context of the CBD was conducted within the Bureau of Urban Transportation, Urban Planning and Police (Traffic Control Center) A questionnare was distributed among the staff in these bureaus. Sixteen public officials responded to the

survey.

In an attempt to give decision making groups a sense of the benefits and costs associated with the criteria with reference to each of the proposed ARZ alternative, series of effforts were made. First, six officials who have been dealing with ARZ types of actions in the Bureau of Urban Transportation were chosen for interviews as to the feasibility of implementation with regard to the proposed ARZs and the magnitude of the benefits and costs. The six respondents understood fairly well what was intended after discussion and were willing to devote the necessary time. They were also asked to provide the author with currently available data on all criteria.

Second, after receiving the currently available data on all criteria, author throughly analyzed the data and came up with approximate figures for quantifiable criteria and simple ranking for non-quantifiable criteria. Also the implementability of each of the proposed ARZs were examined. A number of telephone calls were made and several meetings were held for this purpose.

Third, it was deemed necessary at this point to interview all sixteen public officials. The author presented them the characteristics of each of the proposed ARZs and magnitude of benefits and costs associated with all criteria. A week later, the author prepared a questionnare that was designed to determine the set of criteria that should be

considered in the multicriteria analyses in Chapter VI and
the establishment of the relative scorings or ratings for all
alternative ARZ schemes and weights for all the criteria. The
questionnare shown in Figure V-1 identifies the objectives
and ARZ alternatives.

Figure V-1   Survey Questionnare

I am interested in obtaining opinions of city
officials concerning their perception of the
transportation objectives and automobile restricted
zone schemes within the context of the centeral
business district. Appearing below is a list of
set of objectives and ARZ alternatives. Should you
find that additional objectives or ARZ
alternatives are necessary, please include them
under "other." The list of objectives and ARZ
alternatives is to be ranked in terms of importance
to the transportation situations in the CBD. The
ranking can be done on a scale between 0 and 10
where 10 indicates the most desirable objectives or
alternatives.

Objectives   Rank

1. Minimize capital cost   ------
2. Minimize current operating cost ------
3. Maximize revenue
4. Reduce travel time for auto and taxi ------
5. Reduce travel time for public transit ------
6. Reduce pollution   ------
7. Minimize traffic accident   ------
8. Minimize instituitonal obstacle ------
9. Minimize inforcement problem   ------
Other: (please specify)   ------

  ARZ alternatives   Rank

a. On-street parking fee increase   ------
b. Extensive parking meter installation ------
c. Public transit priority signals   ------
d. Core area license scheme (ALS)   ------
e. Core ALS with transit improvement ------
f. Toll increase for tunnel gates   ------
g. Toll charges at bridge entrances ------
h. Outer area license scheme   ------
i. Toll charge at bridges with parking
   lots   ------
j. Pedestrian streets   ------
k. Entrance ramp metering at bridges ------
l. Outer ALS with transit improvement ------
m. Outer ALS with transit improvement
   and fringe parking lots   ------

The respondants ranked the objectives and ARZ alternatives in order of importance. The results provided a basis for selecting important objectives and ARZ alternatives. Using unweighted average ranking, the seven-top-ranked ARZs were selected.

a. Off-street Parking Fee Increase

b. Extensive Parking Meter Installation

c. Public Transit Priority Signals around Core Ring

d. Core Area License Scheme

e. Core Area License with Transit Improvement

f. Toll Increase for Tunnel Gates

g. Toll Charges at Bridge Entrances

Since the underlying concepts, mechanisms and effects of ARZs have been explored in detail in Chapter II, the special characteristics of each alternative in the context of Seoul are briefly discussed.

a. Off-street Parking Fee Increase
  (from W500 to W1000 per hour)

Parking in Seoul is characterized by disorganized arrangement, close spacing and inconsideration for other users. The city government has not been effective in controlling these parking problems. Where there are high traffic flows, some degree of observance and enforcement

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exists, but generally the majority of the existing parking restrictions are ignored.

Parking in the CBD is currently available at both off-street and on-street locations. As shown in Table V-1, the number of parking spaces available in the CBD amounts to 16,306. These spaces apprear to be far fewer than the total demand. The total demand was estimated to be 38,947 spaces for the CBD. On-street parking spaces are controlled by the city government, and 200 Won (.25 U.S. Dollar) is being charged for every 30 minutes for these parking areas. Most off-street parking lots are privately owned and used for commercial purpose. The standard rate for these off-street spaces is 500 Won per one hour. .

Table V-1   Parking Spaces in Seoul

Type	CBD		Other Areas	
	No. of facilities	No. of spaces	No. of facilities	No. of spaces
On-street (public spaces)	108	3346	28	835
Off-street (parking lots)	482	12960	2693	56725
Total	590	16306	2721	57560

Source: Division of Parking Facilities in Transportation Bureau of Seoul, 1983

The off-street parking fee increase would put an additional charge only on private automobiles and government and company-provided vehicles. This policy would be effective for morning peak hours between 7:00 A.M. and 10:00 A.M. which represent the most congested hours of the day.

A rate of 500 Won per hour appears to be rather low in terms of restricting the parking demand. This rate is equivalent to .625 American dollar. Most parking lots in the city centers charge the equivalent of more than one U.S. dollar per hour. A parking charge of 500 Won per hour does not seem be a burden for those in high income bracket in Seoul. Considering that auto owners typically fall in the high income category in Korea, these auto owners seem to be rather price inelastic to an increase in parking charge. Thus small increse in the parking charge would probably not induce them to switch to other modes.

The impact of a parking fee increase would be felt most strongly by long-term commuters who arrive in the core between 7:00 A.M. and 10:00 A.M. and park there all day. Most non-work trips are made after 10:00 A.M. when the fee increase would no longer be in effect. Thus non-work trips would not be affected significantly. The parking fee increase might have impacts beyond those related to modal shifts. Auto owners or hired drivers might avoid the fee increase at private commercial parking facilities by shifting to street spaces, thereby creating congestion on the streets.

b. Extensive Parking Meter Installation (500 Parking meters)

The second ARZ alternative considered is the extensive parking meter installation. The amount of public spaces would be increased by 15 percent. Five hundreads additional parking meters are to be installed under this alternative. This on-street parking restriction is designed to discourage short-term parking by auto drivers or hired drivers on heavily travelled or congested roadways in the CBD. One hundread and fifty parking meters have been installed in four locations since April 1981. The parking meters were purchased from the VDO company of West Germany at 157,670 Won ($197) each (Department of Transportation, Seoul, 1983). Much of the on-street parking is now being filled by public lots scattered around the CBD. Most cars parked on these lots are also short-term.

c. Public Transit Priorty Signals around Core Ring

This scheme involves time delays on private automobiles and taxis willing to enter the core area during the peak hours. A priority would be given to buses at entrance points in the rings around the CBD as shown in Figure V-3, Demand-responsive signals would be installed at thirteen entrance

Figure V - 2   Proposed Locations for 13 Transit Priority Signals

N

R2

R1

Han River

CBD

R3
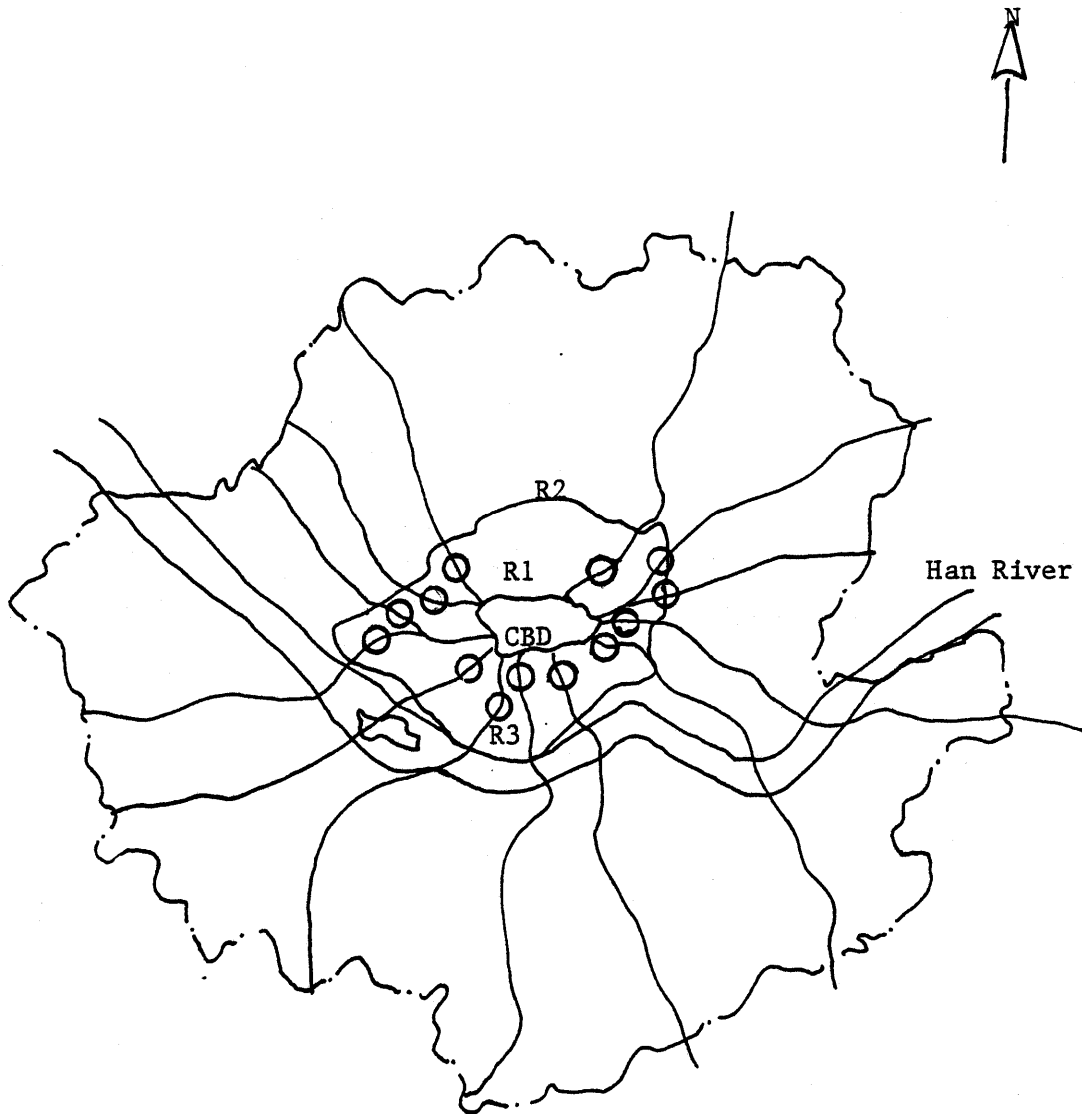
0 Proposed Locations for Signals

R1 - R3 Ring Roads

points to the core area. Time delays imposed on private automobiles and taxis depend on the level of congestion in the core area. Time delays generally range from 5 minutes to 20 minutes. There are presently 131 electronic demand-responsive signals in Seoul metropolitan area. The demand-responsive signals installed at 13 entrance points in the CBD can be converted into public transit priority signals. Demand-responsive signals require capital investment and impose ongoing costs associated with enforcement. Enforcing the time delay on automobiles and taxis would be expensive because of the large man-power requirement. This scheme would reduce travel times for all transit vehicles, including bus and microbus. A modal shift from auto and taxi to public transit would be expected to occur as a result of this scheme.

d. Core Area License Scheme (w 1,000)

This alternative is designed to increase traffic handling capacities of the core area by imposing restrictions on auto and taxi modes. Automobiles and taxis carrying fewer than four passengers would be required to display area licenses during morning peak hours. A license would be necessary for operating such a vehicle within the core area. The core area

Central Business District   Figure V - 4   Area for Area License Scheme

SCALE = 1 : 40000

for the area license scheme (ALS) is shown in Figure V-4. Options include daily, monthly and yearly licenses. Vehicles would display a special sticker when entering the core area

through 13 entrance points. The price level considered is 1,000 Won ($1.25) per day. A charge this high is necessary to divert auto traffic to other modes or times. The license would be required for the morning peak hours only. Pricing applied only in the morning peak would affect about 80 percent of commuters. Given the area that could be covered, this policy would have an impact not only on the core area itself but also on the metropolitan area as a whole. Shifting peak-hour work trips from auto and taxi to either bus or subway would increase public transit ridership, thereby making waiting times longer.

e. Core Area License Scheme with Transit Improvement

This alternative is essentially the same as the Core Area License Scheme except that public transit would be improved. Before considering area license policy, it must be recognized that when charges are imposed for auto and taxi use, alternative services must be offered to accomodate those who do not wish to pay or who find the charges excessive. These alternative services would consist primarily of improved public transit service and increased transit

capacity. Transit service improvements in core areas would include increased frequency of service on existing corridors. Sensitivity analysis will be performed to investigate the effect of changes in the frequency of public transit service.

f. Toll Increase for Tunnel Gates

This alternative consists of increasing tolls from 200 Won to 500 Won at three tunnel gates. Three toll gates are shown in Figure V-5. The toll for automobiles is currently 200 Won (one way). There are presently eight toll gates in Seoul metropolitan area including five tunnel toll gates. These toll gates are owned and operated by the Bureau of Transportation in Seoul. The toll gates were originally installed to cover the capital costs incurred for tunnel construction. These tunnels provides access to the CBD from southern and northern Seoul. Some of these tunnels also provide for through trips. Among five tunnels, three tunnels (1st Namsan, 3rd Namsan and Geomwha) are the most heavily traveled tunnels in Seoul. Hence, peak-period congestion on these tunnels is substantial. Evidence of these congested situations is shown in Table V-2. The number of lanes in tunnels ranges from one to five lanes. The other tunnels and roadways where tolls are installed are usually not congested during peak hours, unless accident or construction delays are

encountered. It should be mentioned here that there would be traffic impacts from the toll increase. A volume of traffic may decrease as a result of toll increase, but the magnitude of volume decrease may not be significant due to relatively little increase in toll charge and no viable alternative roads.

Table V-2   Toll Gates and Lanes

Toll gates	Number of Machines	Number of lanes Inbound	Outbound	Daily traffic volumes
1st Namsan	4	2	3	37,600
2nd Namsan	2	1	1	10,000
3rd Namsan	10	5	5	60,100
Bookak	4	2	2	25,100
Geomwha	8	4	4	40,500
Yongbigyo	4	2	2	23,800
Nambusoonwhan	8	4	4	19,300
1st Gangnamro	Collected by persons	1	1	Not available

Source: Division of Toll Gates in Transportation Bereau of Seoul.

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Figure V-5 Locations of Toll Gates at Major Tunnels and Bridges

Central Business District

SCALE = 1 : 40000

◯ Locations of Toll Gates
   at Major Tunnels

△ Locations of Toll Gates
   at Bridges

g. Toll Charge at Bridge Entrances

     This alternative involves installation of toll gates at
the five bridge entrances.   500 Won (62.5 U.S. cents) would
be charged for each vehicle entering the bridges during
morning peak hours.   There are thirteen major bridges
connecting suburban areas to the CBD.   Among these thirteen
bridges, five bridges play an important role in providing
access to the CBD during the morning peak hours. As shown in
Table V-3,   these five bridges are extremely congested during
the morning peak hours.

     Table V-3   Traffic volumes on Major Bridges

Bridges	Average daily traffic	Hourly traffic per one lane during peak hrs.
Jesam	119,745	1,248
Seoul	105,119	1,167
Banpo	80,587	*
Seongsoo	80,291	1,388
Jamsoo	76,423	1,150

Source: Josun Newspaper, January 29, 1983.

     Automobiles amount to 74 percent of all traffic in these

five bridges, and trucks and buses represent 15.5 percent and 10.5 percent respectively. Since toll gates have been installed only in Seongsoo bridge to cover the construction cost incurred when the bridge was completed, Seongsoo bridge is excluded for the toll charge.

3. Objectives and Criteria Proposed

While the previous section describes the ARZ alternatives, the purpose of this section is to identify the underlying objectives. The set of objectives should provide a framework within which the performance of the alternatives can be evaluated. The objectives selected should be defined so as to represent all those charateristics of an alternative which may be considered desirable or undesirable.

The objectives should also include those characteristics of a project which may improve or lessen the likelihood of approval and implementation. Performance measures provide criteria for evaluating the success with which alternative ARZ schemes meet the objectives. The criteria for selection of these measures include the accuracy with which they reflect the relevant objectives. In formulating the problem

in a multicriteria context, objectives should be quantified to the fullest extent possible in the form of costs and benefits. A method to achieve this quantification is to express each objective in terms of a set of measurable criteria.

As was stated previously, the development of objectives for the evaluation of ARZ schemes is based on the surveys and interviews conducted with city officials in Seoul. It was decided to exclude the accident and energy minimization objectives as these objectives not only received the lowest ranking but also are difficult to estimate due to the scarcity of information. Goals related to secondary effects were not considered here. Four major goals are identified. Goal one deals with minimizing capital and maintenance costs. Goal two implies reducing travel time for auto, taxi, bus and subway. Goal three focuses on minimizing undesirable impacts of the transportation system such as pollution. The fourth goal involves objectives which are responsive to the political and institutional system within which they are implemented. These goals, along with objectives and criteria, are described below. The goals here can be used as a general and abstract of desired transportation situations. The objectives are specific and operational statements of goals.

(i)   Goal: Minimize the net costs of improving the quality
              of transport service

Objectives   Performance Measures

Minimize capital costs   Cost (monetary)

Minimize current operating   Cost (monetary)
Costs
Maximize Revenues   Monetary value

(ii). Goal: Improve the quality of transport service

Objectives   Performance Measures

Reduce travel time   OVTT saved for auto
for auto & taxi   OVTT saved for taxi
                                        OVTT saved for bus
Reduce travel time   IVTT saved for auto
for public transit   IVTT saved for taxi
                                        IVTT saved for bus
                                        (OVTT=Out-of-vehicle-
                                        travel time
                                        IVTT=In-vehicle-

(iii).   Goal: Minimize the undesirable impacts of the
                   transport system

Objectives   Performance Measures

Reduce pollution   Pollution level
                                        measured on ordinal
                                        scale for auto, taxi
                                        and bus.

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(iv). Goal: Minimize political obstacles to the
            alternatives

Objectives   Performance Measures

Minimize   Institujtional
institutional   preference index
obstacles

Minimize enforcement   Enforceability
problems   index

(1) Capital Cost Borne by City

     For most alternatives, there are capital costs involved

in constructing and purchasing the system.   The components

may include fixed and variable costs borne by the city

government.   Since the alternatives examined are

transportation system managemnt (TSM) type of actions, no

major capital cost is likely to be involved.   For the

alternatives examined, the following costs are considered

capital cost:

     - Purchase of parking meters
     - Purchase of public transit priority signals
     - Construction cost of toll gates at bridges
     - Cost associated with signs and markings.

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Having discussed the types of capital costs relevant for
ARZs, it seems appropriate to describe the capital costs for
each scheme in detail.

a. Off-Street Parking Fee Increase

No capital cost is necesary.

b. Extensive Parking Meters in Core

Parking meters would be purchased at W 160,000 ($200) per
meter. five hundreads parking meters are needed. Marking and
installation costs would be W 10,000 per meter.

c. Public Transit Priority Signals

The existing 13 electric signals would be converted into
the public transit priority signals. Signs and markings are
also needed. City officials estimated the capital cost to be
W 5000,000 per priority signal.

d. Core Area License Scheme

Signs and Markings would cost W 1,000,000 ($1,250) at
each entrance point. Signs and markings are necessary for 13
entrance points. Police staff estimated that five additional

patrol cars would be needed to effectively enforce this scheme within the core area. Each vehicle would cost W 7 million (Hyundai Automobile Manufacturing Company, 1983).

e. Core Area License Scheme with Bus Improvement

The area extent of bus improvement generally corresponds to that for area license within the core area. The transit improvement can also be provided on routes leading to the core from various parts of the metropolitan area. The main type of service improvement considered is an increase in bus capacities and a reduction in wait times for buses. This improvement can be achieved by decreasing "headways" and improving the route structure. Accordingly, an increased number of buses are needed. Service would be provided every five minutes. This is a significant improvement given that the average headway in the core area was between 10 and 15 minutes (Korean Institute of Science and Technology, 1978). The number of buses which would be required is estimated from these service characteristics. If service frequency on peak-hour routes in the core area were doubled in order to obsorb modal shifts from automobiles and taxis, it would require a doubling of the bus fleet. Capital costs associated with a doubling of bus fleet would be borne by private bus companies. Capital costs in this sense are not relevant on the part of city government. Put differently,

costs to society as a whole are to be ignored.

f. Toll Increase for Tunnel Gates

The capital costs to be considered include posting new sign boards. New sign boards would cost W 800,000 per each tunnel. Labor costs involved in erecting new sign boards are included in this amount.

g. Toll Charge at Bridge Entrances

It was estimated by public officials that four toll gates would be required for each bridge. As was stated previously, Seongsoo bridge is excluded because toll gates are already in operation. The capital costs associated with constructing a toll gate and purchsing a automatic toll machine were estimated to be W 10,000,000 (based on a discussion with officials in Transportation Division, 1983). Overall, the capital costs associated seven ARZ alternatives are summarized as Table V-4.

Table V-4   Summary of City-Born Capital Costs of ARZs

ARZs	Capital Costs (million won)
a. On-Street Parking Fee	0
b. Parking Meters in Core	80
c. Public Transit Signals	65
d. Core ALS	48
e. Core ALS with Bus Improvement	41.5
f. Toll Increase for Tunnel Gates	4
g. Toll Charge at Bridge Entrances	160

(2) Current Operating Costs Borne by City

        Associated with each of ARZ alternative discussed above
are costs of maintenance.   In contrast to capital costs, the
current operating costs are incurred after the system is in
operation.   The actual costs would depend on how each alternative is
implemented and the way it fits in the current administrative
structure.   For the sake of calculation, current operating costs

would be expressed on an annual basis.

a. Off Street Parking Fee increase

Administrative Cost

Some administrative cost includes the notifying and monitoring this policy. However, these types of administrative work can readily be handled by existing staff. Thus administrative cost is not required.

Enforcement Cost

No major enforcement cost would be necessary. Given that higher fees tend to put more pressure on illegal parking places elsewhere, some enforcement staff might be required to control the illegal parking. It is assumed that enforcement costs due to the illegal parking are negligible.

b. Parking Meters in Core Area

Administrative Cost

Two additional staff: w 3 mil. per person-year.

Enforcement Cost

It was estimated by transportation division that 30 enforcement staff would be required to enforce this scheme. City government currently pays w 200,000 per person-month. It would cost w 2.4 mil. per person-year. it should be noted

that there are presently 10 enforcement staff in the core area to control parking meters.

c. Public Transit Priority Signals

Administrative Cost

City officials noted that public transit priority signals can be controlled and monitored by the staff currently available in the Traffic/Control Center in Seoul.

Enforcement Cost

Five enforcemnt staff for each system would be needed to enforce this scheme. Total of 65 staff for entire locations would be paid at w 200,000 per person-month.

d. Core ALS

Administrative Cost

(i) Two additional staff would be required centrally to control and monitor this scheme. It would cost w 3 mil. per person-year.

(ii) License printing also involves administrative cost. Total trips that are likely to be affected by the ALS was estimated to be 321,747 (see Appendix). Since a modal shift is most likely to occur after implementaiton, it is assumed

that only 75 percent of total peak hour trips is taken into consideration. A licence would be sold every six month. A multicolor license with adhesive backing would cost w 30 per licence (interviewed with two printing companies in Seoul, 1983). An estimated sale rate of 90% is assumed.

Enforcement Cost

Fifty additional staff would be paid at w 2.4 mil. per person-year. This scheme also would require 5 additional patrol cars each operating 100 km per day at w 100 per km. (This estimate is based on the information provided by police Bureau of Seoul). Also 10 additional police staff would be needed to effectively perform the duties associated with patrols. The police staff would be paid at w 3.6 mil. per person-year. 315 working days are assumed.

e. Core ALS with Bus Improvement

Administratic Cost

It was estimated that four additional staff would be necessary. As with the core ALS, two additional staff would be used centrally to control the ALS. The Public Transport Section in Transportation Bureau needs two additional staff to control and monitor the bus improvement program. Each staff would be paid at w 3 mil. per year.

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Enforcment Cost

City officials estimated that 80 enforcement staff Twould be necessary at the minimum level. The duty of 50 staff includes enforcing the ALS and the remaining 30 staff involves enforcement related to the bus improvement program.

These staff would be paid at w 2.4 mil. per person-year. The enforcement cost concerning patrol car operations is essentially the same as for the Core ALS. The costs associated with patrols are the same as for the Core ALS.

f. Toll Increase for Tunnel Gates

Administrative Cost

No administrative cost would be necessary.

Enforcement Cost

No enforcement cost would be necessary

g. Toll Charge at Bridge Entrances

Administrative Cost

Three staff would be needed for each bridge. Their primary duty involve controlling toll machines and work associated with toll collecitons. Each staff would be paid at w 2.4 mil. per year.

enforcement Cost

No enforcement cost would be necessary.

Table V-5   Summary of City Born Current Operating and
                   Enforcement Costs (million Won)

ARZs	Administrative Cost	Enforcement Cost	Total Cost
a. Parking Fee Increase	0	0	0
b. Parking Meter	6	72	78
c. Pulbic Transit Signals	0	156	156
d. Core ALS	19	171.5	190.5
e. Core ALS with Bus	25	243.5	268.5
f. Toll Increase for Tunnels	0	0	0
g. Toll Charge at Bridges	7.2	0	7.2

c. Revenue to the City

A major impact of the pricing-related ARZ schemes is
that they generate more revenues than costs. Because large
numbers of cars remain on the road, paying the charged price,
revenues are quite large compared to capital and maintenace
costs. The revenues can be generated from five ARZ schemes
proposed. In calculating the revenues, several factors
should be taken into account: the number of modal shifts,
the number of time shifts and peak-hour factors.

b. Parking Meters in the Core

The daily revenues collected from the parking meters
currently installed in the core area amount to w 258,954
which is equivalent to w 1811 per meter (Parking Division in
transportation Bureau, 1983). The annual revenues can be
derived on the basis of these daily revenues.

d. Core ALS

The CBD bound trips during morning peak hours that are
likely to be affected by the ALS was estimated to be 321,747
per day. Since some drivers will switch modes, change the
time period of their trips, or eliminate the trip entirely, a
modal shift of 25 percent was entered into the calculation.

The   25 percent is also based on the results of a logit model
employed in deriving the travel times.

e. Core ALS with Bus Improvement

The   revenues   to   be generated   from   this   scheme   are
essentially the same as for the core ALS.

f. Toll Increase for Tunnel Gates

The   revenues resulting from the toll increase can   be
calculated based on the daily revenues presently collected at
tunnel gates.   The daily revenues collected at tunnel   gates
are presented in Table V-6.

Table V-6   Daily Revenues Collected at Tunnels

1st namsan	3638
3rd Namsan	5804
Geomwha	3660

Source: Tunnel division in Transportation Bureau of Seoul, 1983.

In   order   to calcalate revenues to be collected   during
the   morning peak hours,   it is necessary to apply   a   factor
which   represents   a ratio of the trips moring peak hours   to

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the trips during the entire day. A ratio of 0.4 was used for
this purpose.

g. Toll Charge at Bridges

Average daily traffic volumes were used to calculate the
annual revenues. The ratio used for morning peak hour
revenue to that for the entire day is 0.4. Based on the
traffic volumes for four bridges shown in Table V-3, annual
revenues turned out to be 29,193 million Won.

Table V-7   Revenues Resulting from Five ARZs

ARZs	Annual revenues (mil. Won)
Parking Meters	285
Core ALS	76013
Core ALS with Bus Improvement	76013
Toll Increase for Tunnel Gates	4782
Toll Charge for Bridges	24283

Table V-7 summarizes revenues resulting from five ARZ
alternatives. The magnitude of revenues appears to be far
greater than capital and maintenance costs.

(4) and (5) Travel Time Saving for Auto, Taxi and Bus

The ARZ schemes proposed are designed to reduce the travel time by imposing some restricitions. In order to develop insights concerning likely changes in travel time, one needs to predict travel flows in an equilibrican state in the transportation system. The supply and demand functions should provide a basis for predicting flows in the following way. A flow pattern F, consists of the volume using the system V, and the level of service L, experienced by travelers. For a particular transportation system T and activity system A, the flow pattern which will actually occur, Fo = F(T,A), is the volume Vo and level of service Lo, determined as the equilbrium solution to the supply and demand relations:

$$
\left.
\begin{array}{l}
L = S(T,\ V) \\
\\
V = D(A,\ L)
\end{array}
\right\} \longrightarrow (Vo,\ Lo)
$$

In other words, by specifying the transportation system T and the activity system A the supply and demand for transportation can be defined. The use of supply and demand representation to reach a prediction of travel flow is called

an "equilibrium ·solution".

In view of the prediciton of equilibrium flow, Transportation Teaching Package 2.1 (TTP 2.1) was used to predict the equilibrium flow which leads to the estimation of the change in travel time. TTP 2.1, a computer pakage developed by Tsunokwan and Manheim (1981), models transportation supply through network representation and demand using origin-destination flows and a choice model for modal split. Once the supply demand relations are defined, an equilibrium solution is approximated and travel impacts assessed on the basis of those solutions.

The particular demand model used in this analysis is of the multinomial logit type, calibrated on observed travel decisions of individuals living in the Jongro corridor in Seoul by maximum likelihood estimation (Jaimu Won, 1980).

The general form of multinomial logit model can be expressed as follows:

$$P(i: A) = \frac{e^{V(x_i, s_t)}}{\sum_{j \in A} e^{V_j(x_j, s_t)}}$$

P(i:A) = probability that traveler "t" will select
         alternative "i" from the set of available
         alternatives A .

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x_i = a vector of attributes of alternatives "i"
(e.g., level of service variables)

s_t = a vector of socioeconomic characteristics
describing traveler "t" (e.g., income,
occupation, etc.)

$V(x_i, s_t)$ = the utility of consumer "t" associated
with the selection of alternative "i".

The parameters of the utility functions are estimated using observation of actual choices. The dependent variables of the models travel choices made. The independent variables are invehicle-travel-time (IVTT), out-of-vehicle-travel-time (OVTT) and out-of-pocket-travel-cost (OPTC). The models are used to predict the magnitudes of changes in travel behavior (relative to present conditions) resulting from a particular change in independent variables from present levels.

Table V-8 shows the parameters of the logit model calibrated for the Jongro corridor. Out-of-vehicle-travel-time appears to be more onerous than in-vehicle-travel-time. Travelers living around Jongro corridor are also much more sensitive to out-of-pocket-travel-cost

Table V-8   Logit Parameters for Jongro Corridor

Mode	Constant	IVTT	OVTT/Dist.	OPTC/Income
1	0.00000	-0.02600	-0.05700	-0.04200
2	2.75000	-0.02600	-0.05700	-0.04200
3	1.83000	-0.02600	-0.05700	-0.04200

Note: IVTT: In-Vehicle-Travel-Time (includes roadway travel time (zone-to-zone) for auto mode) or transit running time)).

OVTT: Out-of-Vehicle-Travel-Time (includes terminal time at origin and destination for both auto and transit).

OPTC: Out-of-Pocket-Travel-Cost (includes parking cost at destination for auto mode and fare for transit mode).

Mode 1: Automobile
Mode 2: Bus
Mode 3: Taxi

The transportation supply was modeled in TTP 2.1 using network charateristics of the Jongro corridor such as links, lines, paths and volume-delay curves. Link characteristics include distance, lanes, volume-delay curve for in-vehicle time and out-of-vehicle time, and link cost. Line data define the links over which the line is operating and the line headway. Path data are input by destination by mode, and they specify travel paths in terms of link-line pairs and path costs.

An incremental assignment technique is used for the travel flow prediction in TTP 2.1. The volume to be assigned for a particular iteration is divided according to the modal split, and assigned to links on the specified minimum path for each mode. The network serivce level is updated, and the next iteration is considered. The overall procedure built in TTP 2.1 appears in Figure V-6.

Figure V-6   Procedure built in TTP 2.1

Base case   ┌─────────────────┐ ┌─────────────────┐ ┌─────────────────┐
                   │ Transportation │ │ LOS: O-D   │ │ Demand   │
                   │ system: │←→│ Cost   Volume   │←→│ Model: │
                   │ Links   │ │ Volume/   │ │ Paremeters   │
                   │ Paths   │ │ Delay   │ │ of Logit   │
                   │ Lines   │ │ Curves   │ │ Model   │
                   └─────────────────┘ └─────────────────┘ └─────────────────┘

Test of a   ┌─────────────────┐
Policy   │ Revise LOS   │←─────────────────┐
                   │ variables   │   │
                   └─────────────────┘   │
                            │   │
                   ┌─────────────────┐   │
                   │ Modal Split   │   │
                   │ Impact   │   │
                   └─────────────────┘   │
                            │   │
                   ┌─────────────────┐   │
                   │ Service   │   Feedback│
                   │ Funcitons   │   │
                   └─────────────────┘   │
                            │   │
                   ┌─────────────────┐   │
                   │ Incremental   │   │
                   │ Assignment   │   │
                   └─────────────────┘   │
                            │   │
                   ┌─────────────────┐   │
                   │ New LOS   │←─────────────────┘
                   │ Variables   │
                   └─────────────────┘
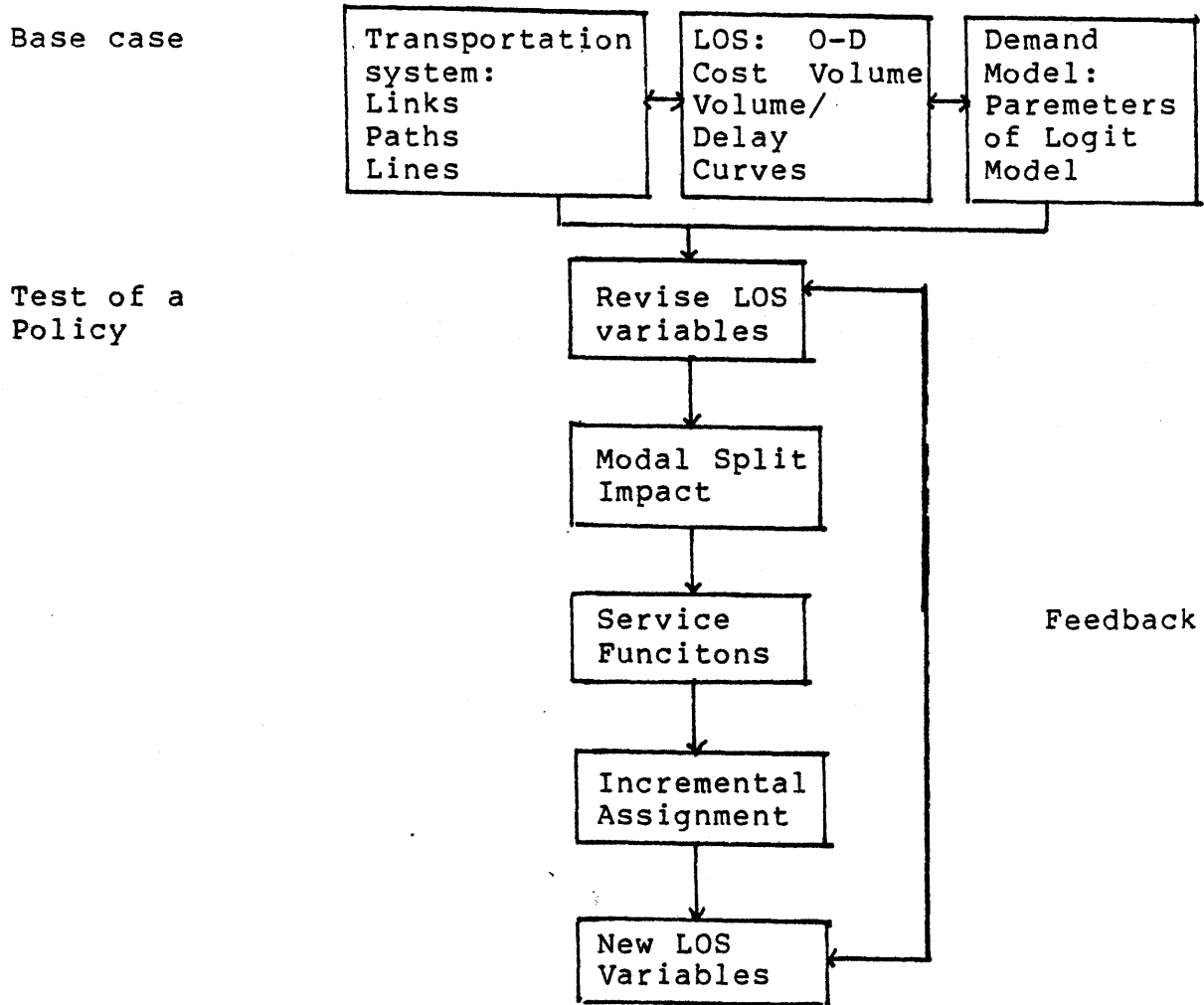
* LOS: Level-of-service

Seven alternative ARZ policies have been analyzed using TTP. The results are presented in terms of the reduction in travel time for bus, taxi and auto. Only three modes are examined in each case because of TTP's built-in computational limitation. The estimated savings in travel time are based on data representative of the Jongro corridor, and in a strict sense, therefore, are applicable only to the Jongro corridor. However, the Jongro corridor has been shown to be similar in its broad charateristics to the rest of the CBD. Further, when cosidering travel charateristics within the outer ring area, the characteristics of the Jongro corridor have been shown to correspond to large western and southern parts of the CBD (Jai Mu Won, 1980). The levels of traffic congestion, parking availability, and transit service generally represent uniform patterns throughout the entire CBD. Therefore, the underlying assumption here is that the travel characteristics of Jongro corridor are similar to those of the entire CBD.

Table V-9, shows the results of the travel times after ARZs become effective. Annual time savings presented in Table 5-10 are derived from simulated individual travel times during the peak hours in Table V-9.

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Table V-9   Simulated Individual Travel Times During Peak
             Hours After ARZ Alternatives Using TTP2.1 Flow
             Prediction Models

Out-of-Vehicle-Travel Times (Minutes)

Modes	Base	a	b	c	d	e	f	g
Bus	10	10	10	11	12	9	10	11
Taxi	15	13	13	12	10	12	12	13
Auto	8	3	6	6	5	5	7	7

In-vehicle-Travel Times (Minutes)

Modes	Base	a	b	c	d	e	f	g
Bus	38	38	37	34	34	34	35	35
Taxi	28	28	26	26	22	23	26	25
Auto	24	22	20	20	18	19	20	22

ARZ Alternatives: (a) On-Street parking Fee Increase,
(b) Parking meters in Core, (c) Public Transit priority
Signals, (d) Core Area License Scheme, (e) Core ALS
with Bus Improvement, (f) Toll Increase for Tunnel
Gates, (g) Toll Charge at Bridge Entrances.
Base:These are the travel times when no action is taken.

    The simulated travel times derived from the logit models

are generally consistent with a priori expectation. The logit

models imbeded in TTP.2 turned out to be sensitive to the

changes in values of OVTT and IVTT.   For example, OVTT for

auto decreases from 8 minutes to 3 minutes if alternative 1 (On-Street parking Fee Increase) were to be implemented. Area License Schemes apperar to be most effective in reducing both OVTT nad IVTT for all modes.

Table 5-10   Simulated Annual Time Savings for Three Modes Using TTP2.1 Flow Prediction Models

Out-of-Vehicle-Travel Times (Minutes)

Modes	a	b	c	d	e	f	g
Bus	0	0	+315	+315	-315	0	+315
Taxi	-630	-630	0	-1575	-945	-945	-630
Auto	-1575	-630	0	-945	-945	-315	-315

In-Vehicle-Travel-Time (Minutes)

Modes	a	b	c	d	e	f	g
Bus	0	-315	-1260	-1260	-1260	-945	-945
Taxi	0	-630	+630	-1890	-1575	-630	-945
Auto	-630	-1260	+630	-1890	-1575	-1260	-630

* 315 working days per year are assumed.
Note: "t" means increase in travel time after ARZs become effective. "-" means decrease in travel time after ARZs become effective.

Table V-10 was constructed from the Table V-9. Annual working days (315 days) are multiplied by teh differences in

individual travel times between base case and each of the proposed alternative. Travel times listed under the "Base" indicate the current travel times taken from the origin to the destination when no action is taken.

(6) Reduction in Pollution

So far, we have only considered only those objectives for which monetary values and travel times can be objectively and accurately assigned. For the last three criteria, there are no quantified data from which to derive the values. For this reason, one has to resort to the judgement . of the decision maker or expert. The level of pollution can be measured through such measures as HC and CO, but these measures may be very difficult or costly to obtain.

Given the fact that the citeria to be followed are not easily quantifiable, it seems necessary to employ some weighting method. After the concepts of weighting methods were critically examined, it was decided to use an approximate weighting method advanced by Churchman and Ackoff. The Churchman and Ackoff technique (CAT) has been described in numerous texts, and successful applications have been reported in the field of operation research and

management science (Turban and Metersky, 1971; Stimson, 1969).

The CAT consists of five steps to be carried out by the decision makers or chosen panel of experts (henceforth called "decision makers"):

(1) ranking the objectives by importance level. Let ol represent the outcome that is judged to be the most important, o2 is the next, o3 the next, and o4 the last ;

(2) Tentatively assign the value 100 to the most valued outcome and assign values that initially seem to reflect their relative values to the others. For example, the deciiosn maker might assign 100,80,50 and 30 to ol,o2,o3 and o4 respectively. Call these tentative values vl,v2,v3, and v4 respectively. These are to be considered as first estimates of the true values of V1,V2,V3, and V4;

(3) now make the following comparison. ol versus (o2 and o3 and o4) i.e., if the decision maker had the choice of obtaining ol or rhe combination of ‧ o2,o3, and o4, which he would select? Suppose he asserts that ol is preferable. Then the value of vl ahould be adjusted so that V1 > v2 +v3 + v4;

(4) now compare o2 versus o3 and o4. Suppose o3 and o4 are preferred. The further adjustment of the values is necessary.;

(5) evaluations are completed. It may be convenient, however, to normalize these values by dividing each by $\sum_{j} v$.

In order to establish a degree of relative importance and to provide a test of consistency in the numerical weighting to follow, the same public officials in Seoul city government were interviewed to make a series of comparison. The public officials in the Urban Planning and Police Department were asked to "role play", assuming the point of

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view of the Transportation Bureau, in order to provide ratings they thought were most representative of the Transportation Bureau's position. The initial ratings were obtained as displayed in Table V-11. The public officials were asked to provide ratings on the effects of ARZ alternatives on the reduction of the pollution. They were requested to give a 100 value to the most effective ARZ alternative and 0 value to the worst effective one.

Table V-11   Public Officials' Evaluation on Pollution Reduction

Reduction in Pollution Level	a	b	c	d	e	f	g
Values	23	36	51	100	75	44	68

Alternatives: (a) off-street Parking Fee Increase, (b) Extensive Parking Metera, (c) Public Transit Priority Signals, (d) Core Area License Scheme, (e) Core Area License with Bus Improvement, (f) Toll Increase for Tunnel Gates, (g) Toll Charge at Bridges.

A series of comparisons were conducted with the panel members in the manner described in Table V-12. It was extremely difficult to do comparisons because most public officials interviewed were not cooperative after a couple of meetings. The evaluations were tentatively completed as follows:

v1	v2	v3	v4	v5	v6	v7
100	75	68	51	44	36	21

Two weeks later, the same officials were asked to provide second set of ratings. The results of second ratings showed that the consensus was in favor of v2 plus v7 over v1 although the original assessment was 96 versus 100. A necessary adjustment was made such that the ratings coincided with the majority decision. v2 was arbitarily increased from 75 to 80. Since panel members decided that v3 is greater than the sum of v4 and v7, v3 was increased from 68 to 74.

.

Table V-12   The CAT for the Evaluation of Pollution Reduction

Comparisons	Decision			Majority Decision (c:consitency i: inconsistency)
	Yes	No	Equal	
v1>v2+v3	2	14	0	c
v1>v2+v4	2	13	1	c
v1>v2+v5	4	19	2	c
v1>v2+v6	7	9	0	c
v1>v2+v7	5	9	2	i
v1>v2+v3+v4	0	16	0	c
v1>v2+v3+v5	0	16	0	c
v1>v2+v3+v6	0	16	0	c
v2>v3+v4	1	15	0	c
v2>v3+v5	3	12	1.	c
v2>v3+v6	1	13	2	c
v2>v3+v7	6	10	0	c
v2>v3+v4+v5	0	16	0	c
v2>v3+v4+v6	0	16	0	c
v3>v4+v5	0	15	1	c
v3>v4+v6	5	11	0	c
v3>v4+v7	12	4	0	i
v3>v4+v5+v6	0	16	0	c
v4>v5+v7	2	12	2	c
v5>v6+v7	10	5	1	c

The next decision, the third, confirmed with the second ratings.   Therefore, final ratings, based on the procedure described previously, are the same as the second set of ratings.   The final ratings were followed by normalization. The normalization was done by dividing each value of v_j by the summation of v_j.

v1	v2	v3	v4	v5	v6	v7
0.246	0.197	0.182	0.126	0.108	0.089	0.052

(7) Institutional Preference

The feasibility of an ARZ alternative will largely depend upon institutional factors. The willingness and ability of government to carry out certain ARZ alternatives, in general, are likely to be important factors in determining implementability. The feasibility of implementation will also depend on the ability of the agencies to control and operate ARZ alternatives in ways which meet the established goals and objectives (Jaimu Won, 1982). In view of this, institutional preference or attitude toward each ARZ policy should somehow be reflected in the evaluation process.

As in the pollution criterion, ratings on instituitonal preferences with regard to ARZ alternatives were elicited from the same public officials. The panel members gave ratings based on their own perspectives and experience. The initial ratings were obtained as follows:

	a	b	c	d	e	f	g
Institutional Preference	86	78	62	49	42	100	35

Based on the initial ratings, the following consistency tests were performed. After adjustment of values, the susequent tests were conducted using the adjusted values. Table V-13 shows the results of consistency tests.

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Table V-13   Institutional Preference

| Comparisons | | Decision | | Majority Decision |
	Yes	No	Equal	
v1>v2+v3	0	16	0	c
v1>v2+v4	1	14	1	c
v1>v2+v5	2	14	0	c
v1>v2+v6	5	9	1	c
v1>v2+v7	3	11	2	c
v1>v2+v3+v4	0	16	0	c
v1>v2+v3+v5	0	16	0	c
v1>v2+v3+v6	0	16	0	c
v2>v3+v4	0	16	0	c
v2>v3+v5	2	14	0	c
v2>v3+v6	0	15	1	c
v2>v3+v7	2	12	2	c
v2>v3+v4+v5	0	16	0	c
v2>v3+v4+v6	0	16	0	c
v3>v4+v5	2	14	0	c
v3>v4+v6	4	12	0	c
v3>v4+v7	6	10	0	c
v4>v5+v6	2	14	0	c
v4>v5+v7	6	10	0	c
v4>v6+v7	4	11	1	c

* c: Consistent with initial ratings

It is interesting to note that all comparisons turned out to be consistent with the initial ratings. The institutional preferences rated by public officials should be viewed as opinions at a time when the survey was conducted. Institutional preferences may change over time due to a host of other factors such as pressures or education. The result of the normalization follows:

v1	v2	v3	v4	v5	v6	v7
0.221	0.190	0.173	0.137	0.108	0.193	0.077

(8) Enforceability

The enforcement is one of the most critical factors in the success of ARZ types of transportation policies. The same panel members were used to provide ratings on the enforceability. Public officials belonging to Police Department were more knowledgeable about the enforceability with respect to each ARZ scheme. The initial ratings obtained are as follows:

	a	b	c	d	e	f	g
Enforceability	91	69	61	47	32	100	56

The second ratings showed that inconsistency occured for v3 versus v6 and v7 where v3 was preferred to the sum of v6 and v7. Thus v3 was increased from 69 to 77. With this adjusted value, the third ratings revealed that the panel members voted in favor of v5 and v6 over v1 by a 11 to 5 majority. V5 was, therefore, raised from 56 to 59. A consensus was reached at the fourth stage.

	v1	v2	v3	v4	v5	v6	v7	v_j
V	100	91	77	62	59	45	31	
Normalized Values	0.215	0.196	0.165	0.133	0.127	0.097	0.067	1

Having derived the ARZ preference weights for each of

the three unquantifiable criteria, it is also necessary to calculate weights for twelve criteria themselves. The weights for the twelve criteria are of particular importance for conducting empirical analyses in the next chapter.

Since there are twelve criteria to be weighted, the method employed in deriving weights for the three criteria is not particularly suitable. Churchman and Achoff suggest more relevant alternative procedure for case where there are more than seven criteria involved. The alternative procedure is described as follows:

(i) Rank the entire set of criteria in terms of preference without assigning quantitative values.
(ii) Selecet at random one criteria from the set. Let cl represent this criteria'. Then, by random assignment subdivide the remaining set of criteria into groups of no more tham five, and preferably into groups of approximately equal size. Each outcome other than cl should be included in one and only one group.
(iii) Add cl to each group and assign the value of 1.00 to it (vl = 1.00)
(iv) Use the method employed in deriving the rankings for unquantifiable criteria to obtain unstandardized values for the criteria in the groups formed in step 3 of this procedure.
(v) Compare the rankings obtained from steps 2 through 4 of this procedure with those obtained by the method employed in deriving the weights for unquantifiable criteria. If the rank orders differ, reconsider ranking and if necessary proceed again from setps 2 to 4 of this procedure.
(vi) Once consistent results are obtained, normalize the values obtained in step 5 of this procedure by dividing the value assigned to each criteria by the sum of the values assigned to all the criteria.

The procedure just described can be applied to the

derivation of weights for twelve criteria. The initial
ranking of the criteria by public officials was requested.
An average of all the values for each criteria was calculated
for the sixteen public officials and these ratings become the
starting point of adjustment. The initial rankings are shown
as:

Criteria	Ranking
c1	7
c2	6
c3	5
c4	12
c5	11
c6	2
c7	10.
c8	8
c9	1
c10	9
c11	3
c12	4

c2 is selected at random and the remaining criteria are
assigned at random to four groups as follows:

(a)	(b)	(c)	(d)
c7	c6	c1	c3
c12	c9	c11	c10
c4	c8	c5	c2
c2	c2	c2	

Using the same method as one employed in deriving the
weights for the three unquantifiable criteria (as shown in
Table V-11), The following initial results were obtained.

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(a)	(b)	(c)	(d)
v7 = .30	v6 = 2.50	vl = .50	v3 = 1.10
v12= 1.75	v9 = 3.50	v11= 1.75	v10= .65
v4 = .00	v8 = .75	v5 = .25	v2 = 1.00
v2 = 1.00	v2 = 1.00	v2 = 1.00	

The procedure described in Table V-11 was used to check
the consistencies with the help of the same public officials.

$v7 > v12 + v4$

(a) $v7 > v12 + v2$

$v7 > v4 + v2$

$v12> v7 + v2$

$V12> v4 + v2$

$V12> v7 + v4 + v2$

$V6 > v9 + v8$

$v6 > v8 + v2$ .... Inconsistency

(b)

$V6 > v9 + v2$

$V9 > v6 + v8$

$V8 > v6 + v2$

$vl > v11 + v5$

$vl > v11 + v2$

(c)

$V1 > v5 + v2$

$v11> v5 + v2$ .... Inconsistency

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$$v11 > v1 + v2$$

$$v2 > v1 + v11$$

$$v3 > v10 + v2$$

(d) $$v10 > v3 + v2$$

$$v2 > v3 + v10$$

A series of comparisons were offered to the public officials. Two inconsisencies occured in group (b) and (c) respectively. Two-third of public officials felt v9 to be less than the summation of v6 and v8 in group (b). They also suggested that v9 should be decreased from 3.50 to somewhere around 2.80. Of the sixteen offcials interviewed, ten officals agreed that v11 in group (c) should be at least the same as the summation of v1 and v2. Thus v1 was increased from .50 to .75 and no further objection was expressed. No consistencies occured at fourth interview. It was unnecessary to conduct further interview for this reason. The final values obtained were normalized in Table V-15.

Table V-14   Normalized Weights for 12 Criteria

Criteria	Normalized Weights
c1	.056
c2	.073
c3	.080
c4	.000
c5	.019
c6	.182
c7	.021
c8	.056
c9	.202
c10	.047
c11	.136
c12	.128

It should be noted that it was extremely difficult to articu late weights of the public officials because they were usuall busy with routine work and were not willing to participate in the thinking process for deriving the rankings and comparisons. They have little understanding about the rrequirements of the technique or little appreciation of the benefits which whould accrue from the interview.

The Churchman-Ackoff technique employed has the advantage that the decisions required of the panel members are rather straightforward and simple. On the other hand, the technique

suffers from the fact that large number of comparisons must be made unless the number of alternatives are small. Furthermore, the values obtained at the final decision may change over time. Therefore, this tequnique should be viewed as an approximate and tentative weighting method.

4. Conclusion

This chapter has examined the relevant ARZ alternatives and criteria within the context of Central Business District of Seoul, Korea. The ARZ alternatives and criteria developed in this chapter will be used for an empirical analysis to be conducted in next chapter.

The central objective of this chapter has been to determine relevant criteria and ARZs in the context of Seoul CBD. The first part of the chapter was devoted to the description of ARZ alternatives including rationale, types and proposed locations. The second part of the chapter discussed the objectives and corresponding criteria. The third part of the chapter was concerned with the quantification of criteria weights. Those criteria which can be quantifiable have been examined using accounting and travel demand models. For the remaining unquantifiable criteria, the Churchman-Achoff method was used to derive the weights.

CHAPTER VI   EMPIRICAL ANALYSES OF THREE MULTICRITERIA METHODS

1. Introduction

With the ARZ alternatives and criteria advanced in the previous chapter, the objective of this chapter is to 1) discuss the underlying theoretical structure of the Concordance Analysis, the Goal-Achievement Matrix and the Compromise Solution; and 2) to conduct the empirical analyses. The ARZ alternatives and criteria examined in the previous chapter will provide a vehicle for conducting the empirical analysis. This will provide the foundation for discussion of limitations and advantages of three methods which is the subject of the next chapter.

2. Concordance Analysis (CA)

a. Theory

This section examines a concordance analysis developed by Roy (1968) and subsequently modified by Van Delft and

Nijkamp (1977), Nijkamp and Vos (1977), and Guigou (1971).
This method is used for selecting one alternative from a set
of alternatives with respect to relevant criteria. Each
criterion is assigned a weight which corresponds to its
relative importance.

The concordance analysis starts with a number n of
alternative sets, denoted by a_i, i = 1, ... n. These
alternatives are evaluated against a set of criteria, c_k =
c_1, c_2, ... c_m. An effect matrix can be expressed as
follows:

$$
v = \begin{bmatrix}
v_{11} & \cdots & \cdots & v_{1n} \\
\vdots & & & \vdots \\
v_{m1} & \cdots & \cdots & v_{mn}
\end{bmatrix}
$$

where a typical element v_{ki} represents the outcome of
the ith alternative. The outcomes of criteria can be
expressed in any reasonable unit of measurement. Both
quantifiable and non-quantifiable criteria could be entered
in this matrix.

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The next step is to provide a weight corresponding to each criterion m. The weight is determined by the preference structure of the decision makers. The weight vector can be represented as follows:

$$W_k = [w_1, \ldots\ldots\ldots, w_m]$$

$$k = 1 \ldots\ldots\ldots\ldots\ldots m$$

where each w_k reflects the relative preference weight attached to criterion m. These weights can be represented on a ratio scale, interval scale, or even cardinal scale. In this way, the method offers considerable flexibility in using non-quantitative information as well as uncertain information. It is assumed that the weights are normalized, i.e., that $W_k = 1$. A weghted effect matrix can be obtained by multiplying each element v_{ki} with its corresponding relative weight wk.

The next step is to make a pairwise comparison between competing alternatives. The preference relationship between the hth and j^{th} sets of n alternatives can be established for each criterion. The relationship between the hth and j^{th} alternatives for a given criterion can be represented as follows:

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h preferred to j ; h > j;

h and j equivalent ; h = j

The concordance set CS$_{hj}$ associated with pair (h, j) is defined as follows:

$$CS_{hj} = (k \mid v_{ki} > v_{kj})$$

One subset consists of all criteria k for which alternative h is preferred to j. The symbol > denotes a preference of alternative i to alterntive j, as far as criterion m is concerned.

The concordance set is expressed in terms of absolute values with respect to alternatives and criteria. The relative value of the concordance set is measured by means of an index. The concordance index is then equal to the sum of the preference weights defined above. To obtain an index which ranges from 0 to 1, the index is divided by the sum of all weights. Thus the concordance index for any pair of alternative sets, h and j can be expressed as follows:

$$CI_{ij} = \frac{\sum\limits_{k \in Chj} Wk}{\sum\limits_{k=1}^{m} Wk}$$

It is assumed that weight vector w are normalized, i.e.,

$$\sum_{k=1}^{m} wk = 1$$

Then, the concordance index is generally expressed as follows:

$$CI_{hj} = \sum_{(k \in C_{hj})} Wk$$

This is the sum of weights with respect to those criteria for

which alternattive a_h outranks alternatives a_j, thus providing a measure of the degree to which the preference weights are in agreement with the dominance of a_h over a_j. The following relationships hold in concordance analysis.

   (i) if Chj = 1,   there is a complete dominance
                     of all criteria of h with
                     respect to j.

  (ii) if Chj = 0,   there is no dominance for any
                     criterion.

The indices derived can be expressed in matrix form of CI with with n x n. Each entry CI_{hj}, h = 1, ..., n; j = 1, ..., n, includes the concordance index with respect to pairwise comcparison of a_h with a_j.

$$CI = \begin{bmatrix} \text{\_\_\_\_} & CI_{12}, & CI_{13}, & \cdots & CI_{1n} \\ CI_{21} & \cdots & \cdots & \cdots & CI_{2n} \\ & \vdots & & & \vdots \\ & \vdots & & & \vdots \\ & \vdots & & & \vdots \\ & \vdots & & & \vdots \\ & \vdots & & & \vdots \\ CI_{n1}, & CI_{n2} & \cdots & CI_{n,n-1}, & \text{\_\_\_\_} \end{bmatrix}$$

The next step is to examine the relative degree of discordance between the various alternative pairs. This measures the degree to which outcomes of alternatives a_h are worse than those of a_j. As was the case with concordance analysis, a discordance index will be established. In order to establish the discordance index, an interval scale common to all k criteria can be defined. This is done by defining a scale such that a certain number of points out of a maximum of 100 is assigned to each criterion (the choice of 100 is arbitrary, and any other number will work equally well). The choice of the number of points to assign to each criteria depends on the level of importance the decision makers wish to attach to the range between the best and worst levels of each criterion. The discordance set DS^{hj} is expressed as follows:

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$$DS^{hj} = (k \mid v^{kh} < v^{kj})$$

The symbol < denotes "not preferred to". The discordance index can be expressed as follows:

$$DI_{hj} = \max_{(k \in Dhj)} \frac{\left| v^{kh} - v^{kj} \right|}{DI_{kmax}}$$

where the expression $\left| v^{kh} - v^{kj} \right|$ denotes the absolute differenc between the effects of alternative a_i and a_j. The following relationship holds in discordance anaysis.

(i) if dhj = 1, there is maximum discordance
   between two alternatives.

(ii) if dhj = 0, there is minimum discordance
    between two alternatives.

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A discordance matrix can thus be established as follows:

$$
\begin{bmatrix}
\overline{\quad} & DI^{12} & \cdots\cdots\cdots & DI^{1n} \\
DI^{21} & \cdots\cdots\cdots\cdots & & DI^{2n} \\
\vdots & & & \vdots \\
\vdots & & & \vdots \\
\vdots & & & \vdots \\
\vdots & & & \vdots \\
\vdots & & & \\
DI^{n1} & DI^{n2} \quad \cdot\cdot \quad DI^{n,n-1} & \overline{\quad}
\end{bmatrix}
$$

The next step is to eliminate less favourable alternatives. Roy (1968) and Delft (1977) have shown two methods by which elimination can proceed. Firstly, by defining a critical value for both concordance and discordance indices (in general, the average value of all indices), one may state that alternative a_h outranks a_j if and only if $c_{hj} > \bar{c}$ and $d_{hj} < \bar{d}$ with respect to each criterion. These relatoinship can be expressed as follows:

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$$c^{hj} \geq \bar{c}$$
$$d^{hj} \geq \bar{d}$$

Alternatively, one may construct a zero-one concordance dominance matrix G with elements g^{hj}, which can be expressed as follows:

$$g^{hj} = 1, \text{ if } c^{hj} \geq \bar{c}$$
$$g^{hj} = 0, \text{ if } c^{hj} \leq \bar{c}$$

Similarly, a zero-one disconcordance dominance matrix Y with elements h^{hj} can be constructed as follows:

$$h^{hj} = 1, \text{ if } d^{hj} \leq \bar{d}$$
$$h^{hj} = 0, \text{ if } d^{hj} \geq \bar{d}$$

If the second method described above used, it is

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necessary to calculate the aggregate dominance matrix G and discordance dominance matrix Y. The elements t^{hj} of T satisfy the folowing conditions:

$$t^{hj} = 1, \text{ if } g^{hj} = 1 \text{ and } y^{hj} = 1$$

$$t^{hj} = 0, \text{ otherwise}$$

If $t^{hj} = 1$, then alternative a^h is favoured over alternative a^j both for concordance and discordance criteria. The final selection strategy is to find alternative a^i with a nondominated solution, namely, an alternative that satisfies the following conditions:

$$t^{hj} = 1, \quad j = 1, \ldots, n; \quad j \neq h$$

$$t^{kh} = 0, \quad k = 1, \ldots, n; \quad k \neq h; \quad k \neq j$$

Then, based on the relationships examined, the conditions can also be expressed as:

$$c^{kh} < \overline{c} < c^{hj}$$

$$d^{hj} < \overline{c} < d^{kh}$$

b. Implementation of Concordance Analysis

As was stated in the theory section, an effect vector or impact matrix can be calculated based on information which reflects all relevant outcomes of all alternatives. The outcome of an effect vector is presented in Table VI-1. The criteria are measured in such a way that a high value of an impact is preferred to a low value, except criteria 1 and 2, for which a low value is preferred to a high value.

Table VI-1 includes the information necessary to carry out the concordance anaysis. The implementation of a

concordance analysis requires transformation of the impact matrix into dimensionless units. The normalization procedure gives rise to the normalized impact matrix as shown in Table VI-2. Each criterion is divided by the maximum value of that criterion. Maximum value of 160 and 1268.5 were used for the criteria - capital and maintenence costs. For the criteria 10, 11, 12 shown on Table VI-1, the normalized values already obtained in chapter V were used.

Having established a normalized impact matrix, it is necesary, asdescribed earlier to specify weights in order to perform a concordance anaysis. The need to specify a weight vector is considered one of the major drawbacks of concordance anaysis because of the difficulties and inherent arbitariness in choosing weights.

A set of weights, denoted by row vector w, was obtained from the sixteen public officials discussed in the previous chapter. This set is presented as follows:

	1	2	3	4
w = (	.056	.073	.080	.000
	5	6	7	8
	.019	.182	.021	.056
	9	10	11	12
	.202	.047	.136	.128)

Using the normalized impact matrix and a set of weights, a
concordance matrix can be calculated. Concordance pairs are
needed at this point. Concordance pairs are presented in
Table   VI-3.   These are calculated for each pair   of
alternatives.   This means that preference relationships
between h^{th} and j^{th} sets of n alternative sets   are
established for each criterion.

Table VI-1   Impact Matrix before Normalization

	1	2	3	4	5	6	7
1.Capital cost	0	80	65	48	41.5	4	160
2.Operat. cost	0	78	156	190.5	268.5	14.4	7.2
3.Revenue	0	285	0	76013	76013	4782	24283
4.OVTT for auto	-1575	-630	0	-945	-945	-315	-315
5.OVTT for taxi	-630	-630	0	-1575	-945	-945	-630
6.OVTT for bus	0	0	315	315	-315	0	315
7.IVTT for auto	-630	-1260	630	-1890	-1575	-1260	-630
8.IVTT for taxi	0	-630	630	-1890	-1575	-630	-945
9.IVTT for bus	0	-315	-1260	-1260	-1260	-945	-945
10.Reduction pollution	.052	.089	.126	.246	.197	.108	.182
11.Institu. preference	.190	.173	.137	.108	.093	.221	.077
12.Enforce- ability	.196	.165	.133	.127	.067	.215	.097

Source: This table includes 9 quantifiable and 3 non-
quantifiable impacts with respect to each of the 7
alternatives. Capital costs operating costs and revenues are

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based on table V-4,V-5 and V-7 respectively. The criteria relating to travel time come from table 5-10. Criteria 10,11 and 12 are based on the Churchman and Ackoff technique in the chapter 5.

* ARZ Alternarives: 1. Off-Street Parking Fee Increase
                    2. Parking Meters in Core Area
                    3. Transit Priority Signals
                    4. Core Area License Scheme (ALS)
                    5. Core ALS with Bus Improvement
                    6. Toll Increase for Tunnel Gates

                    7. Toll Charge at Bridges

Table VI-2   Normalized Impact Matrix

	a1	a2	a3	a4	a5	a6	a7
c1	.000	.500	.406	.300	.259	.025	1.000
c2	.000	.291	.581	.709	1.000	.054	.027
c3	.000	.000	.000	1.000	1.000	.063	.319
c4	1.000	.400	.000	.600	.600	.200	.200
c5	.400	.400	.000	1.000	.600	.600	.400
c6	.000	.000	-1.00	-1.00	1.000	.000	-1.00
c7	.333	.667	-.333	1.000	.833	.667	.333
c8	.000	.333	-.333	1.000	.833	.333	.500
c9	.000	.250	1.000	1.000	1.000	.750	.750
c10	.052	.089	.126	.246	.197	.108	.182
c11	.190	.173	.137	.108	.093	.221	.077
c12	.196	.165	.133	.127	.076	.215	.097

Source: Each criterion in table VI-1 is divided by the maximum value of that criterion.

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Table VI-3   Concordance Pairs (sets)

```
C12 = (c1,c2,c4,c5,c6,c11,c12)
C13 = (c1,c2,c4,c5,c6,c7,c8,c11,c12)
C14 = (c1,c2,c4,c6,c11,c12)
C15 = (c1,c2,c4,c11,c12)
C16 = (c1,c2,c4,c6)
C17 = (c1,c2,c4,c5,c6,c7,c11,c12)
C21 = (c7,c8,c9,c10)
C23 = (c2,c4,c5,c6,c7,c8,c11,c12)
C24 = (c2,c6,c11,c12)
C25 = (c2,c6,c11,c12)
C26 = (c4,c6,c7,c8)
C27 = (c1,c4,c5,c6,c7.c11.c12)
C31 = (c9,c10)
C32 = (c1,c9,c10)
C34 = (c2,c9,c11,c12)
C35 = (c2,c9,c11,c12)
C36 = (c9,c10)
C37 = (c1,c9,c11,c12)
C41 = (c3,c5,c7,c8,c9,c10)
C42 = (c1,c3,c4,c5,c7,c8,c9,c10)
C43 = (c1,c3,c4,c5,c6,c7,c8,c10)
C45 = (c2,c3,c4,c5,c7,c8,c9,c10,c11,c12)
C46 = (c3,c4,c5,c7,c8,c9,c10)
C47 = (c1,c3,c4,c5,c7,c8,c9,c10,c11,c12)
C51 = (c3,c5,c6,c7,c8,c9,c10)
C52 = (c1,c3,c4,c5,c7,c8,c9,c10)
C53 = (c1,c3,c4,c5,c6,c7,c8,c10)
C54 = (c1,c6)
C56 = (c3,c4,c5,c6,c7,c8,c9,c10)
C57 = (c1,c3,c4,c5,c6,c7,c8,c9,c10)
C61 = (c3,c5,c7,c8,c9,c10,c11,c12)
C62 = (c1,c2,c3,c5,c9,c10,c11,c12)
C63 = (c1,c2,c3,c4,c5,c6,c7,c8,c11,c12)
C64 = (c1,c2,c6,c11,c12)
C65 = (c1,c2,c11,c12)
C67 = (c1,c4,c5,c6,c7,c9,c11,c12)
C71 = (c3,c8,c9,c10)
C72 = (c2,c3,c8,c9,c10)
C73 = (c2,c3,c4,c5,c6,c7,c8,c10)
C74 = (c2,c6)
C75 = (c2,c11,c12)
C76 = (c2,c3,c8,c10)
      (c2
```

Note: One subset, called the concordance pair(set), is
composed of all criteria for which alternative h is preferred

over alternative j.

These concordance pairs will be applied to derive a
concordance matrix. This matrix, denoted by CI, is presented
in Table VI-4. For example, concordance index CI 16 can be
obtained through the concordance pair of c16(c1,c2,c4,c6) in
Table VI-3.

$$c16 = (c1,c2,c4,c6)$$

$$CI\ 16 = (.056,\ .073,\ .000.\ .182) = .311$$

Table VI-4   Concordance Matrix

$$
CI = \begin{bmatrix}
1 & \underline{\quad} & .594 & .671 & .575 & .393 & .311 & .797 \\
2 & .326 & \underline{\quad} & .615 & .519 & .519 & .259 & .542 \\
3 & .249 & .305 & \underline{\quad} & .539 & .539 & .249 & .522 \\
4 & .425 & .481 & .461 & \underline{\quad} & .762 & .425 & .745 \\
5 & .628 & .481 & .461 & .238 & \underline{\quad} & .607 & .663 \\
6 & .689 & .741 & .751 & .575 & .393 & \underline{\quad} & .744 \\
7 & .385 & .458 & .478 & .255 & .410 & .256 & \underline{\quad}
\end{bmatrix}
$$

In addition to a concordance matrix, a discordance

matrix should be calculated as well. As in the case of
concordance matrix, it is necessary to derive discordance
pairs. Discordance pairs are shown in Table VI-5.

Table VI-5   Discordance Pairs (sets)

```
D12 = (c7,c8,c9,c10)
D13 = (c9,c10)
D14 = (c3,c5,c7,c8)
D15 = (c3,c5,c7,c8,c9,c10)
D16 = (c3,c5,c7,c8,c9,c10)
D17 = (c3,c8,c9,c10)
D21 = (c1,c2,c4,c5,c6,c11,c12)
D23 = (c1,c9,c10)
D24 = (c1,c3,c4,c5,c7,c8,c9,c10)
D25 = (c1,c3,c4,c5,c7,c8,c9,c10)
D26 = (c1,c2,c3,c5,c9,c10,c11,c12)
D27 = (c2,c3,c8,c9,c10)
D31 = (c1,c2,c4,c5,c6,c7,c8,c11,c12)
D32 = (c2,c4,c5,c6,c7,c8,c11,c12)
D34 = (c1,c3,c4,c5,c6,c7,c8,c10)
D35 = (c1,c3,c4,c5,c6,c7,c8,c10)
D36 = (c1,c2,c3,c4,c5,c6,c7,c8,c11,c12)
D37 = (c2,c3,c4,c5,c6,c7,c8,c10)
D41 = (c1,c2,c4,c6,c11,c12)
D42 = (c2,c6,c11,c12)
D43 = (c2,c9,c11,c12)
D45 = (c1,c6)
D46 = (c1,c2,c6,c11,c12)
D47 = (c2,c6)
D51 = (c1,c2,c4,c11,c12)
D52 = (c2,c6,c11,c12)
D53 = (c2,c9,c11,c12)
D54 = (c2,c3,c4,c5,c7,c8,c9,c10,c11,c12)
D56 = (c1,c2,c11,c12)
D57 = (c2,c11,c12)
D61 = (c1,c2,c4,c6)
D62 = (c4,c6,c7,c8)
D63 = (c9,c10)
D64 = (c3,c4,c5,c7,c8,c9,c10)
D65 = (c3,c4,c5,c6,c7,c8,c9,c10)
D67 = (c2,c3,c8,c10)
D71 = (c1,c2,c4,c5,c6,c7,c11,c12)
D72 = (c1,c4,c5,c6,c7,c11,c12)
D73 = (c1,c9,c11,c12)
D74 = (c1,c3,c4,c5,c7,c8,c9,c10,c11,c12)
D75 = (c1,c3,c4,c5,c6,c7,c8,c9,c10)
D76 = (c1,c4,c5,c6,c7,c9,c11,c12)
```

Note: One subset, called the discordance pair(set), includes
all criteria for which alternative h is not preferred over

alternative j.

Instead of using the normalized impact matrix presented in Table VI-2, a weighted impact matrix can be used for calculating the set of discordance indices. This is done by multiplying each element v_{mn} in normalized impact matrix with its corresponding relative weight w_m.

Table VI-6   Weighted Normalized Matrix

	a1	a2	a3	a4	a5	a6	a7
c1	.000	.028	.023	.017	.015	.001	.056
c2	.000	.021	.042	.052	.073	.004	.002
c3	.000	.000	.000	.080	.080	.007	.034
c4	.000	.000	.000	.000	.000	.000	.000
c5	.008	.008	.000	.019	.011	.011	.008
c6	.182	.182	.000	.000	.364	.182	.000
c7	.007	.014	-.007	.021	.017	.014	.007
c8	.000	.019	-.019	.056	.047	.019	.028
c9	.000	.051	.202	.202	.202	.152	.152
c10	.002	.004	.006	.012	.009	.005	.009
c11	.026	.024	.019	.015	.013	.030	.010
c12	.025	.021	.017	.016	.009	.028	.012

Table VI-7 contains discordance indices, showing predominantly values above .500.

Table VI-7   Discordance Matrix

$$
DI = \begin{array}{c|ccccccc}
 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\
\hline
1 & \underline{\quad} & .336 & 1.00 & 1.00 & 1.00 & .752 & .752 \\
2 & .500 & \underline{\quad} & .748 & .800 & 1.00 & .500 & .500 \\
3 & .575 & .507 & \underline{\quad} & 1.00 & 1.00 & .688 & .627 \\
4 & .712 & .500 & .250 & \underline{\quad} & 1.00 & .938 & .685 \\
5 & 1.00 & .712 & .425 & .421 & \underline{\quad} & 1.00 & .973 \\
6 & .055 & .000 & .248 & .913 & .913 & \underline{\quad} & .338 \\
7 & 1.00 & .875 & .589 & .696 & 1.00 & .982 & \underline{\quad} \\
\end{array}
$$

Note: Discordance indeces(DI) are derived from the discordance pairs presented in table VI-5.

The next step to be undertaken is the elimination of less favourable alternatives. By setting critical values $\bar{c}$ and $\bar{d}$ of concordance and discordance respectively, one can state that alternative a_h outranks a_j if and only if $c_{hj} > \bar{c}$ and $d_{hj} < \bar{d}$, where both inequalities have to hold. Then zero-one concordance and discordance dominance matrices G and Y are constructed. The threshold values for the concordance anc discordance indices are assumed such that given these values some of the alternatives are preferred to all others. Aggregation (T) was obtained by intersecting the concordance matrix G and discordance matrix Y. Using the elements of T, the undominated alternatives can be identified.

The threshold value for the concordance index of .700 and discordance index of .300 were used. The threshold values of $\bar{c}$ and $\bar{d}$ are, in effect, arbitary, set in a "satisfying" manner. Now, one can identify dominated alternatives by checking each row od T. In Table VI-8, two alternatives contain one element equal to unity. The alternatives corresponding to those rows should be eliminated because a value of 1 indicates that the alternatives are less favourable. The remaining undominated alternatives are the desired output.

Table VI-8   Determination of G, H and T by .700 and .300

$$
G = \begin{pmatrix}
\_ & 0 & 0 & 0 & 0 & 0 & 1 \\
\bar{0} & \_ & 0 & 0 & 0 & 0 & 0 \\
0 & \bar{0} & \bar{0} & 0 & 0 & 0 & 0 \\
0 & 0 & \bar{0} & \_ & 1 & 0 & 1 \\
0 & 0 & 0 & \bar{0} & \_ & 0 & 0 \\
0 & 1 & 1 & 0 & \bar{0} & \_ & 1 \\
0 & 0 & 0 & 0 & 0 & \bar{0} & \_
\end{pmatrix}
\qquad
H = \begin{pmatrix}
\_ & 0 & 0 & 0 & 0 & 0 & 0 \\
\bar{0} & \_ & 0 & 0 & 0 & 0 & 0 \\
0 & \bar{0} & \_ & 0 & 0 & 0 & 0 \\
0 & 0 & \bar{1} & \_ & 0 & 0 & 0 \\
0 & 0 & 0 & \bar{0} & \_ & 0 & 0 \\
1 & 1 & 1 & 0 & \bar{0} & \_ & 0 \\
0 & 0 & 0 & 0 & 0 & \bar{0} & \_
\end{pmatrix}
$$

$$
T = \begin{pmatrix}
\_ & 0 & 0 & 0 & 0 & 0 & 0 \\
\bar{0} & \_ & 0 & 0 & 0 & 0 & 0 \\
0 & \bar{0} & \_ & .0 & 0 & 0 & 0 \\
0 & 0 & \bar{0} & \_ & 0 & 0 & 0 \\
0 & 0 & 0 & \bar{0} & \_ & 0 & 0 \\
0 & 1 & 1 & 0 & \bar{0} & \_ & 0 \\
0 & 0 & 0 & 0 & 0 & \bar{0} & \_
\end{pmatrix}
$$

The remaining undominated alternatives were, however, too large to provide any meaningful basis for selecting the desired alternative. Thus it was deemed necesary to either decrease c or increase d. After examining the indices in both concordance and discordance matrices, it was decided to decrease c to .500 and increase d to .500. The results are presented in Table VI-9. Of seven ARZ alternatives, four

alternatives contained elements equal to 1. .The four alternatives were eliminated, implying that the remaining three alternatives warrent closer scrutiny and evaluation.

Table VI-9   Determination of G, H and T by .500 and .500

$$G = \begin{bmatrix} & 1 & 1 & 1 & 0 & 0 & 1 \\ \overline{0} & & 1 & 1 & 1 & 0 & 1 \\ 0 & \overline{0} & & 1 & 1 & 0 & 1 \\ 0 & 0 & \overline{0} & & 1 & 0 & 1 \\ 1 & 0 & 0 & \overline{0} & & 1 & 1 \\ 1 & 1 & 1 & 1 & \overline{0} & & 1 \\ 0 & 0 & 0 & 0 & 0 & \overline{0} & \end{bmatrix} \qquad H = \begin{bmatrix} & 1 & 0 & 0 & 0 & 0 & 0 \\ \overline{1} & & 0 & 0 & 0 & 1 & 1 \\ 0 & \overline{0} & & 0 & 0 & 0 & 0 \\ 0 & 1 & \overline{1} & & 0 & 0 & 0 \\ 0 & 0 & 1 & \overline{1} & & 0 & 0 \\ 1 & 1 & 1 & 0 & \overline{0} & & 1 \\ 0 & 0 & 0 & 0 & 0 & \overline{0} & \end{bmatrix}$$

$$T = \begin{bmatrix} & 1 & 0 & 0 & 0 & 0 & 0 \\ \overline{0} & & 0 & 0 & 0 & 0 & 1 \\ 0 & \overline{0} & & 0 & 0 & 0 & 0 \\ 0 & 0 & \overline{0} & & 0 & 0 & 0 \\ 0 & 0 & 0 & \overline{0} & & 0 & 0 \\ 1 & 1 & 1 & 0 & \overline{0} & & 1 \\ 0 & 0 & 0 & 0 & 0 & \overline{0} & \end{bmatrix}$$

Through the use of varired values of c and d, it was possible to greatly reduce the number of alternarives. The value of c and d was varied by restricting the operations only to current undominated subset of alternatives. When new parameters of .300 for the concordance matrix and .700 for the discordance matrix were used, only two alternatives were undominated. The two undominated alternatives were: the Core Area License Scheme and the Core Area License Scheme with Bus Improvement.

Table VI-10   Determination of G, H and T by .200 and .700

$$
G = \begin{pmatrix}
 & 1 & 1 & 1 & 1 & 1 & 1 \\
\bar{1} & & 1 & 1 & 1 & 1 & 1 \\
0 & \bar{1} & & 1 & 1 & 0 & 1 \\
1 & 1 & \bar{1} & & 1 & 1 & 1 \\
1 & 1 & 1 & \bar{1} & & 1 & 1 \\
1 & 1 & 1 & 1 & \bar{1} & & 1 \\
1 & 1 & 1 & 1 & 1 & \bar{0} & 1
\end{pmatrix}
\qquad
H = \begin{pmatrix}
 & 1 & 0 & 0 & 0 & 0 & 0 \\
\bar{1} & & 0 & 0 & 0 & 1 & 1 \\
1 & \bar{1} & & 0 & 0 & 1 & 1 \\
0 & 1 & \bar{1} & & 0 & 0 & 1 \\
0 & 0 & 1 & \bar{1} & & 0 & 0 \\
1 & 1 & 1 & 0 & \bar{0} & & 1 \\
0 & 0 & 1 & 1 & 0 & \bar{0} & \_
\end{pmatrix}
$$

$$
\begin{pmatrix}
 & 1 & 0 & 0 & 0 & 0 & 0 \\
\bar{1} & & 0 & 0 & 0 & 1 & 1 \\
0 & \bar{1} & & 0 & 0 & 0 & 1 \\
0 & 1 & \bar{1} & & 0 & 0 & 1 \\
0 & 0 & 1 & \bar{1} & & 0 & 0 \\
1 & 1 & 1 & 0 & \bar{0} & & 1 \\
0 & 0 & 1 & 1 & 0 & \bar{0} & \_
\end{pmatrix}
$$

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The findings based on this analysis sugggest that area license schemes appear to be more favourable than other ARZ alternatives. When threshold values for the concordance index and the discordance index of .200 and .700 respectively, one alternative was undominated. As shown in Table VI-10, the sole undominated alternative turned out to be altertnative 5 (Core Area License Scheme with Bus Improvement). This outcome is generally consistent with a priori expectation as the ALS is very effective in reducing OVTT and IVTT for the bus mode, both of which have been assigned high weights. The other reason for the final outcome seems to be that the ALS with Bus Improvement would not require any municipal expenditures associated with the bus improvement. The bus improvement costs are to be borne by private bus companies. While the capital and maintenance costs required for instituting ALS schemes seem rather high, the remaining criteria are more than enough to offset these cost-related criteria. Despite the low weight scores on the institutional preference and enforceability, the two ALSs outranked the other ARZ alternatives on criteria relating to travel time, pollution and revenue that are generally considered important.

It should be emphasized that the concordance analysis examined is intended to provide empirical and explicit information as the basis for decision making and that the framework imbeded in the concordance analysis is helpful in

structuring the decision making process. However, the results of the analysis should be critically discussed rather than simply adopted. Viewed in this way, it may be wise to use the results of the analysis as a tool to narrow the range of ARZ alternatives. Ultimately the final selection of a best ARZ will be accomplished through negotiation among implementing agencies, planning agencies and interest groups.

There are several ways to conduct a sensitivity analysis. The sensitivity analysis is performed to test the robustness of the concordance analysis with respect to changes in some parameters. The several ways are: (1) variations in weights, (2) variations in critical values, (3) increase in the number of criteria. For example, a scenario can be established which stresses criteria other than those weighted heavily in the original anlysis. If the decision maker wishes to assign high priority to the finalcial criteria, The criteria 1, 2 and 3 should be given high weights relative to other remaining criteria. Therefore, weight changes do have an impact on selecting the best alternative. The same is true for variations in critical values and changes in the number of criteria. Numerous interactions with decision makers are required to conduct various sensitivity analyses.

3. Goal-Achievement Matrix (GAM)

a. Description of Theory

The GAM method of evaluation was advanced by Morris Hill (Hill 1967; Hill 1968; Hill 1973) and has been used for evaluating public projects (Hill 1971; Miller 1980; Hill and Tzamir 1972; Hill and Alterman; 1974). The GAM allows disaggregate treatment of cost and benefit accounting by objectives, and by incidence of goal achievement throught the relevant population.

The method retains qualitative data in the accounts and explores simple alternative weightings for the objectives and their differential impacts. The method's contribution to realism can be briefly summarized as a recognition of the full subjectivity of any formal weighting process and of the concomitant need to find a balanced means of presenting disaggregate information. The decision makers may be provided with both a variety of alternative summary figures and the full set of underlying disaggregated accounts.

The GAM essentially attempts to overcome limitations inherent in cost-benefit analysis. Hill criticizes the traditional cost-benefit evaluation of transportation plans because non-economic objectives are neglected. He also

criticizes multi-criteria methodologies which attempt to relate all categories of impacts to a common scale.

> Thus one of the limitations of the development of balance sheet is that it does not always appear to recognize that benefits and costs have only instrumental value, that they have meaning only in relation to a well-defined objective. A criterion of maximizing net bemefits in the abstract is meaningless. Whereas benefits can be computed referring to different planning objectives, the benefits and costs are not necessarily additive or comparable (Hill, 1973).

Hill proposes a methodology in which a separate cost-benefit analysis would be constructed for each goal, each goal weighted, and then the degree of achievement of weighted goals compared for each alternative.

The first step in Hill's methodology is the determination of goals, which are defined as "an end to which a planned course of action is directed". Goals include increased accessibility, reduction of displacement, separated pedestrian and vehicular traffic, minimized air pollution, and minimized traffic congestion. Hill suggests a number of approaches to goal selection, among which are consultation with elected officials and community groups, public opinion sampling, and examination of previous allocations of public investment. Hill believes that in practice, the number of important goals will be relatively small.

Once goals are selected, the impact of transportation alternatives on the goals are examined. Up to this point,

Hill's Goals-Achievement Matrix methodology is similar to a standard environmental impact statement. Important issues are identified (goals) and the future impacts of each alternative are estimated.

But Hill is not content to merely report the consequences of alternative actions, his methodology must make these consequences comparable. Early in his presentation Hill states that benefits such as reduced driving time cannot be directly added to the costs of air pollution.

Hill's solution to this problem of comparability is to aggregate similar impacts within each goal category and then compare the results for different alternatives. For example, the air quality impacts of highway alignment A at different locations would be added together and compared to the total air quality impacts of highway alignment B. One could indicated the better alternative with a "+" and the loser with a "-". A more rigorous approach, which Hill describes, is to convert the aggregated air quality impacts to a numerical scale which is referred to as its degree of goal achievement.

Alternatives can now be compared with respect to specific goals. "A" may be superior to "B" with respect to the goals of air quality and residential displacement, but "B" may be superior to "A" with respect to travel time and accident rates. If alternative selection is to be made on a

rational basis, the dissimilar categories must be compared. It would be naive to assume that all goals are equally valued by the community. Therefore, Hill recommends using similar survey and consultation techniques to weight the goals with respect each other. Since "the public interest" does not take a bodily form with the ability to answer our questions as to the weighting of alternatives, we must somehow aggregate the goal preferences of all those consulted.

Hill does not describe how to weight the importance of each consulted party other than to say it is difficult, and that "relative valuation of objectives by the community ought to be approached from a particular theory of government.

Once each alternative has its goal achievement score, and each goal is properly weighted, then,

> "the combined weight of the objectives and their incidence is assigned to the measures of achieve- ment of the objectives. The weighted indices of goals-achievement are then summed and the preferred plan among those alternatives compared is that with the largest index (Hill, 1973)."

By consulting the public and decision makers as to their favorite goals and determining how they order those goals, the alternative which best serves the public interest is chosen without any political interference. It is a very rational process.

The GAM reaches out to the community to embrace a diversity of evaluation criteria, as opposed to the economic

focus of cost-benefit analysis. It does not try to add apples to oranges, at least not directly. If one were to evaluate a set of transportation alternatives in a community where there was a clear consensus as to the most important goals and their order of importance, this methodology would surely determine the transportation alternative that was in the "pulic interest". This methodology might also work well if it were possible to rationally determine, in the absence of consensus, the proper weighting of objectives or of the relative importance of affected parties.

Such consensus may exist in the case of small transportation improvements or in rural areas where few persons are directly affected. But Morris Hill's Goals-Achievement Matrix would have serious deficiencies if applied to urban settings where pluralism is more prevalent than consensus.

In order to properly weigh the goals, as Hill suggests, it is necessary to determine either a shared community-wide valuation of goals or calculate an average goal weighting of all affected parties. Hill suggests looking at past public decisions to determine how a community would weight objectives. This technique assumes that the community as a whole displays a constant set of preferences as does an individual. But, if we assume that past decisions are merely the outcomes of battles fought out by different parties in a pluralist system, the past may not always be a good indicator

of future political choice. The battles may not always have the same winners. Furthermore, people's values determined in the abstract may not remain constant when applied to real life choices.

An alternative technique that Hill suggests is to survey affected parties and then somehow average their preferences. But how much weight is to be given to the preferences of each group? Should all groups be given the same weight despite differences in size, or income, or differences in potential gains and losses? Any weighting process must make decisions as to the relative importance of competing groups. This is as deep a political choice as one can make and should not be hidden under the guise of rational planning.

If the weighting process is indeed a political one rather than a rational one, why not leave those choices to the politicians and public? Hill thinks that it is the rational planner's duty to make these choices.

"The simplest strategy is to present the decision-maker with the entire goals-achievement account without attempting to synthesize the extent of goals-achievement. This approach is obviously least demanding of the planner and most demanding of the decision-maker. The onus would then be on the decision-maker to trade off the extent of achievement of the set of objectives with the weights of those objectives (Hill 1973)."

b. Implementation of the GAM

Following the logic of the GAM described, for each goal and each group a goal-achievement account is established to distinguish between impacts that represent a regression from a goal (Hill's definition of costs) and impacts that represent a progression toward a goal (Hill's definition of benefits). As discussed in the theory section, the first step in the GAM is to determine goals and estimate impact matrix based on these goals. The impact matrix presented in Table VI-1 in concordance analysis is also suitable for this requirement. In order to facilitate the comparison of impact matrix accounts, the accounts should first be normalized. Table VI-11 shows the normalized impact matrix in which a ratio of each account to the highest account for criteria is used.

The next step is to derive weights for goals expressed in terms of criteria. The set of weights used in condordance analysis was directly applied in calculating overall scores. Since the set of weights employed in concordance analysis included small numbers, each weight is multiplied by 1000 as shown in Table VI-12.

Each normalized account is then multiplied by the weight for each alternative, and product are summed to generate an

overall, weighted, normalized account for each alternative. The outcome of this procedure is presented in Table VI-13.

The next step is to aggregate similar impacts within each goal category and then compare the results for different ARZ alternatives. Benefit categories include criteria 3 to 12. Cost categories contain criteria 1 and 2. The summation sign at the bottom of a column in Table VI-14 indicates that all the impacts for the corresponding goal are quantified and therefore can be totaled. The differences between benefits and costs are thus obtained. These differences provide the framework for camparing each alternative policy.

Execution Procedure for the GAM

Goal: Objectives

Alternatives ⟶ Goal
Achievement ⟶ Normalized
Acount   Goal-Achievemment
              Account

Weights
for Goals

Overall
Goal-
Achievement
Score

Table VI-11   Normalized Impact Matrix

	a1	a2	a3	a4	a5	a6	a7
c1	.000	.500	.406	.300	.259	.025	1.000
c2	.000	.291	.581	.709	1.000	.054	.027
c3	.000	.000	.000	1.000	1.000	.063	.319
c4	1.000	.400	.000	.600	.600	.200	.200
c5	.400	.400	.000	1.000	.600	.600	.400
c6	.000	.000	-1.00	-1.00	1.000	.000	-1.00
c7	.333	.667	-.333	1.000	.833	.667	.333
c8	.000	.333	-.333	1.000	.833	.333	.500
c9	.000	.250	1.000	1.000	1.000	.750	.750
c10	.211	.362	.512	1.000	.801	.439	.740
c11	.860	.783	.620	.489	.421	1.000	.348
c12	.912	.767	.619	.619	.312	1.000	.451

Source: This Table is derived from Table VI-1 (Impact Matrix).

Table VI-12   Weights for Criteria

Criteria	Weights (Add up to 1000)
1	56
2	73
3	80
4	0
5	19
6	182
7	21
8	56
9	202
10	47
11	136
12	128

Source: Each weight in Table VI-15 is simply multiplied by 1000.

Table VI-13   Goal-Achievement Scores

	a1	a2	a3	a4	a5	a6	a7
c1	.0	28.0	22.74	16.80	14.50	1.40	56.0
c2	.0	21.24	42.41	51.76	73.0	3.94	1.97
c3	.0	.0	.0	80	80	5.04	25.52
c4	.0	.0	.0	.0	.0	.0	.0
c5	7.6	7.6	.0	19.0	11.4	11.4	7.6
c6	182.0	182.0	.0	.0	364.0	182.0	.0
c7	7.0	14.01	-7.0	21.0	17.50	14.01	7.0
c8	.0	18.65	-18.65	56.0	46.65	18.65	28.0
c9	.0	50.50	202.0	202.0	202.0	151.5	151.5
c10	9.92	17.01	24.06	47.0	37.65	20.63	34.78
c11	116.96	106.49	84.32	66.50	57.26	136.0	47.33
c12	116.74	98.18	79.23	79.23	39.94	128.0	57.73

Source: This Table is constructed by multiplying each value
in   Table   VI-11   (Normalized   Imapct   Matrix)   by   the
corresponding weight of criteria in Table VI-12.

Table VI-13   Goal-Achievement Matrix

	a1	a2	a3	a4	a5	a6	a7
c1							
c2							
⋮							
c11							
c12							
Benefits	440.22	494.44	363.96	570.73	856.4	667.23	359.46
Costs	0	49.24	65.15	68.56	87.50	5.34	57.97
	440.22	445.2	298.81	502.7	768.9	661.89	301.49

Source: This Table is derived from Table VI-13. Benefits and
costs are summed seperately, and aggregate costs are
subtracted from aggregate costs.

The Area License Scheme with Bus Improvement receives the highest overall weighted scores (696.9), followed closely by the Toll Increase for Tunnel Gates. As far as the most desired ARZ alternative is concerned, both the concordance analysis and the goal-achievement matrix select the ALS with Bus Improvement. While the underlying structure of both methods differs substantially, the results obtained by an elimination of less favourable alternatives through a pairwise comparison in the CA turned out to be similar to those obtained by subtracting cost-related goal-achievement scores from benefit-related goal-achievement scores in the GAM. Thus it may be argued that the undominated solution in the concordance.analysis is the same as the alternative that receives the highest score in the goal-achievement.

The comparison on the second and the third ranking between these two methods reveals that the core ALS and the Toll Increase for Tunnel Gates place second and third respectively in the concordance analysis while the Toll Increase for Tunnel Gates and Core ALS receive the second and the third ranking in the GAM. The reason why the core ALS received the third ranking in the GAM compared to the second ranking in the CA is that the Core ALS in the GAM has smaller values for benefit criteria 6,11 and 12 than the Toll Increase for Tunnel Gate for the same criteria.

It appears that the weighted scores themselves are directly reflected in the GAM. Recalling that the goal-

achievement scores are derived from directly multiplying the normalized impact scores by the weights, this result is not too unpreditable. The problem associated with direct multiplication of impact scores by the weights in the GAM does not exist in the concordance analysis as all the normalized impact scores are converted into the concordance indices and the discordance indices.

In view of experience gained from two empirical analyses, it seems obvious that the GAM is theoretically appealing and computationally efficient, but it is rather difficult to apply to transportation projects which cover wider areas. While the analyst's burden in terms of computation is heavier in the Concordance Analysis, close contacts between the analyst and the decision maker can be established.

4. Compromise Solution (CS)

a. Theory

The Compromise Solution was developed by Zeleny (1980).
The Compromise Solution can be considered as being a member
of the family of multicriteria evaluation methods. The
Compromise Solution is an attempt to provide the decision
maker a basis for selecting the best alternatives.   This
method is used in a situation involving multicriteria and is
designed for deriving compromise solutions between the
analyst and the decision maker.

The method retains both qualitative and quantitative data
and explores weights for various criteria. The Compromise
Solution is value-oriented approach in that the decision
maker should provide the analyst with several value
judgments with regard to preference weights and membership
functions (the choice of membership functions simply
indicates the means of achieving compromise.   Relevant
membership functions are determined by interactions between
the analyst and decision maker).   On the basis of the
preferences revealed by the decision-makers, the analysts
gives information to the decision-makers as to the
feasibility range of outcomes and about reasonable compromise

solutions.

Zeleny (1974) suggests that because of the conflicting nature and noncommensurability of multicriteria a concept of compromise solution, rather than optional solution, is probably more useful for an analysis. By arguing that reliable construction of a ulility function or trade-off function is often too complex or unrealistic to be practical, he viewed the Compromise Solution as an effort to help the decision makers to reduce the set of nondominated solutions by eliminating "obviously bad" solutions.

The Compromise Solution starts with a set of initial feasible alternatives, denoted by

$$A = (a^1, a^2, \ldots\ldots, a^n)$$

These alternatives are evaluated against a set of n criteria. The kth alternative can be expressed as

$$a^k = (a_1^k, a_2^k, \ldots\ldots, a_n^k)$$

$$k = 1, \ldots\ldots, m$$

Each a_i^k represents the level of criterion i attained by

alternative k, where i=1,..., n; k=1,..., m. Now the multicriteria decision problem can be expressed as:

$$\text{Max } a_i^k \qquad \text{subject to} \qquad a \in A$$

which represents the vector function maximization problem. Max stands for maximization over feasible set A. This can be solved by assessing the utility functions of the decision makers such as

$$U(A) = U(a_1^k , a_2^k ,........ a_n^k).$$

However, an assessment of utility functions of decision makers is often a difficult task. The assessment of utility functions is also beyond the scope of present study (for utility function assessments, see keeney and Raiffa, 1976).

The underlying logic behind the Compromise Solution is built upon the notion that among all achievable scores for any i^{th} criterion, there must be at least one extreme ideal value that is preferred to all others. The ideal point can be denoted by a_i^*. This can be stated as:

$$a_i^* = \text{Max } a_i^k \qquad i = 1, 2, \ldots\ldots, n$$

If there is a $a_i^* \in A$ such that $(a_i^*, \ldots\ldots, a_n^*) = A^*$
, all alternatives are "ideal". Thus it is not necessary to bother with decision problems. Such an ideal case is hardly attainable in real decision-making practices. Our goal is, therefore, to find a solution which would be "as close as possible" to the "ideal".

The next step is to transform all a_i^k into membership functions. The membership function, denoted by z_i^k, is designed to map the scores of ith criterion into the interval $(0, 1)$ (Zadeh, 1974). The membership funciton can be interpreted as the degree of closeness to the ideal point a_i^*. The degree of closeness to a_i^*, ideal point, has the following properties:

1. If a_i^* is a maximum, then

$$z_i^k = \frac{a_i^k}{a_i^*}$$

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2. If a_i^* is a maximum, then

$$zk_i = \frac{a_i^*}{a_i^k}$$

3. If a_i^* is a feasible goal value, for example, a_i^* is preferred to all a_i^k, smaller and larger than a_i^*, then

$$z_i^k = \left[\frac{1}{2}\left(\frac{a_i^k}{a_i^*} \cdot \frac{a_i^*}{a_i^*} \right) \right]^{-1}$$

4. If the most distant feasible score is to be labeled by zero regardless of its actual closeness to a_i^*, we can define:

$$a_{i*} = \min a_{ik}$$

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and write z_i^k as

$$z_i^k = \frac{a_i^k - a_{i*}}{a_i - a_{i*}}$$

where a_{i*} is anchor value in the case of $\min_i^k$.

The value of z_i^k can be varied because of changed situations, learning and other dynamic factors. The change is possible through the following two operations:

1. Concentration:

$$z_i^k \;\;----\;\; (z_i)^{\alpha \, k} \quad\quad 0 < \alpha < 1$$

2. Dilation:

$$z_i^k \;\;----\;\; (z_i^k)^{\alpha} \quad\quad \alpha > 1$$

The first operation reduces the degree of closeness

relativey less for higher values of z^k and relatively more
for lower values of z^k_i . Similarly, the operation of
dilation has the opposite effect than that of concentration.
Then we can construct the following table.

Table VI-15   Degree of closeness with respect to i and k

k (alternatives) i (criteria)	al..................am	
1	z11...............z1m	Z1
.	.	.
.	.	.
.	.	.
.	.	.
n	zn1................znm	Zn

The next step is to derive $e_i(z_i)$, the entropy measure
of the ith criterion. The entropy measure is being
increasingly used in the analysis of business and economic
data.   It is simply another measure of dispersion which can
be related to the moments of the probability function.   The

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larger is the entropy or contrast intensity of the ith criterion, the greater is the amount of decision information contained in and transmitted by the criterion. The entropy, in this case, is taken to derive the weights and the criterion's importance. Criterion's importance g_i, is a measure of its relative importance in a given decision situation.

In table VI-14, we observe

$$z_i = \sum_{k=i}^{m} z_i^k \qquad i = 1, \ldots, n$$

which indicates the strength of vector z_i

$$z_i = (z_i^1 \ldots \ldots \ldots, z_i^m).$$

Then the entropy measure of the ith criterion's contrast intensity is

$$e(z_i) = -k \sum_{k=1}^{m} \frac{z_i^k}{z_i} \ln \frac{z_i^k}{z_i}$$

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where k>0 and

$$0 \leq z_i^k \leq 1$$

$$e(z_i) \geq 0$$

Total entropy of Z can be introduced as

$$E = \sum_{i=1}^{n} e(z_i)$$

The larger $e(z_i)$ is, the less information is transmitted by the ith criterion.
Since weights of a criterion's importance $\tilde{g}_i$ are reversely related to $e(z_i)$, $1 - e(z_i)$ would be used.

$$\tilde{g}_i = \frac{1}{n - E} [1 - e(z_i)]$$

where n is the number of criteria.

Note that by reducing Z we could shift the ideal point and thus change z_k as well as $e(z_i)$, E and the $\tilde{g}$'s.

Ultimately such changes get reflected in a new set of $\tilde{g}_i$'s.

Now it is necessary to have information on a weight vector, $w_i = (w1_i,.....wm_i)$ which represents the subjective assessment of importance of ith criterion. The assessment can be expressed as one possible hypothesis of a criterion's importance, g_i, as:

$$g_i = \tilde{g}_i \cdot w_i$$

or after normalization:

$$g_i = \frac{\tilde{g}_i \cdot w_i}{\sum_{i=1}^{n} \tilde{g}_i \cdot w_i} \qquad i = 1,.......,n$$

The next step is to derive compromise solutions by minimizing $L_p(g,k)$ for $p = 1, 2,$. A family of Lp-matrics, distance membership functions, is used as a wide

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range of geometric measures of closeness of any a^k to a^* in terms of z^k and z^*. The Lp-matrics can be expressed as follows:

$$Lp(g^k, k) = \left[\sum_{i=1}^{n} g^p (1 - z_i^k)^p \right]^{1/p}$$

where p represents the distance parameter $1 \leq p \leq \infty$. Therefore $Lp(g, k)$ evaluates the distance between the ideal alternative z^* and the actual vector of degrees of closeness induced by an alternative z^k. The power $1/p$ can be disregarded for $1 \leq p \leq \infty$ since the solutions would not be affected.

Setting $\sum_{i=1}^{n} g_i = 1$, $Lp(g, k)$ with respect to varying p values can be stated as:

$$L1(g, k) = 1 - \sum_{i=1}^{n} g_i Z_i^k$$

$$L2(g, k) = \left[\sum_{i=1}^{n} g_i^2 (1 - Z_i^k)^2 \right]^{1/2}$$

$$L_\infty(g, k) = \max_i [g_i (1 - Z_i^k)]$$

It can be observed that as "p" goes up, more and more weight as given to the largest distance (Distance means that the set of alternatives are mapped through z_{ik}'s into a distance space). Ultimately, the distance completely dominates. As for p = 1 and p = 2, there is at least one maximum distance for any a^k with regard to a certain criterion i.

The choice of p then reflects the strengh of our concern about making such maximal deviation from the ideal as small as posible (Zeleny, 1974). Put differently, the choice of a Lp-matrix simply reflects the means of achieving a compromise. Therefore, that alternative which is the closest to the ideal can be considered "compromise alternative". The compromise alternative can be obtained by minimizing Lp($_g$, k) with respect to p values.

b.Implementation of the Compromise Solution

The theory of the Compromise Solutions just described was applied for seven alternatives and twelve criteria. The ideal point for each criterion with respect to an individual alternative was obtained which is presented in Table VI-15. For example, a^{3*} (ideal point) is 68411. Since a low value

is preferred to a high value for criteria 1 and 2, the ideal point for this criteria is, of course, the lowest value.

Each individual component was transformed into the degree of closeness to the points, for the 12 criteria respectively, $a^* = 0, 0, 68411, -1575, -1575, -315, -1890, -1890, -1260, 0.245, 0.211, 0.215$. In other words, the set of ARZ alternatives A were mapped through z_{ik}'s into a distance space as shown in Table 6-16. For criteria 1 and 2, $z_{ik} = a_{ik}/a_{i*}$ was used because a_{i*} was a minimum.

Table VI-16   Impact Matrix for ARZ Alternatives and Criteria

	a1	a2	a3	a4	a5	a6	a7
c1	0	80	65	48	41.5	4	160
c2	0	78	156	190.5	268.5	14.4	7.2
c3	0	285	0	76013	76013	4782	24283
c4	-1575	-630	0	-945	-945	-315	-315
c5	-630	-630	0	-1575	-945	-945	-630
c6	0	0	315	315	-315	0	315
c7	-630	-1260	630	-1890	-1575	-1260	-630
c8	0	-630	630	-1890	-1575	-630	-945
c9	0	-315	-1260	-1260	-1260	-945	-945
c10	.052	.089	.126	.246	.197	.108	.182
c11	.190	.173	.137	.108	.093	.221	.077
c12	.196	.165	.133	.127	.067	.215	.097

*ARZ Alternatives: 1. Off-street Parking Fee Increase;
2. Parking Meters in Core; 3. Transit Priority Signals;
4.   Core ALS; 5. Core ALS with Bus Improvement; 6. Toll

Increase for Tunnels; 7. Toll Charge at Bridges.
*Criteria: 1. Capital Cost; 2. Maintenance Cost; 3.
Revenue; 4. OVTT for Auto; 5. OVTT for Taxi; 6. OVTT for
Bus; 7. IVTT for Auto; 8. IVTT for Taxi; 9. IVTT for
Bus; 10. Reduction in Pollution; 11. Instituitonal

Preference; 12. Enforceability.

Table VI-17   Transformation of Alternatives and Criteria

·	a1	a2	a3	a4	a5	a6	a7	Zi
c1	(1)	.00013	.00015	.00021	.00024	.0025	.00006	1.0033
c2	(1)	.00013	.00006	.00005	.00004	.0007	.0014	1.0024
c3	0	.0042	0	(1)	(1)	.0721	.4267	2.5030
c4	(1)	2.5000	0	1.667	1.667	5.000	5.000	16.8340
c5	2.5000	2.5000	0	(1)	1.667	1.667	2.500	11.8340
c6	0	0	-1.000	-1.000	(1)	0	-1.000	-2.0000
c7	3.0000	1.5000	-3.000	(1)	1.200	1.500	3.000	8.2000
c8	0	3.0000	-3.000	(1)	1.200	3.000	2.000	7.2000
c9	0	4.0000	(1)	(1)	(1)	1.333	1.333	9.6660
c10	.2110	.3620	.512	(1)	.801	.439	.740	4.0650
c11	.8600	.7830	.620	.489	.421	(1)	.348	4.5210
c12	.9120	.7670	.619	.591	.312	(1)	.451	4.6520

The next step is to derive a normalization table using the information in Table 6-16. Individual components in each criterion was added up to 1. implying that the set of ARZ alternatives was mapped into unit interval (0, 1). Table VI-17 includes the information necessary for deriving an entropy or a measure of contrast intensity. As was stated in the

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theory section, the entropy measure is required in order to derive a weight of each criterion's importance.

Since there are seven ARZ alternatives, e^{max} and k were obtained as follows:

$$e^{max} = \ln 7 = 1.946$$

$$k = 1/e^{max} = .5139$$

Using e^{max}, the entropy measure can be calculated. For example, e(z3) was obtained as:

$$e(z3) = -(.514)[.002(\ln.002) + .4(\ln.4)$$
$$+.4(\ln.4) + .029(\ln.029) +$$
$$.171(\ln.171)$$
$$= .592$$

Table VI-18   Normalization

	a1	a2	a3	a4	a5	a6	a7	Zi
c1	.997	0	0	0	0	.003	0	1
c2	.998	0	0	0	0	.001	.001	1
c3	0	.002	0	.400	.400	.029	.171	1
c4	.059	.149	0	.099	.297	.297	.297	1
c5	.211	.211	0	.085	.140	.140	.211	1
c6	0	0	.500	.500	-.500	0	.500	1
c7	.366	.183	-.366	.122	.146	.183	.366	1
c8	0	.417	-.417	.139	.167	.417	.278	1
c9	0	.414	.103	.103	.103	.138	.138	1
c10	.052	.089	.126	.246	.197	.108	.182	1
c11	.190	.173	.137	.108	.093	.221	.077	1
c12	.196	..165	.133	.127	.067	.215	.097	1

Then E, the sum of all $e(z^i)$ was calculated. "E" was used to derive $\tilde{g}^i$, a weight of each criterion's importance. Then the values of g^i 's stand for relative contrast intensities measuring the intrinsic average information transmitted by each criterion. The final weights of importance to be assigned were then calculated using $\tilde{g}^i$ i and w^i .

Table VI-19   Values for $\tilde{g}^i$, w^i and g^i

i	g_i	w_i	g_i
1	.230	.056	.159
2	.231	.073	.207
3	.095	.080	.098
4	.038	.000	.000
5	.103	.019	.024
6	.150	.182	.329
7	.050	.021	.012
8	.032	.056	.024
9	.040	.202	.098
10	.012	.047	.012
11	.007	.136	.012
12	.012	.128	.024

As to w^i, the set of weights used in the concordance analysis was also used as the set of weights reflects the preferences of public officials interviewed. Table VI-19 contains the values for g^i, w^i and g^i.

Table VI-20   Values for $(z^{i*} - z^{ik})$

	a1	a2	a3	a4	a5	a6	a7
c1	0	1	1	1	1	.997	1
c2	0	0	0	0	0	.999	.999
c3	1	.996	1	0	0	.928	.573
c4	0	-2.5	1	-.667	-.667	-4	-4
c5	-1.5	-1.5	1	0	-.667	-.667	-1.5
c6	1	1	0	0	0	1	0
c7	-2	-.5	4	0	-.2	-.5	-2
c8	1	-2	4	0	-.2	-2	-1
c9	1	-3	0	0	0	-.333	-.333
c10	.789	.638	.488	0	.199	.561	.260
c11	.140	.217	.380	.511	.579	0	.652
c12	.088	.233	.381	.409	.688	0	.549

The next step is to sibstitute the values of g_p^i 's into the distance membership functions, L^p - matrics. Then the compromise solutions can be obtained for p = 1, 2, . Table VI-20 includes the values of deviations, $z_i^{i*} - z_{ki}$ which would provide a basis for calculating $g_{*i}(z_i^{i} - z_{ki})$ in conjuction with $L^p (g, k)$.

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Table VI-21 Values for $g^i(z^{*i} - z^{ki})$

	a1	a2	a3	a4	a5	a6	a7
c1	0	.158979	.158976	.158967	.158962	.158960	.158990
c2	0	0	0	0	0	.207000	.207000
c3	.098	.098000	.098000	0	0	.091000	.056000
c4	0	0	0	0	0	0	0
c5	-.036	-.036000	.024000	0	-.016000	-.016000	-.036000
c6	.329	.329000	0	0	0	.329000	0
c7	-.024	-.006000	.048000	0	-.002000	-.006000	-.024000
c8	.024	-.048000	.096000	0	-.005000	-.048000	-.024000
c9	.098	-.294000	0	0	0	-.033333	-.033000
c10	.009	.008000	.006000	0	.002000	.007000	.003000
c11	.002	.003000	.005000	.006000	.007000	0	.008000
c12	.002	.006000	.009000	.010000	.017000	0	.013000
	.502	.219000	.445000	.175000	.162000	.690000	.353000
Max	.329	.329000	.158976	.158967	.158962	.329000	.207000

The results are presented in Table VI-21 in which the minimum values are circled. The results reveal that the fifth alternative, Area License Scheme with Bus Improvement, has the smallest value, .162, representing the closest value

to the ideal point with respect to $p = 1$. The same ARZ alternative turned out to be the closest value, .158962, to the ideal point with respect to $p = max$. It was difficult to identify the closest value because alternatives 3, 4 and 5 show the identical values as far as 3 decimal points are concerned. Thus calculation was performed up to 6 decimal point in order to derive a ranking. The results of the Compromise Solution seem to imply that the Compromise Solution may not be effective in providing a ranking among the preferred alternatives.

Table VI-22 Values for $g_i(z^{*i} - z^{ki})^2$

	a1	a2	a3	a4	a5	a6	a7	2i
c1	0	.02500	.02500	.02500	.02500	.12500	.02500	.02500
c2	0	0	0	0	0	0	.04300	.04300
c3	.01000	.01000	.01000	0	0	.00900	.00300	.01000
c4	0	0	0	0	0	0	0	.00000
c5	.00025	.00025	.00100	0	.00044	.00044	.00025	.00100
c6	.10800	.10800	0	0	0	.10800	0	.10800
c7	0	0	0	0	0	0	0	.00000
c8	.00100	.00400	.01600	0	.00004	.00400	.00100	.00100
c9	.01000	.09000	0	0	0	.00100	.00100	.01000
c10	0	0	0	0	0	0	0	.00000
c11	0	0	0	0	0	0	0	.00000
c12	.00002	.00005	.00010	.00020	.00050	0	.00030	.00100

.12927 .23730 .28940 .02520 .02598 .15644 .07355

When the value of p = 2 was used, the fourth alternative, Core Area License Scheme was the closest to the ideal point as shown in Table VI-22. The ALS (Area License Scheme) alternatives have the property of being "as close as possible" to the ideal solution. The reason seems to be that the ALS alternatives received relatively higher weights from

the decision making groups for what is considered to be "important criteria." For example, the criteria such as OVTT and IVTT for bus trips seem far more effective under ALS schemes than under other alternatives because the public officials provided high weights on these criteria.

In other words, while the city government incurs financial burdens in the ALS case, its return expressed in "revenue" seem very high, perhaps inordinately so in the case of the ALS with Bus Improvement. In total, the ALS schemes retain their superior advantage on the travel times for bus. Also it would seem that the clear advantage of the ALS scheme is not too heavily eroded by low weights received for instituitonal preference and enforceabiltity criteria. The oucome confirms that ALS alternatives are clearly superior to the other alternatives.

These nonextreme undominated solutions could facilitate the decision making process. However, these undominated solutions should be interpreted as "temporary and short-term solutions." in that different policy scenarios for an impact matrix could alter the process of deriving the compromise solutions. The final decision making should, of course, be made by the decision maker after careful consideration of legal, institutional and social implications of recommended nondominated solutions.

The ARZ alternatives selected through the compromise solutions are similar to those chosen under the concordance

analysis. Two ALS alternatives (the fourth and the fifth) were selected before the sole undominated alternative was chosen in the concordance analysis.

The reason why the results from the compromise solutions are similar to those in the concordance analysis seems to be that two methods has a similar theoretical structure: identification of effects and weights which generally leads to identification of the nonextreme undominated solutions within which the best-compromise solutions lie.

5. Conclusion

This chapter has considered theories of three methods. Empirical analyses within the context of Seoul have been made following the procedures of each method.. Several conclusions can be drawn from the above empirical analyses:

(1) The three methods have been shown to be implementable in practical circumstances;

(2) The applicability of the methodologies to transportation projects have shown to be possible. In fact, empirical analyses demonstrate the practicality and utility of the three methods for such TSM type of projects as ARZ policies;

(3) The multicriteria, including intangibles, were successfully incorporated into the methodologies. As has been observed, only the GAM seems to be relevant for

presenting a number of criteria and alternatives to a variety of decision making groups. The Concordance Analysis and the Compromise Solution appear to be methodologically similar. The Concordance Analysis and the Compromise Solution are particularly appropriate as elimination procedure so that the ultimate selection is reduced to a very limited number of remaining alternatives. An evaluation of the three methods on the basis of empirical analyses is the subject of the next chapter in which methodologies are evaluated in a number of respects.

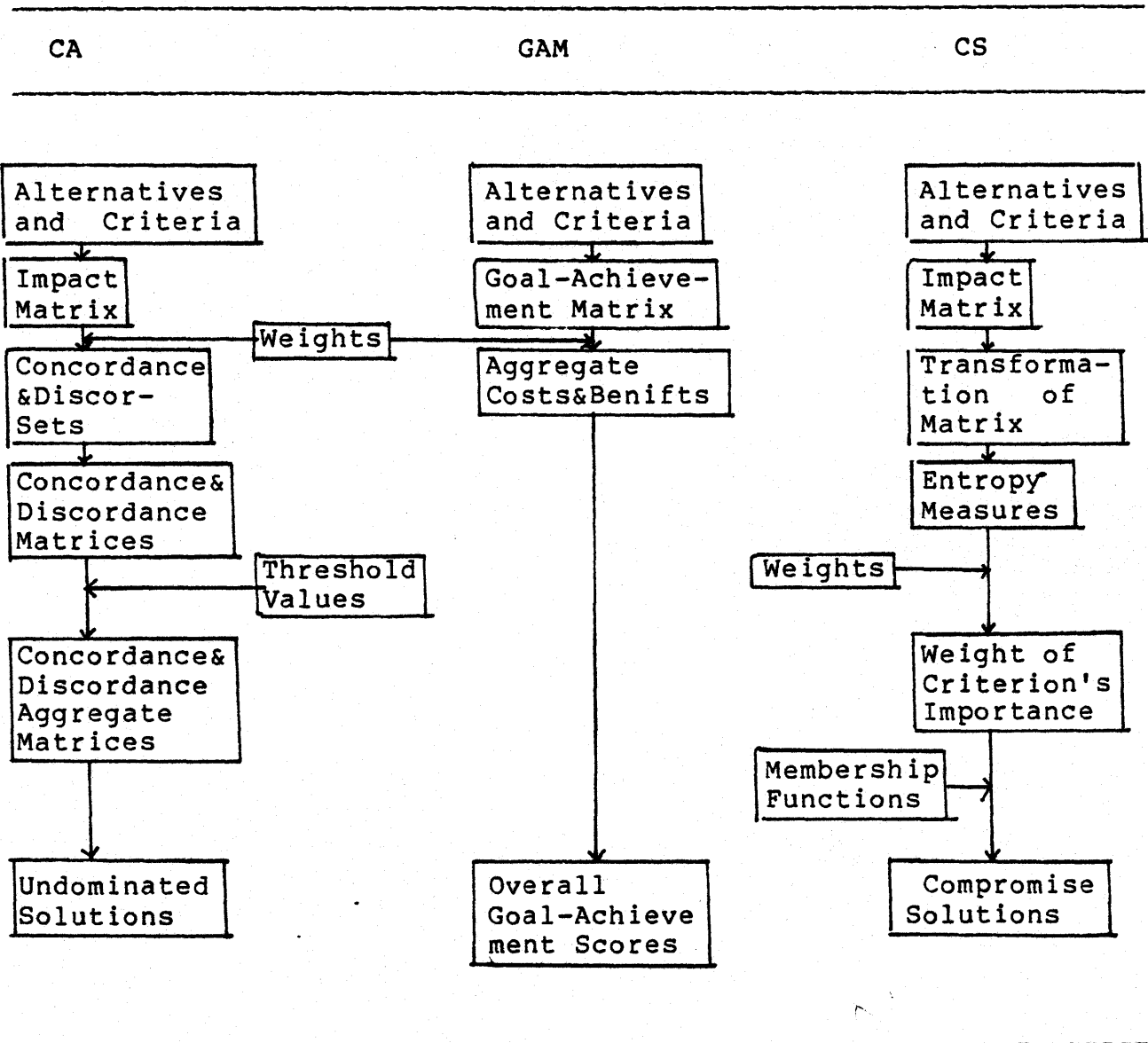Chapter VII   Evaluation of the Three Methods

I. Introduction

    Chapter VI was devoted to the discussion of the theories
and   empirical analyses with respect to each of the three
methods.   The purpose of this chapter is to describe criteria
that can be used to evaluate the relative strengths and
limitations of the three methods and to present an assessment
of the three methods in terms of such criteria.   The compari-
son reveals that the overall results obtained from the three
methods   are   quite similar but that they   differ   in
computational burdens, in the degree of interaction with the
decision maker, and in many other regards.

II. Synopsis of the Three Methods

    As   the   previous chapter discussed   the   underlying
theoretical structure of the three methods in greater detail,
it seems appropriate to summarize these methods before
assessing their strengths and limitations.   The objective of

the synopsis is to give the reader an averall picture of
their structure (see Figure VII-1).

Table VII-1   Major Components of the Three Methods

CA	GAM	CS

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┌─────────────┐        ┌─────────────┐        ┌─────────────┐
│ Alternatives│        │ Alternatives│        │ Alternatives│
│ and  Criteria│       │ and Criteria│        │ and Criteria│
└──────┬──────┘        └──────┬──────┘        └──────┬──────┘
       ↓                      ↓                      ↓
 ┌──────────┐          ┌─────────────┐         ┌──────────┐
 │ Impact   │          │Goal-Achieve-│         │ Impact   │
 │ Matrix   │          │ment Matrix  │         │ Matrix   │
 └────┬─────┘   ┌──────────┐  │               └────┬─────┘
      ↓     ────│ Weights  │──→↓                    ↓
 ┌───────────┐  └──────────┘ ┌─────────────┐  ┌─────────────┐
 │Concordance│               │ Aggregate   │  │Transforma-  │
 │&Discor-   │               │ Costs&Benifts│ │tion    of   │
 │Sets       │               └──────┬──────┘  │Matrix       │
 └─────┬─────┘                       │         └──────┬──────┘
       ↓                             │                ↓
 ┌───────────┐                       │         ┌──────────┐
 │Concordance&│                      │         │ Entropy  │
 │Discordance │                      │         │ Measures │
 │Matrices    │                      │         └────┬─────┘
 └─────┬──────┘  ┌──────────┐         │              │
       ←─────────│ Threshold│  ┌──────────┐          ↓
       ↓         │ Values   │  │ Weights  │──→┌──────────────┐
 ┌───────────┐   └──────────┘  └──────────┘   │ Weight of    │
 │Concordance&│                               │ Criterion's  │
 │Discordance │                               │ Importance   │
 │Aggregate   │             ┌──────────────┐  └──────┬───────┘
 │Matrices    │             │ Membership   │──→       │
 └─────┬──────┘             │ Functions    │          ↓
       ↓                    └──────────────┘
 ┌───────────┐             ┌──────────────┐   ┌──────────────┐
 │Undominated│             │ Overall      │   │ Compromise   │
 │Solutions  │             │ Goal-Achieve │   │ Solutions    │
 └───────────┘             │ ment Scores  │   └──────────────┘
                           └──────────────┘
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AS shown in Figure VII-1, inputs or initial information

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required by the three methods are alternatives (transportation plans such as ARZ alternatives) and criteria (performance measures). These are the essential inputs for the analysis, and the inputs are the same for all three methods. After impacts are predicted on the basis of the chosen criteria and the alternatives, weights should be assigned to all criteria.

These weights represent the relative preferences of the decision maker (or decision making groups) for each criterion. These weights can provide a basis for deriving pairwise comparisons of competing alternatives in the Concordance Analysis, aggregate impacts in the GAM and the weight of criterion's importance in the Compromise Solution. All that remains is to choose the best (undominated) alternatives by threshold values in the Concordance Analysis and by membership functions in the Compromise Solution. The GAM does not need these types of values to arrive at the best alternatives as its underlying logic assumes that the decision making groups' preferences are fully reflected in the aggregate impact matrix.

The foregoing discussion has been necessarily brief, but it indicates the basic stages of the three methods, namely:

(1) the prediction of the impacts and the generation of the alternatives;

(2) the formulation of the weights of the decision makers;

(3) the derivation of the best alternatives by threshold

values in the Concordance Anaysis and membership functions in the Compromise Solution.

With the background of the major components of the three methods, a critical assessment of each is made in the section following. The purpose of this assessment is to clarify relative strengths and weaknesses of the three methods.

3. Evaluation of the GAM, CA and CS

Evaluating the three methods is itself a multicriteria problem. A number of criteria can be established in order to conduct the evaluation. The intent here is not to suggest which is the best method, for, as will become apparent, the methods examined have counterbalancing strengths and weaknesses. Although the needs and thus criteria for evaluating the methods are likely to vary for particular circumstances and decision makers, several criteria must enter into the evaluation of methods in virtually all circumstances. The criteria to be considered are as follows:

    a. Computational burden

    b. Incorporation of transportation effects

    c. Degree of interaction with the decision maker

    d. Ease of testing for sensitivity

    e. Real-world applicability

f. Applicability to Transport Planning Environment in Seoul

At the outset, it is necessary to present the table wherein the three methods are assessed against the above-mentioned criteria. The purpose of the table is to give an overall look at the results of the assessment. A ranking is used to show whether each method scores favorably or unfavorably. Undoubtedly, the criteria are not all of equal importance. Table VII-1 shows that each method has both advantages and disadvantages; no method is strongly favorable without some drawbacks. The results obtained from the assessment are discussed in the section to be followed.

Table VII-1   Assessment of the methods against the criteria

Criteria	Methods		
	CA	GAM	CS
a. Computational Burden			
(1) Information requirement	–	+	
(2) Computational efficiency	–	+	–
(3) Possibility of sensitivity analysis	++	–	++
(4) Inclusion of qualitative information	++	+++	++
b. Degree of Interaction with the Decision Maker			
(1) Understandability of methods	–	++	–
(2) Encouragement of public participation	–	+++	–
(3) Interaction requirement	++	–	++
c. Real-World Applicability			
(1) Applicability to ARZ type	++	+	++
(2) Applicability to large-scale transport project	–	++	–
(3) Incorporation of Uncertainty	+	+	–
(4) Linkage to planning process	–	+	–
(5) Linkage to decision-making process	+	++	–
d. Applicability to transport environment in Seoul			
(1) Adaptabality to scarce information	+	–	+
(3) Applicability to rapidly changing environment	++	–	+

Note: +++ very favorable
      ++ favorable
       + moderately favorable
       – less favorable

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a. Computational Burden

The computational burden may be hard to evaluate as the amount of computation that must be conducted varies, depending upon the various aspects such as information requirements, parameters and iteration. This is attributed to the fact that the decision makers' requirements for necessary information vary a great deal from one method to another. Also, many different alternative ways can be established for testing each method's sensitivity to the weights and effects. Thus rather than attempting to evaluate all these aspects in the present analysis, the computational burden will be examined with reference to the empirical analyses performed in the previous chapter.

Information Requirement and Computational Efficiency

Of the three methods none of them is clearly superior. The GAM, however, appears to be easier to use because the computational burden is rather light compared to the Concordance Analysis (CA) and the Compromise Solution (CS). However, the advantage of the method's straightforward approach may be offset by the quantity of information that must be assimilated by the analyst. To apply this method well, considerable resources are required for data collection

and for adequate public participation.

While an analysis of various incidence sectors ("incidence sectors" refer to the affected groups, classified by area, income, land use and so forth) to be affected by transpotation projects has not been undertaken in this thesis, the GAM requires, in its original concept, an impact evaluation of these various incidence sectors. In particular, the sizable amount of empirical work on the incidence of benefits and costs may be overly time-consuming unless those impacts are large. The success of incidence anlaysis depends upon the appropriate choice of sectors for analysis. In this sense, implementation of the GAM in our case neglected, to some extent, comprehensive consideration of sectors to be affected by transportation plans. Therefore, a danger exists that the GAM would be used to prejudice the results by focusing on trivial incidence sectors and ignoring more important ones.

The Concordance Analysis has a heavier computational burden than the GAM. Furthermore, the results obtained from the Concordance Analysis need still further analysis to be useful. The burden of information collection and assimilation on the analysts and the information-processing burden on the decision makers are clear disadvantages of the Concordance Analysis. Recall that the Concordance Analysis begins with determining the weights to develop a full impact matrix, implying that prior computation must be performed

with a technique such as the Churchman-Ackoff method. Each sensitivity analysis performed increases the amount of information to be absorbed just as it improves the multi-objective scope of the study (except in the happy instance where all results point the same way).

The computational burden of the Compromise Solution is similar to that of the Concordance Analysis. The algorithms for developing non-dominated sets involve substantial computation. An entropy calculation is quite time-consuming. In order to select the best alternative, compromise solutions through membership functions should be undertaken which require iterations. The Compromise Solution also limits the analyst's scope by ruling out more intuitive approaches to the information. It is hard to imagine a consultant content to be merely a mixer of paints, as it were.

Possibility of Sensitivity Tests

Concordance Analysis is superior for conducting sensitivity tests. The involvement of the decision maker in the sensitivity tests in the CA is much easier than that of the GAM as the Concordance Analysis aims at single or few decision makers.

Sensitivity tests seem to be a difficult task because of the requirement of various public inputs. The GAM only provides results at the end of what is likely to be a very-

time-consuming process, and it cannot readily feed back into the design of alternatives which are assumed to be fixed. This seems unfortunate, since through completion of the procedure the analyst would inescapabily have a great deal of specialized knowledge to offer about the situation. By this point in the decision-making process, however, those modifications are no longer welcome, and the special familiarlity with the way in which impacts are distributed would be in a sense wasted.

The Compromise Solution is attractive in terms of this criteria. In the Compromise Solution, the decision is reached by an iterative process concentrating on sequential identification of "bad" solution. Sensitivity tests are likely to be burdensome unless the computation is aided by computer programs.

Inclusion of Qualitative Information

Qualitative effects can essentially be incorporated into the structure of the three methods. Corcordance Analysis is particularly conducive to the inclusion of the qualitative effects. This is because Concordance Analysis only requires statements as to the superiority and inferiority of one alternative over another according to a certain criterion, regardless of the specific scale used to measure performance

according to this criterion. However, an interval or ratio appears to be superior measurement scale for the Concordance Analysis. An interval scale is particularly useful for deriving a ranking among alternatives in the Concordance Analysis.

The GAM functions best as a means to incorporate qualitative information. The chief advantage of the GAM is its ability to accomodate and preserve qualitative information in a meaningful way. Also full subjectivity of any formal weighting process with regard to qualitative information is recognized. Any measurement scale can essentially be used in the GAM although Hill (1973) suggests that a ratio scale is preferrable to interval and interval scale is preferable to ordinal.

The Compromise Solution can easily accomodate qualitative information as long as the qualitative information is expressed in terms of measurable units. A ratio scale seems to be the most useful scale for the Compromise Solution because noncommensurable (dollars, travel times, etc.) must be transformed into the degree of closeness to the ideal point.

c. Degree of Interaction with the Decision Maker

None of the three methods is intended to substitute for human decision making; all methods can be viewed as decision aids that synthesize the contents of the impact matrix into more essential and meaningful information.

Understandability of Methods

Technical complexity may make Concordance Analysis difficult for the decision maker or layman to comprehend. Concordance Analysis would not seem to be conducive to communication with non-experts. This seems to be a major drawback because the Concordance Analysis is designed to replicate the thinking process of human mind.

The GAM, on the other hand, can easily be constructed by the analyst and understood by the decision maker. One distinct adavantage of the GAM is that the concept is simple and underlying process of goal-achievement is understandable for non-experts. Another advantage of the GAM is the lack of insistance on a bottom-line recommendation to the decision maker. While the results fo the GAM reveal the best alternative, the GAM does not lead to a definitive statement of the best alternative.

The theoretical structure of the Compromise Solution has similar drawbacks to those of Concordance Analysis in terms of communicating with non-experts. Membership functions may be difficult to understand on the part of the decision maker.

Encouragment of Public Participation

The Concordance Analysis and the Compromise Solution are not appropriate for encouraging public participation. In these methods, public or administrative participation seems limited to an after-the-fact-analysis review process, although it could be argued that public values are partially accounted for in the impact matrix.

The GAM appears to be the best way to encourage public participation. The GAM is designed to evaluate consequences across a broad range of community objectives. The GAM could conceivably lend itself to participatory reviews, since all goals are preserved, and weights are simple to interprete. In developing goals, the analyst needs to consult with elected officials, community groups, public opinion sampling and examination of previous transportation investment.

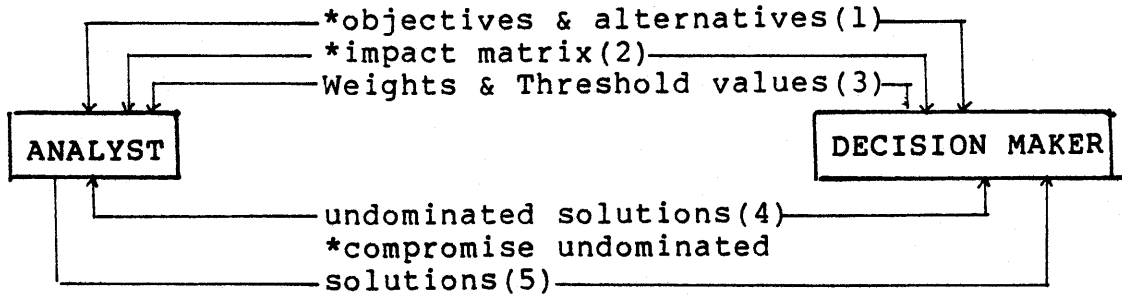## Interaction Requirement between the Analyst and Decision Maker

For evaluating the three methods with reference to this

criteria, it seems necessary to stress particularly the stages of interactions between the analyst and the decision maker. In contrast to the CA and CS, the decision maker in the GAM is the community to be affected by the transportation plans.
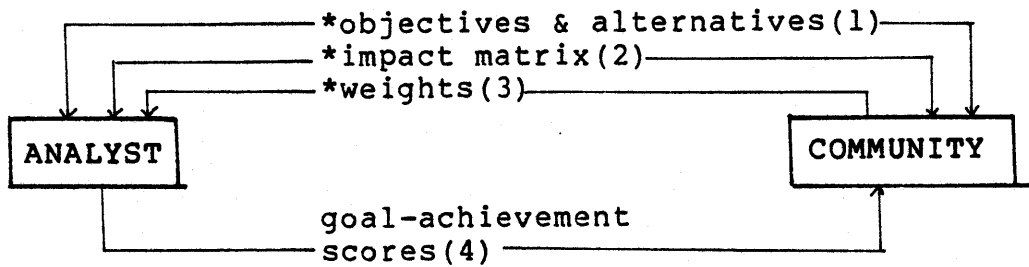

Figure VII-2 Stages of Interactions Between the Analyst and the Decision Maker
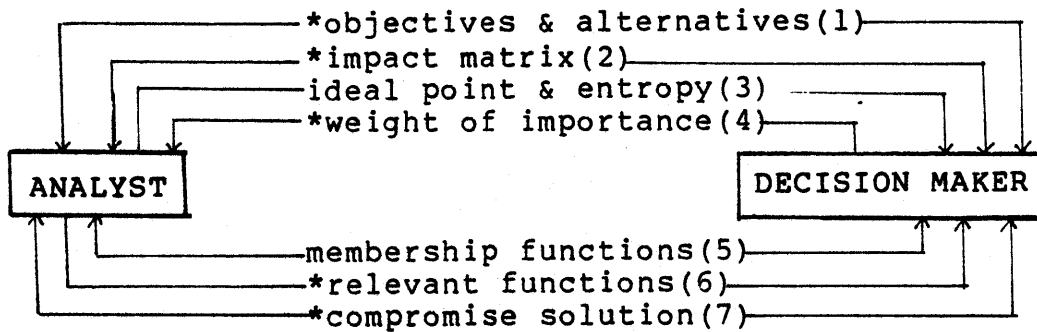
Concordance Analysis

*objectives & alternatives(1)
*impact matrix(2)
Weights & Threshold values(3)

ANALYST   DECISION MAKER

undominated solutions(4)
*compromise undominated
solutions(5)

GAM

*objectives & alternatives(1)
*impact matrix(2)
*weights(3)

ANALYST   COMMUNITY

goal-achievement
scores(4)

COMPROMISE SOLUTION

*objectives & alternatives(1)
*impact matrix(2)
ideal point & entropy(3)
*weight of importance(4)

ANALYST   DECISION MAKER

membership functions(5)
*relevant functions(6)
*compromise solution(7)

Note: Elements marked by "*" are preceded by interaction between the analyst and the decision maker.

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From Figure VII-2, the differences among the three methods are generally apparent. The methods differ in the degree of value judgments required for deriving undominated solutions. The Concordance Analysis is attractive in terms of interaction requirement between the analyst and the decision maker. In Concordance Analysis, there is an opportunity for active involvement of the decision maker in many stages of the procedure, including specification of the objectives and criteria and determination of the weights. Close interaction between the analyst and the decision maker is expected at an early stage in the process.

The GAM is a weak method with respect to this criteria. In contrast to the Concordance Analysis, the underlying philosophy of the GAM is the achievement of specified goals rather than the provision of information to the decision maker. The GAM also is designed to cater to a variety of interest groups, making it difficult for the analyst to interact with multiple decision making groups.

The Compromise Solution can be regarded as a practical interactive method. The Compromise Solution requires an active role on the part of the decision maker throughout the analytical process. Instead of a rather passive position after helping to formulate a set of weights as in the case of the GAM, the decision maker is deeply involved in the process of analysis.

e. Real World Applicability

Applicabiltity to ARZ Types of Transport Projects

An inherent strength of the Concordance Anlysis and the Compromise Solution is that they have a potential applicability to a large number of alternatives. In this sense, the CA and the CS are useful for ARZ types of actions since a variety of similar but alternative types of ARZ schemes often exists within the urban transportation context.

The CA and the CS are also suitable for ARZ types of actions which can be regarded as being flexible and changeable because these methods can be put into operation rather quickly, and are designed to be a short-term aid for the decision maker rather than a guiding framework for the transportation process as a whole.

One weakness inherent in the CA and the CS is that these methods are not effective in handling a large number of decision makers. There are wider variety of decision makers involved in decision making environment surrounding ARZ types of actions. These decision makers' perspectives are not coherent and each decision maker has his own preference.

The GAM appears to be weak for handling ARZ types of transportation projects. The incidence sectors in terms of

gains and losses between   different interest groups do not
seem to be important for ARZ types of actions in the context
of Seoul.   The incidence sectors are in general not
incorporated into the planning and decision making process
for ARZ types of schemes.   Also the siginificant effort
necessary for formulating objectives and weights may not be
worthwhile   for   such   small-scale   and   service-oriented
transportation plans.   The GAM is also of little utiltity
when the effects of transportation projects are minimal.
This is often the case of ARZ schemes. situation prevails.

Applicability to Capital-Intensive Transportation Projects

In contrast to their usefulness for ARZ schemes, the
Concordance Analysis and the Compromise Solution are weak
with respect to this criteria.   The effects of capital-
intensive transportation projects to be considered are
generally considerable and complex.   There is a danger in
applying these methods that these effects may be aggregated
in a crude way.

Capital-intensive projects usually require huge capital
investment ,longer time span and cost-benefit type   of
analysis.   Capital-intensive projects may be successfully
handled by cost-benefit type of analysis in cases where such

evaluation criteria as discount rate, shadow price and opportunity are considered important. The CA and the CS can be used as a means to narrow down the number of capital-intensive projects when the above-situation exists. After the number of alternatives are narrowed, elaborate cost-benefit analysis will be employed for a systematic evaluation of a small number of alternatives.

While it is difficult to generalize the decision making environment surrounding capital-intensive projects, relatively fewer number of agencies and decision makers are involved in making decisions on capital-intensive projects. This environment is conducive to the underlying structure of the CA and the CS.

The GAM appears to be satisfactory for the capital-intensive transportation projects. The GAM is conceptually and practically more relevant than other methods for analyzing the effects of capital-intensive projects because of its comprehensiveness. It provides a basis for incorporating all relevant sectors that must be taken into account in the planning process for such capital-intensive projects. The GAM has a relative advantage for cases where few alternatives are available as often the case with capital-intensive projects. In this sense, the underlying philosophy of the GAM is closely matched with on-going transportation practice of capital-intensive projects. The GAM would function best when sufficient time is available

for formulating goals and weights. Major disadvantages occur when the area to be affected by the capital-intensive projects become large.

Incorportion of Uncertainty

In Concordance Analysis and Compromise Solution, the problem of uncertainty is superficially stressed. These methods suggest performing sensitivity analyses for dealing with uncertainty. It seems, however, that sensitivity itself cannot effectively handle the uncertainty because of dynamic nature of effects and complex computational requirements. Since the underlying philosophy of these methods is the provision of information to the decision maker on the "one-shot" basis, it appears difficult to incorporate uncertainty in a systematic manner.

The adaptability of the GAM may enable it to handle uncertainty better than other methods. The GAM also explicitly recognizes the difficulties inherent in uncertainty. The fact that the GAM is potentially capable of dealing with capital-intensive transportation projects is conducive to dealing with uncertainty since uncertainty can be generally considered important in capital-intensive transportation projects. In the GAM,

project consequences (e.g., increase in travel time and environmental change) may be accompanied by probablistic statements or they may be expressed by a range of possible outcomes.

Linkage to Planning Process

Figure VII-3 Stages of Planning and Decision Making Process
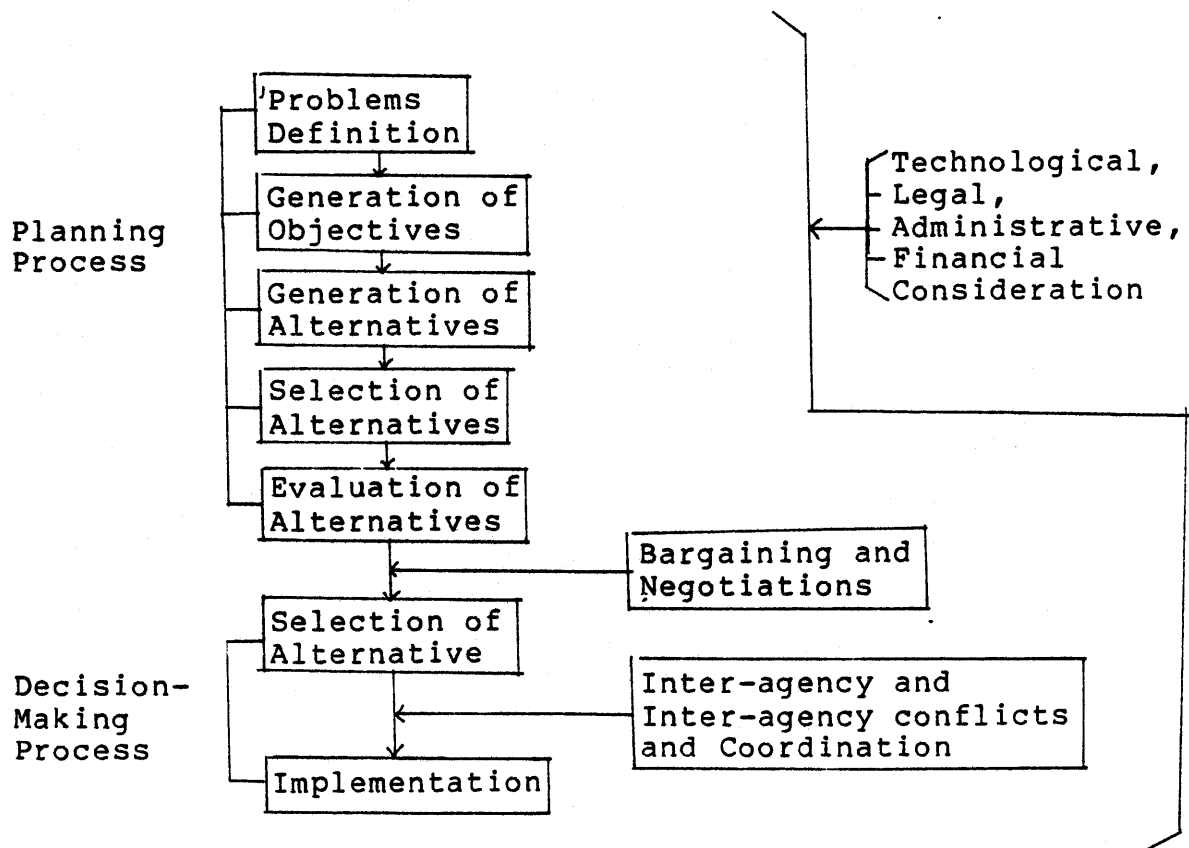
The linkage to the overall planning process is weak in Concordance Analysis. The underlying structure of Concordance Analysis is oriented toward helping the decision maker formulate preferences. Also this method is aiming at single or few decision makers. As shown in Figure VII-3, Concordance Analysis can be employed in the stage of "selection of alternatives" in the overall planning process. In this sense, the Concordance Analysis would probably not occupy more than a fraction of the larger planning process if it were applied in the real world.

The philosophical basis of the GAM is more suitable for the overall planning process. The analyst doing the GAM is expected not only to formulate community objectives with the help of planners or decision making groups but also to evalaute selected alternatives. A continuity of the analsyt from the first inkling of project design through final evaluation is, therefore, essential.

The Compromise Solution is not attractive with respect to the planning linkage criterion. The Compromise Solution is a method of searching out the best solutions through interaction between the analyst and the decision maker. It can be regarded as a decision-oriented rather than a planning-oriented method. The Compromise Solution begins by examining alternatives and impacts which are assumed to have been previously designed. Therefore, it is implicit in the Compromise Solution that the analyst enters the planning

process at a relatively late point, particularly the stage of "evaluation of alternatives".

Linkage to Decision Making Process

The Concordance Analysis is satisfactory with respect to this criteria if there is only a single or a few decision makers. As shown Figure VII-3, the decision making process consists of both the selection of the best alternative and implementation. If there are multiple decision makers, this method is inferior because the alternative selection procedure and implementation must be heavily influenced by many different decision making groups in real-world situation.

The GAM is considerably more realistic about the decision making process than are the other two methods. Even in the goal setting process, it tries to reflect the value structures of the diverse decision making groups. Although the GAM suggests consultation with relevant agencies and review of planning documents for setting the goals, intra and inter-agency relationship stemming from the intersectoral nature of transportation projects could not be taken into account.

The Compromise Solution is not sensitive to the decision

making process , including the alternative selection and implementation process. There is in fact no attempt to address the issues surounding the decision making process. Legal, administrative and financial considerations are hardly incorporated into the analytical process. This is a major limitation because the environment in which transportation planning takes place is charactrerized by the existence of legal, administrative and financial constraints.

f. Applicability to Transportation Environment in Seoul

There is no common pattern in terms of the environment in which transportation systems operate in developing countries. Distinct philosophical orientations and traditions of government may lead each developing country to differ in its interpretation of transportation problems, recognition of objectives and alternatives and handling of evaluation and decision making. Thus it would be futile to draw conclusions about the issues surrounding this criteria solely from the experience of Seoul.

Before assessing the three methods in terms of the Seoul experience, it seems necessary to describe the characteristics of the transportation planning environment and perception of public officials toward transportation planning. This is based on the author's experience with public officials interviewed in the Seoul city government.

While the public officials interviewed in general understand the importance of the ranking technique used for articulating their preferences, they are reluctant to participate in the thinking process. This is the major obstacle for conducting the analysis. Problems lie in their perception of ARZ types of transportation projects. Difficulties arise for a variety of reasons ranging from

transportation-related ones to methodology-related ones. They may be summarized as follows:

Transporation -Related Problems

1. Failure to derive needs for ARZ types of schemes from comprehensive program of transportation improvement with designated priority for action.

2. Failure to appreciate potential importance of ARZ types of transportation projects.

3. Failure to relate ARZ types of projects to capital-intensive transportation projects in an integrated manner.

Methodology-Related Problems

1. Failure to understand the linkage between outcomes of ranking technique and decision making process.

2. Failure to incorporate multiobjective or multicriteria into evaluation process.

3. Unwillingness to actively participate in the analysis process.

Formulation of Weights

An essential problem with an interview method such as the Churchman and Arkoff technique (CAT) is its heavy reliance on the value judgements assigned to criteria by the analyst or interviewer. The analyst's value judgements cannot be avoided since the CAT implicitly encourages the analyst to come up with preliminary "screened criteria and alernatives.

This problem is particularly accute in several agencies in Seoul where interviews were conducted. They have no clear notion about the objectives for urban transportation in the context of the central business district in Seoul. This lack of a clear notion makes the analysis very cumbersome. A significant amount of work is required for the analyst himself in this situation. The analyst should not only educate the decision making groups in the logic behind the CAT but also conduct the preliminary evaluation on potential criteria and alternatives.

The CAT becomes more difficult for the decision making groups to follow as the number of consistency checks and criteria increases. The public officials find a process of consistency checks a difficult undertaking requiring the painstaking tracing of relationship. The CAT is also hampered by the fact that even after its completion, there is

no acceptable means of assessing the validity and accuracy of the weights derived by the decision maker.

Experience with these public officials also reveals that, among some public officials interviewed, only the financial costs and revenues (returns) are of interest and not the environmental pollution and enforcement problem. To some degree, externalities are generally considered as one of several criteria in transportation-related agencies in Seoul, but in most cases these are given low priority.

Applicability in the Case of Scarce Information

The Concordance Analysis works reasonably well for a situation in which scarce and vague information is avaiable if the decision maker is willing to provide value judgements on several parameters. The burden of the analyst can be significantly reduced in this case. While a conclusion made in the absense of full information is less reliable, it can still provide the results for drawing inferences about desirable alternatives.

The GAM is rather weak in terms of applicability in the case of vague and scarce information. While it may be theoretically possible to derive weights through ranking or rating techniques, a difficulty lies in the process of

articulating the common denominator (weights) for the various interest groups.

The Compromise Solution is favorable for the situation of scarce and vague information for the reason discussed in the case of the Concordance Analysis. The Compromise Solution can be used as a "screening purpose" if this situation prevails. After the number of alternatives are narrowed, effort should be made to collect more accurate data for more detailed analysis

Applicability to a Rapidly Changing Environment

The environment in which transportation planning takes place in Seoul is characterized by rapid change in socio-economic characteristics, demand, objectives and people's preferences. A method capable of incorporating one or more iterations can be potentially useful for this situation. The method should be that of constant feedback and iteration with objectives being redefined and modified.

The Concordance Analysis functions best under these requirements of iteration and feedback. Close contact between the analyst and the decision maker in this case is important because of the requirement of a constant feedback.

The GAM is an inferior method for incorporating

iteration and feedback. In GAM, the decision makers would be provided with both a variety of alternative summary figures and the full set of disaggregate accounts behind them. This underlying requirement tends to make the GAM inherently difficult for incorporating an iteration. The GAM also suffers from a lack of a dynamic dimension: it is essentially "one-shot". Thus it is difficult to deal with the change in on-going transportation systems.

The Compromise Solution works well in terms of performing iteration and feedback. In addition to specifying new weights, the decision maker can add constraints, such as budget limitations or enforcement problems, and revise his ordinal ranking of priorities. The analyst may also experiment using his own judgmental weights based on past actions and documents related to transportation plans. The ideal situation would, therefore, be the case where the decision making unit is a single decision maker.

4. Conclusion

The goal of this chapter has been to compare the

limitations and usefulnesses of the three methods. The three methods have been evaluated from a number of respects. The assessment has highlighted the limitations and usefulnesses of each.

The results of assessment reveal that each method has both advantages and disadvantages; no method is strongly favorable without some drawbacks. None of the three methods is intended to substitute for human decision making. All methods can be viewed as decision aids that synthesize the contents of impact matrix into more esential and meaningful information. A brief summary of asessment results as follows.

Comparision reveals that the underlying structure of the Concordance Analysis is similar to that of the Compromise Solution. The Concordance Analysis and Compromise Solution are decision-oriented rather than planning-oriented methods. The underlying philosophy of the GAM is the prediction of effects for various incidence sectors with reference to articulated objectives while the internal logic of the Concordance Analysis and Compromise Solution is the provision of information to single or a few decision makers.

The technical complexity inherent in the Concordance Analysis and the Compromise Solution seems to make these methods difficult for the decision maker and layman to comprehend while the GAM can easily be constructed by the analyst and understood by the decision maker. The Concordance Analysis and Compromise Solution have, however, a

potential usefulness as a tool to facilitate the interaction between the analyst and the decision maker and to make a preliminary cut of a large number of alternatives.

The Concordance Analysis and Compromise Solution are suitable for the transportation situations involving single or few decision makers. The GAM is, on the other hand, useful for the case where a variety of decision making groups exists as it requires the public inputs of incidence sectors when formulating goals, objectives and weights.

The Concordance Analysis and Compromise Solution are superior for ARZ types of transportation projects because of their potential applicability to a large number of alternatives. Since there are numerous ARZ types of transportation projects that can be feasible in given urban contexts as examained in Chapter IV, these two methods are particularly useful for ARZ schemes. The GAM functions best for capital-intensive and large-scale transportation projects due to its comprehensiveness. The GAM appears to conceptually and practically more relevant for capital-intensive projects.

The Concordance Analysis and Compromise Solution are not particularly adaptable to the overall planning process while the GAM is considerably more realistic about the overall planning process.

None of the methods is superior for decision making although the GAM attempts to reflect the value

structure of a large number of decision making groups. However, none of the three methods deals explicitly with the environment in which major transportation decisions are made. This is a major limitation because decision making environment of major transportation projects is characterized by a number of legal, administrative and financial constraints.

The conclusion of the thesis will be presented in the next chapter summarizing the thesis and its potential contributions and suggesting directions for further research.

CHAPTER VIII   SUMMARY AND CONCLUSION

The purpose of this chapter is to summarize and conclude the thesis. The conclusions are based on the two major objectives of the thesis. In view of the experience gained in the context of this research, potentially useful directions for further research are suggested.

The objective of the thesis was twohold: (1) to discuss auto restricted zone policies in general and the rationale behind restricting auto traffic in central cities in developed countries and developing countries as well; (2) to assess the usefullnesses and limitations of the three multicriteria evaluation methods through the application to auto restricted zone policies in Seoul.

1. Thesis Summary

The first chapter briefly introduced the concept and experience of ARZ schemes. It continued on to discuss the multicriteria problems inherent in a transportation context

and to review the literature on the multicriteria evaluation methods in transportation field. The first chapter also discussed the objectives and organization for thesis.

Chapter II began with a discussion of auto restrction policies in general: the philosophical rationale behind restricting automobile traffic in central cities, a cursory examination of cases of ARZ application in U.S., Europe, Asia (Singapore), and a taxamony of these and other examples. This chapter continued with a comparison of objectives and underlying characteristics of ARZ experience in both developed and developing countries. Also issues associated with ARZ application were addressed from the intercultural dimension. The chapter progressed with an exploration of relevant ARZ policies and techniques in developed and developing countries as well.

Chapter III examined the evaluation methods with respect to transportation projects. Conventional approaches were discussed along with their drawbacks and usefulnesses. Posing the problems associated with these approaches directed the attention to alternative methods. This was followed by the review of multicriteria evaluation mewthodologies with reference to transportation plans or projects.

Chapter IV described the characteristics of Seoul Central Business District and transportation systems. Mode shares and socio-economic characteristics of travellers were also discussed.

Chapter V centered around the discussion of criteria and ARZ alternatives. Quantifiable criteria were expressed in measurable units, and unquantifiable criteria were expressed in terms of qualitative weights.

Chapter VI was devoted to the implementation of three multicriteria evalaution methods: the concordance analysis, the goal-achievement matrix and the compromise solution. Each method began with a discussion of theory followed by a discussion of the implementation.

Chapter VII evaluated the three multicriteria evalaution methods in terms of several criteria. The criteria seen as essential for assessing the methods include: the computational burden, degree of interaction with the decision maker, real-world applicability and applicability to developing countries as explained by the case of Seoul.

Chapter VIII summarized and concluded the thesis. The conclusions were based on the two major objectives of the thesis. In view of the experience gained from this research, potentially useful directions for further research can be suggested.

2. Thesis Conclusions

Conclusion Related to ARZ Experience

The main conclusion with respect to the first objective of the thesis is that the rationale behind auto restricted zone policies generally varies within the U.S. and Europe and between developed and developing countries. Accordingly, the objectives of ARZ schemes vary from one city to another, depending upon individual circumstances. Most American ARZ experience was based on economic revitalization. The environmental objective is generally stressed in the concept of ARZs in European cities. While the objectives of ARZs difffer according to cities and types of ARZ, reducing traffic congestion in the central cities is a principal objective in developing countries.

Examining the ARZ experience of the U.S., Europe and developing countries, each has distinct approaches and solutions to essentially similar transportation problems. Grossly summarizing these experiences, the major reasons for the differences seem to be because each region has different perceptions and attitudes toward the transportation problems themselves. Decision making is, therefore, different. The key factor is that each of the cities has different goals

which greatly affect the ARZ objectives and types.

Also, the degree to which certain ARZ schemes may be useful in accomplishing particular objectives is rather hard to determine. In most cases, no obvious matrix exists between ARZ schemes and objectives. A direct relationship with specific types of ARZ schemes seems difficult to establish because of other forces operating on these objectives.

Conclusion Related to Evaluation of Three Methods

The conclusion with respect to the second objective of the thesis is that the three methods can be successfully implemented for ARZ types of transportation projects. The multicriteria evaluation methods employed in this thesis have, despite certain drawbacks, considerable potential as tools for assisting the decision maker and others concerned with the transportation decision making process. Their major advantages over traditional transportation evaluation methods is that they allow the consideration of a wider range of costs and benefits, and are oriented towards the decision makers.

The empirical analysis also illustrates the usefulness

of including qualitative criteria into the evaluation frame-
work without transforming them to a monetary dimension.
While the three methods have certain limitations that prevent
complete confidence from being placed in their results, it is
contended that the positive aspects of the three methods
outweigh those disadvantages.

All methods can be viewed as decision aids that synthe-
size the contents of the impact matrices into more essential
and meaningful information. The three methods are in general
capable of incorporating the multicriteria imbeded in
transportation plans. A brief summary of the assessment
results is presented as follows.

(1) The Goal-Achievement Matrix (GAM) appears to be easiest
to use because the computational burden is rather light
compared to the Concordance Analysis (CA) and Compromise
Solution(CS).

(2) As examined in Chapter VI, the three methods are in
general capable of encompassing a variety of primary effects
resulting form the implementation of transportation
projects.

(3) The technical complexity inherent in the CA and CS seems
to make these methods difficult for the decision maker and
layman to comprehend while the GAM can easily be constructed
by the analyst and understood by the decision maker.

(4) The CA is not relevant for encouraging public participa-
tion while the GAM appears to be the best approach to
encourage public participation. Because of the time-

consuming and technical nature of the CS, its use may be restricted to the analyst and key decision maker.

(5) The CA and CS are decision-oriented rather than planning-oriented approachs. The underlying philosophy of the GAM is the prediction of effects for various incidence sectors with reference to articulated objectives while the internal logic imbeded in the CA and the CS is the provision of information to a single or to a few decision makers.

(6) The CA and the CS are superior for testing sensitivity because these methods are designed to provide information to a single or few decision makers . The GAM is weak in that it needs to include a variety of incidence sectors when reformulating goals and objectives and respecifying weights.

(7) The CA was found to be superior for ARZ types of transportation projects due to its potential for assessing a large number of alternatives. Since there are numerous ARZ types that can be feasible in given urban contexts, the CA is particularly useful for ARZ schemes. The GAM is weak in its handling of ARZ schemes because the significant effort necessary to formulate objectives and weights from a wide range of incidence sectors may not be worthwhile for such small-scale and service-oriented transportation actions. The CS has a potential usefulness as a tool for screening a large number of transportation alternatives such as ARZ types of actions.

(8) The CA and CS appear to be inferior for capital-intensive

and large-scale transportation projects. The GAM is
conceptually and practically more relevant for capital-
intensive projects.

(9) The linkage to overall plannging process is weak in the
CA and the CS while the philosophical basis of the GAM is
more suitable for the overall planning process.

(10) While none of the the methods can effectively deal with
the decision making process, the GAM is considerally more
realistic about the decision making process for transporta-
tion projects than are the CA and the CS.

(11) The Churchman-Ackoff Technique (CAT) was found to be a
difficult approach to articulating decision-making-group
preferences in transportation-related agencies in Seoul. The
public officials interviewed were not generally willing to
participate in a repetitive thinking process. They appear to
have no clear notion about about objectives and ARZ types of
actions in the context of Seoul. The public officials found
a process of consistency checks a difficult undertaking
requiring the painstaking tracing of relationship.

(12) The CA and the CS work reasonably well for the situation
where scarce and vague information is available while the GAM
seems rather weak for this case.

(13) The CA and the CS function best as a means of iteration
and feedback. This is a considerable advantage for the
transportation planning environment in Seoul in which rapid

change   in   demand,   socio-economic   characteristics   and

4. Consideration for Furture Research

In view of the experience gained in the context of this research,   several   areas for   furture   research   can   be suggested. First,   there   is a need to explore further the objectives   and   relevant ARZ policies in central cities in both developed and developing countries.   Information on ARZ experience   in   developed and developing countries should be searched in order to compare the objectives and relevance of ARZ   policies.   Further   research   should also   be   directed exploring the decision making and institutional   environment. This will lead to identifying the motives and reasons behind restricting automobile traffic in a given urban area.

Second, further research is required to establish a more explicit framework for identifying, measuring and valuing the effects from the proposed transportation plans.   A related research   project would be to incorporate   secondary impacts into the impact matrices.

Third, The Churchman-Ackoff technique employed to assess

the preference structure of decision making groups appears not to be highly reliable. The assessment procedure is time-consuming and requires repetitiveness. Some public officials interviewed exhibit aversion to the thinking process required by the technique. Research is required to improve or modify the assessment procedure. Related research would be to conduct similar analyses for different interest groups or experts which can lead to important additional insights.

Fourth, the three multicriteria evalaution methods employed require extensive and continued development so that the validity of the three methods could further be tested. Further implementation of these methods in different transportation contexts would provide a test of whether the results obtained from new applications are methodologically similar to those found in this study.

Fifth, further research should be done to delineate accurately the travel behavior in Seoul city, including patterns of demand for both individual trips and aggregated trips for the entire city. The logit parameters used for this thesis represent the travel behavior of one corridor in the central city. Thus attempt should be made to calibrate the logit model on the basis of the entire city.

Sixth, the Concordance Analysis and the Compromise Solution are methodologically designed to deal with a single decision maker or a few decision makers. However, the environment in which transportation decisions are made are

characterized by a variety of decision making groups. Clearly, the need exists for incorporating the values of these decision making groups into the analytical process.

Seventh, the uncertainty concerning the estimates of a criteria such as cost, revenue, travel time savings, etc., should further be analyzed. Generally, the uncertainty can be explicitly represented by a probabiltiy distribution function. This representation ensures more confidence in the estimates of criteria as criteria are described as a distribution of values instead of being treated as single values. Along, this line of research, the way to incorporate a probability distribuiton function into the framework of the three methods examined should be explored.

5. Extensions of the Research

In addition to the potential research areas previously discussed, the three methods can be extended in several dimensions. First, the three methods could be supplemented with the use of interactive techniques. The interactive techniques would facilitate the interaction between the analyst and the decision maker and help the decision maker

articulate weights. Through interactive technique, the logic of decisions is constantly tested and value preferences can be explicitly and clearly incorporated.

Second, the three methods could be supplemented by a tradeoff analysis. The tradeoffs among different criteria are important. Little previous reseach has been done in this particular area.

The final suggested extension to the present research would be to develop computer packages for the three methods. The various sensitivity analyses and weight articulations can be effectively aided by the computer programs.

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Appendix II-1 Charateristics of Widely-Used ARZ Schemes

a. Traffic Cell

1)Concept.   This   scheme is designed to discourage auto
drivers   and encourage public transit usage. Several cells
are created within the city center, and borders between cells
are closed to traffic except to pedestrians and public
transit. The auto drivers are then faced with a choice of:
switching to another mode, arriving before peak periods or
parking away from the cell.

2)Mechanism.   Establishing a traffic cell at the city
center is usually within the authority of cities and towns
and   generally held by the transportation   or   traffic
department or its functional equivalent. Appropriations for
the purchase of signs and necessary items, labor for creating
cells and installation of signs and additional enforcement
may be from a city's general funds, or may be covered by the
department's own resources, depending upon the daparmental
funding structures.   A procedure would be required for
determining the number of cells to be created. Pedestrian
streets may be closed until the core area is effectvely

divided into separate traffic cells with few or through connections. The traffic cells can be supplemented by the creation of one-way street and street closing at key points.

3) **Variations.** Traffic cells may vary in the number of cells that can be created in the city center. For example, the number of cells to be created could be by size of area or by the number of main streets. Restrictions may specify where new pedestrian streets can and cannot be constructed. A cell may also be applied to the area where rapid transit service terminates. The traffic cell scheme should be designed so that undesirable traffic spillover does not occur around boundary roads or into surrounding areas. Parking should be created, if necessary, to absorb the traffic to be held in the ring road or surrounding area following the creation of the cell system.

4) **Possible Changes in Commuter Travel**

*diversion to public transit, if available

*diversion to shared rides

*continued single occupant vehicle use, but tendency to arrive at cell area earlires in order to secure a scarce space - possible shift or extension of peak period

*dropoff by family member

*possibly parking outside cell area and taking transit or walking to walk or shop

5) **Side Effect.**

*possible increase of traffic in the boundary road or

surrounding area

*possible increase in vehicle kilometers traveled

    6)Factors Which May Influence Success.

*the stringency of enforcement

*availability of public transit

*whether the street system in the city center is able to serve a significant amount of automobile traffic

*the intrinsic attractiveness of the area

b. Pedestrian Street to Area

    1)Concept. This scheme is designed to give pedestrians of the city center priority over automobile traffic. This pedestrian street is usually created in an area where conflicts between pedestrians and auto vehicles are high. The specified street is closed off for all traffic. This can be applied to the CBD or to suburban shopping malls.

    2)Mechanism. Most local governments have the authority to establish pedestrian streets within their jurisdictions. The decision about which streets to restrict must be reasonable, necessary, and non-discriminatory because this scheme may affect the business activities. Funds for construction and enforcement may be appropriated from general funds, but in other cases, the department in charge may be able to utilize its own funds for such a scheme. Enforcement

of traffic restrictions is the responsibility of the group which enforce all other traffic scheme - usually the police department.

3) **Variation.** The pedestrian street or area may vary significantly according to the area, traffic volume, pedestrian volume, type of land use, and characteristics of business activity. This scheme may be applied to an entire city center in some cities. In others. the pedestrian street may be applied only to streets in the core area which are heavily used by pedestrians. Transit and paratransit may be allowed, depending upon the characteristics of the area. The arrangement of the pedestrian area should not be detrimental to other streets. What seems important for areas which are purely for pedestrians is their clear demarcation from streets for vehicular traffic. This applies in particular where they cannot be blocked off completely because public service vehicles must have access. Relevant roadways may be turned into connections that benefit pedestrians. The meaningful dimensioning of the width of pedestrian street, its density, surface area and classification into single-purpose and mixed purposes depend on the size of the city center, the volume of pedestrian traffic and the density of buildings.

4) **Possible Changes in Travel.**

*diversion to public transit, if available

*dropoff by family member

*diversion to shared rides

*possibly parking outside pedestrian area and walking to work or shops

5)Side Effect.

*increase or decrease of business activities: potential impact on area development unclear

*possible increase in non-wark trips

*may encourage some people or business to leave the city center: this applies to those groups who cannot afford the pedestrian area locations which are expensive because of their scarcity or their exclusivity.

6)Factors Which May Influence Success.

*stringency of enforcement

*avaiablity of transit

*high pedestrian volume

*existence of significant amount of conflict between automobiles and pedestrians

*intrinsic attractiveness of the area

*whether or not city center is tightly structured and walkable with a good mix of land uses and activities

c. Area License Scheme

1)Concept.   This scheme is directed toward the people who are commuting to the city center. Auto drivers are required to purchase a lincense in order to enter the city center. This scheme is intended to force those commuters to make choice between paying a lecense fee and taking another mode to work or arriving at work after peak period.

2)Mechanism   Because an Area license scheme is a traffic regulation scheme, it usually falls under the same sort of authority as described under the cell system. Whether an area license system is legal or not depends on the local situation (legal structure and law). Legal challenge to the constitutionality of area license schemes may be possible in certain area. Permits are typically issued to auto drivers of the city in which the scheme is to be undertaken. A procedure would be established for determining the license structure to be charged and the time of day to be affected. Fringe parking lots and boundary roads outside the area license scheme (ALS)area are essential before implementing these scheme.

3)Variation.   The license fee struture that can be charged to auto drivers may be varied. For example, the level of the license could be some fixed fee, it could be a higher fee for peak hours and a lower fee for off-peak hours, or any of a variety of schemes. This scheme may also be varied by

the target groups to be charged. For example, car with 3 or 4 passengers could be entitled to enter the city center without paying the license. Restrictions may also specify where new boundary roads or parking lots can and cannot be constructed. Restrictions may be applied to entire metropolitan area, as well as the CBD; regulations for all jurisdictions should be coordinated so that undesirable spillover does not occur in one city or district.

4) Possible Changes in Commuter Travel.

*diversion to public transit, if available

*diversion to shared rides

*dropoff by family member

*possibly parking outside restricted area and taking transit or walking to work

*increase in vehicle kilometers traveled particularly in the boundary road

*distribution of overall pattern of transportation system

5) Side Effect.

*possible decrease in peak period travel if sufficient auto drivers wait untill the off-peak period

*change in land use - change in home and firm locations (may be longer term effect)

*possible fee increase when demand becomes greater than road capacity(supply)

*potential impact on urban development - unclear

*imbalance in the use of road system

6)Factors Which may Influence Success.

*stringency of enforcement

*availability of public transit alternatives

*strong will and power of government and effective management

*availability of boundary roads and fringe parking lots

*intrinsic attractiveness of the area.

d. Pedestrian Shopping Mall

1)Concept.   It is the taffic-free shopping streets of the inner cities and suburban centers combined with malls and shopping centers. The idea was developed when the concept of renovating the city center was advanced. This scheme is intended to protect pedestrians from vehicular traffic in the shopping area, usually the city center. Auto traffic is in general not allowed to enter into this area. Usually this scheme is apllied to the area where the street system is unable to serve a significant amount of auto traffic. The intent of this scheme is often to enhance the vitality of economy in the city center.

2)Mechanism.   A pedestrian shopping mall may be accomplished through urban development policies such as urban renewal or a downtown revitalization project. It is conceivable that in some cases, this scheme may be accomplished through modifications to existing zoning

regulations. Most local governments have the authority to create pedestrian shopping malls (exceptions may include streets which are privately owned, or owned by other state or regional agencies). The reduction in the number of streets crossing the pedestrian area may be necessary in order to separate vehicles and pedesrians'. Rerouting crosstown traffic may also be preceded so that major streets do not cut through pedestrian areas.

3) **Variations.** This scheme may be applied to the entire city center ot it may be applied only to few streets in the core area which are currently used by pedestrians and auto traffic. This scheme may be designed to eliminate the automobile or to separate vehicular and pedestrian movement. The pedestrian streets may be created in conjunction with a revised traffic pattern or it may be established with the current road network in the city center.

4) **Possible Changes in Travel.**

*diversion to public transit

*diversion to shared rides

*dropoff by family member

*possibly parking outside pedestrian shopping mall or walking to work or shops

5) **Side Effects.**

*may cause a serious loss of activity in the city center

*banning cars from one street may have repercussions on all

downtown traffic in some circumstances

*possible increase in non-work trip

*surface parking lots which provide most of the off-street parking near pedestrian shopping malls will become a battlegrounds of the fight for space between shoppers and downtown employees

6)Factors Which May Influence Success.

*stringency of enforcement

*availability of public transit

*high pedestrian volume

*existence of boundary or adjacent streets which are capable or absorbing some diverted traffic

*intrinsic attractiveness of the area

*a good mix of land uses and activities to maintain forces of econimic viability in the city center.

Appendix III-1   Detailed Assessment of ARZ Evaluation Cases

a.Cost-Benefit Analysis

(i) Jose Gomez-Ibanez and Gary Fauth (1980)

Decision Problem   The decision problem that is addressed in this study is the issue of whether or not benefits exceed costs when two forms of auto restraint are employed in Boston.   The principal benefit estimated is the savings in travel time resulting from less congestion on the streets in and around the central area.   The principal cost estimated is the increase in travel time, expense, and/or inconvenience to auto users who change to transit or to another route.

Alternatives   Parking charges of various amounts for different times of the day are tested. Area license scheme to both local streets and expressways were compared.   Two other policies - a small auto-free zone in Boston's commercial district and toll increases on the three facilities already charging tolls are analysed less throughly.

Analysis and Findings   This study employed travel demand forecasting models to predict the changes in travel behavior and congestion levels.   The logit models already calibrated from other metropolitan areas were used.   The

results of these medels provide the basis for calculating costs and benefits. Results show that area restraint schemes significantly increased average traffic speeds on central area highways. Almost every type of peak period auto restraint measure produces positive net transport benefits.

Assessment The number and diversity of alternatives and effects the authors sought to investgate are highly ambitious. Because of resource and data constraints, they were prevented from formally analyzing more than a few of them. In addition, over-reliance is placed on the logit model calibrated in other cities in U.S. Like other transportation studies, this study was directed toward the cost savings (time) likely to accrue to road users. The problem of how to place a monetary value to time savings raises an issues commonly discussed in the evaluation of transportation plans. A subjective judgement entered into the process of evaluating the value of time. While reference was made to externalities, there was no attempt to estimate the benefits and costs associated with them.

Another concern is that time is an important variable in evaluation. Effects or benefits and costs of ARZ schemes may change over time. In this study there was no attempt to distinguish these effects and costs and benefits in terms of short-rum and long-run time frames. Along a similar line of reasoning, consideration of uncertainty does not enter into

the evaluation. Given the fact that the system itself (human and transportation) may be in a state of flux, it is important to consider uncertainty associated with transportation plans. As was already implied above, this study does not incorporate a multiple objective framework. Hence, it provides analysis only on the transport time savings as a benefit and time increase as a cost and does not address other objectives such as environment, safety, economy and so on.

(ii) J.M. Thomson (1967)

Decision Problem The decision problem is to ascertain whether or not two auto restraint proposals are beneficial in the central London. The costs estimated include administration, losses to diverted cars and losses to restrained cars. The benefits estimated include benefits from higher speeds and benefits to traffic generated by the license system. The author evaluates two schemes. One is a daily licensing scheme whereby all cars and cycles moving in the area between 7 a.m. and 8 a.m. are required to display a license valid for that day only. The other scheme is a parking tax scheme whereby an hourly tax is added to the parking charge at all parking sites in the area.

Analysis and Findings This study is limited to the

assessment of traffic effects and associated economic benefits resulting from different levels of charges. The demand functions of different classes of traffic are examined using elasticities. The supply functions i.e. the traffic volumes and speeds, are then calculated. Benefits of licence fee or parking tax are derived. The work by Gomez-Ibanez and Fauth (1980) appears quite similar in its methodological approach. Gomez-Ibanez and Fauth use logit models whereas Thomson employed demand equations for the prediction of travel behavior. In this sense, Gomez-Ibanez and Fauth's work seem to have been heavily inspired by the earlier work of Thomson. Both areas, London and Boston, where these schemes were applied are characterized by relatively high population density and financial and commerical activities. The benefits of an ARZ in these two cities turned out to be significant. In the case of London, little advantage is seen in the proposal for a parking tax. Thomson concludes that if the licence fees were used for the benefit of motorists it would be theoretically possible for all classes to be better off. In terms of implementability, no administrative consideration was discussed in this study.

Assessment From the administrative point, Thomson's area of restraint covers 7 square miles in the center of London. This appears to be large area when compared with 2.5 square mile in Boston in Gomez-Ibanez and Fauth's work. The

other question which arises in this context is that of how elasticities were estimated. The demand functions are rather naive. The demand functions need more variablells in them than just straight cost and taxation.

As discussed in the context of Gomez-Ibanez and Fauth's study, this study is also centered around the evaluation of transport costs and benefits. Suprisingly, no mention is made in the method used to calculate the value of time savings. The magnitude of benefit of the alternatives are particularly sensitive to travel time savings. Intangibles and externalities were not included in the evaluation. As such, this study is purely based on the single objective - maximization of transport benefits over costs.

(iii) Damian Kulash (1974)

Decision Problem and Alternatives The issue of whether or not the effects of introducing road pricing are progressive or regressive is explored in rather systematic fashion. Several values of time saving are used to test the above decision problem. Three metropolitan areas (Boston, San Fransisco, and Washington) are used for this analysis.

Analysis and Findings Using 1970 work trip patterns in Boston, San Fransisco and Washington, Kulash studied the distributional consequences of roadway pricing. As he

argues, the regressivity of net costs (net cost are defined as road user charges less the value of time savings by Kulash) depends on time savings and road user charges. The larger are the time savings or smaller are the road user charges, the more regressive would be the net costs because of the greater trip demands by wealthier motorists. Whether or not his hypothetical combinations of roadway prices and resultant travel time savings are appropriate assumptions in three metopolitan areas is left on open question.

Assessment The conclusion drawn regarding regressivity in three areas is somethat questionable as the travel characteristics of three areas are significantly different from one another. In terms of net costs defined by Kulash, road pricing in a city like Los Angeles would be very regressive because considerable time savings may be achieved in typical "bottle-neck" situation where traffic flow would rather decrease than increase in response to a demand increase. Along a similar line of argument, the choice of "average" income group does not seem to be appropriate. A breakdown by various income groups seems necessary in order to make a convincing argument. Also, trip distance is assumed to be same for all commuters.

(iv) Kenich Tokunaka (1981)

Decision Problem Several decision problems are addressed in this study: (1) whether or not overall benefits of congestion pricing exceed costs; (2) what kind of travelers would be winners or losers in terms of distributional effects?; (3) which toll scheme is better - a flat toll per trip or a toll per vehicle=mile? This study is the most comprehensive cost-benefit analysis that address various issues surrounding the congestion pricing.

Alternatives The following alternatives are systematically considered: (1) a flat toll per trip vs. a toll per vehicle-mile; (2) income distributional effect - rich traveler vs. poor traveler; (3) average trip length - rich traveler vs. poor traveler.

Analysis and Findings For illustrative purpose, a comparison between this studies and other studies can be performed as follows.

Table III-A-1   Comparisons

Other studies   Tokunaka's study

- No considersation of   - Distributional issue is
  distribution   clearly addressed through
                                   systematic analysis

- All trips are of the   - High (low) income travelers
  same average trip length   make longer (shorter) trips

- The average time value   - Time values differ by income,
  is assumed   journey purposes, mode and
                                   small and large time savings

- Toll collection cost is   - Toll collection cost is taken
  assumed to be zero   into account

- Modal choice is fixed   - Modal choice is a function
  regardless of toll   of toll

- No   distinction   between   the   - This   difference   is

considered
  constant toll per trip
  and constant toll per mile

The general conclusion of this study is as follows: In

spite of the regressivity of road pricing, low charges (such

as 10 - 20 cent/trip in Los Angeles) would not always make

the poor worse off.   Rather, low charges might make both the

poor and rich better off in a highly congested area.

However, an efficient toll (63 cent per one way trip) seems

to make the poor person worse off. Bus passengers would gain

if greater demand for bus travel lead to more frequent and wide spread service. One thing the author neglects is the application of distribuitonal weight. The extent to which roadway pricing is regressive also depend on the distributional weight chosen. In addition, because this study is geared toward the distributional effects of roadway pricing soley for motorists, other concerns in terms of environmental and social effects are not treated.

(v) Peat, Marwick, Mitchell & co.

Decision problem and Alternatives This study tries to explore whether pedestrian schemes produce positive benefits. What factors are important in evaluating pedestrian schemes? Several different types of alternative pedestrian schemes are included in order to evaluate these alternatives.

Analysis and Findings This study attempts to apply the principles of traditional cost-benefit analysis to the evaluation of pedestrian schemes. As with most such efforts, the difficulty lies in quantifying abstract benefits, such as convenience, comfort and perceived safety. Safety is the variable affecting pedestrians which is most readily quantified, in terms of number and severity of accidents; so the greatest attention is given to safety in this study. Impacts to abutters, motorists and others are also necessary

to be counted in the calcualations.

Assessment   The application of cost-benefit analysis here runs into the same problems as in previous studies. The major problems in this study are: (1) the arbitrariness with which benefits are assumed to be relevant, discount rates are chosen, and decision rules are decided upon allow considerable bias to be incorporated into the process, for or against particular outcomes; and, (2) the incidence of benefits or impacts tends to be largely ignored.

(i) Kiran Bhatt (1976)

(ii) Trent Bertrand (1978)

Decision Problem   These two studies treat benefits and costs in a more general fashion. The decision problem that is addressed in Bhatt's study is the issue of combining charges (or area license) with expansion of services by high occupancy transportation modes. The decision problem in Bertrand's study is to ascertain whether or not congestion pricing produces potential benefit in the context of Bangkok. He also examines the "second best" decision often required when   there are constraints associated with congestion pricing.

Alternatives   Using hypothetical data, Bhatt compares the benefits of road pricing scheme with the do-nothing

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alternative. In Bertrand's study, congestion pricing and the second best alternative were compared with the Bangkok data. Congestion pricing and benefits were analyzed less thoroughly in Bhatt's study than Bertrand's study.

Analysis and Findings In Bhatt's study, congestion pricing was estimated to produce net benefits to the community. And he calculated the toll revenues to be 12.5 percent greater than the loss of benefits to the users. The revenue can then be used to improve the public transportation. Bertrand's work was rooted in the concept of externality which is long recognized in economics literature. Based on the results of his analysis, Bertrand argues that congestion pricing not only has a substantial impact on aggregate vehicle use-reduction in private cars but also increases the use of buses and taxis. Bertrand's work was based on the traffic system of Bangkok - Thonburi which covers an extensive metropolitan area. The study area appears to be far greater than the other urban areas examined. The question of implementability was raised by Bertrand. He calls the attention to the fact that attempts to raise registration fees on cars in Bangkok have met fierce resistance, including treats to the lives of policymakers. Implied here is the notion that appropriate redistrition mechanism of revenue should be found so that users of transport systems do not lose to the extent without

undermining the incentives for reducing and altering the structure of demands on transport systems.

Assessment   Unlike other studies, Bhatt's study covers a wide spectrum of issues surrounding the ARZ scheme such as the legal aspects, the financial and fiscal implications, the administrative difficulties, the possible impacts on activities and employment in the ARZ area. In Bertrand study, the problem definition and the description of the study area seem to be weak. Neither objectives nor more detailed criteeria for evaluation were used to guide the process of designing alternatives. The treatment of value of time in the context of Bangkok is not explicit while time value may markedly differ from developed countries. Both studies fail to include any indication of the incidence of costs and benefits. These two studies are hampered by many of the same difficulties of intangibles and externalites that appear in systematic cost-benefit analysis.

(iii) Cambridge Systematic Inc.(1976)

Decision Problem and Alternative   Four different ARZ schems (or policies) were evaluated using disaggregate demand models. The four policies investigated were:

Policy 1:   Total all-day auto exclusion, no transportation improvement.

Policy 2:   Total all-day auto exclusion, fixed routes bus system plus areawide transit improvements within ARZ.

Policy 3:   Total all-day exclusion, fixed route bus
             system plus areawide transit improvement within
             ARZ.
Policy 4:   Peak-periods exclusion only, no transportation
             improvements.

Analysis   This study employed disaggregate demand

models to predict changes in two categories of travel demand

associated with the proposed schemes: (1) regional work mode

choice models;   (2) intra-CBD workers frequency – destination

– mode   choice and non-worker destination-mode choice models,

which   incorporated the walk mode.   The models used   predict

demand changes associated with travel time and cost   changes,

i.e., elasticity-based changes rather than absolute levels of

demand.   The general   conclusion derived from this lengthy

analysis can be summarized as follows:

Policy 1:   Increasing the size of the ARZ without providing
             other transportation improvements results in an
             increase in the public transit mode share but in
             an overall decrease in the number of trips
             to downtown.
             For work trips, the latter is the more important
             result, as shoppers find suburban alternatives to
             replace downtown trips.
Policy 2:   For smaller-sized ARZs, providing an internal
             distribution system results in little time saving
             over policy 1 for transit users and   former CBD
             auto users; for larger ARZs, walk time savings
             associated with an internal bus system become
             significant, and
             the number of transit trips and overall shopping
             trips increases.
Policy 3:   This results in a significant shift to public
             transit, including a large increase in ARZ-destined
             shopping trips for smaller ARZs.
Policy 4:   This policy is similar to policy 1 in its impact
             upon work trips, since these occur primarily in
             the peak period. The total number of auto shoppers
             increases because of reduced competition from
             workers for CBD parking spaces.

Assessment   Among the several categories of demand mentioned, intra-CBD worker's mode choice model is much harder to access, because of a high percentage of walk-trips and non-home-based trips included in intra-CBD trips, and the very limited data on pedestrian movements available in most cities. The size of survey in this study is relatively small. The results of this type of study would provide a useful basis for evaluating a more comprehensive benefit or cost-effectiveness analysis.

b. Impact Analysis

In contrast to cost-benefit analysis, impact analysis has been largely used for demonstration and pilot syudies in the transportation field.

(i) Peter and Watson (1978)

Decision Problem and Alternatives   The decision problem that is addressed in this study is whether the Area License Scheme (ALS) has resulted in significant impacts on travel behavior, traffic performance, business activity, the environment, and public opinion. Therefore, no alternatives were examined.

Analysis and Findings   This study carries out an extensive program of data collection before the ALS went into effect and a follow-up program once the scheme was in

operatrion. Car-owning households, which constituted approximately 41 percent of all households in Singapore in 1975, were analyzed separately from non-car-owning households since their response to the ALS was of particular interest. No attempt was made to carry out a comprehensive economic evaluation of the scheme. With the before-and-after data, the following areas of potential impacts were identified: traffic performance, travel behavior, business activity, pedestrian activity, air pollution, and public opinions and attitudes. A number of different methods were employed in order to examine the effects on these areas.

Assessment   This study represents a comprehensive ex post analysis, relying primarily on a number of measurements. The data collection efforts were concerned not only with the measurement of physical or behavioral changes but also with public opinion. The success of the project was determined in terms of the results of these measurement. As with many of the ex post analysis, some estimates in this study were based on respondents. Figures derived from surveys of respondents, however, may not be terribly reliable. This kind of study seems important because the results of the study can provide a basis for cost-benefit analysis. For example, the changes in travel times resulting from the ALS could be used to estimate the benefit of time savings.

(ii) Delaware Valley Regional Planning Commission (1977)

Decision Problem and Alternatives   In the case of the
Chestnut Street Transitway in Philadelpia, both merchants and
area employees were surrveyed in order to ascertain attitudes
about the Transitway itself, its impact on shopper behavior,
perception of the downtown area, purchasing patterns, etc.,
as well as sugestions for improvement.   Similar surveys were
conducted   by   the   Delaware   Valley   Regional   Planning
Commission, in Trenton Commons in New Jersey.   The stated
purpose of the surveys were "to evaluate the effectiveness of
ARZ as a transportation system management strategy to improve
mobility in activity centers in the Delaware Valley Region".

Analysis and Findings   The questions asked in the user
survey were designed to elicit such information as: for what
activities do people use the transitway (shopping, other
walking, eating lunch, riding transit); has the transitway
been   successful   in   achieving   certain   goals   (enhanced
commercial vitality, environmental improvement, eased traffic
conditions, encouraged use of transit, relaxed atmosphere for
pedestrians);   what   would   improve   the   quality   of   the
transitway (remove buses, allow autos after working hours,
more parking, other); mode of transport to work; advantages
and disadvantages of downtown as a shopping area compared
with other shopping areas; and personal statistics (income,

age, sex, auto ownership, occupation, etc.). The questions asked of merchants included; size of business; length of tenure in the transitway location; perceived changes in business activity since the transitway opened; changes in customer accessibility to stores; transitway effect on deliverics; suggested ways of improving accessibility. The general conclusions drawn from observation of the collected data were that Chestnut Street has been successful in accomplshing its major goals: creating a relaxed downtown pedestrian atmosphere, strengthening downtown commercial vitality, and improving its aeshetic and environmental quality. It has not, however, resulted in increased transit use or reduced transit vehicle travel times.

Assessment This study can be considered one of the most comprehensive surveys in the evaluation of ARZ. Wider concerns are addressed. The study allows meaningful conclusions to be drawn concerning the degree of success achieved by the transitway, the reasons behind success, and directions for further improvement. In contrast to the ealier approach in which "success" was defined in terms of transportation efficiency, this study defines success in terms of the perceptions of merchants, patrons and local planners. Such a definition seems more meaningful to implementers of particular ARZ projects.

(i) Transportation Research Record (NCHRP 81)

Decision Problem and Alternatives   In general, the aims of this study were to provide information for determining the success or failure of ARZs for Boston and for Nicollet Transit Mall.   The method employed were two surveys in Boston and traffic counts and surveys in Nicollet Transit Mall.

Analysis and Finding   For the Boston ARZ evaluation, two major surveys were conducted on the behavior of the downtown shoppers and workers.   The results of surveys are as follows:

1. The volume of pedestrians on streets within the ARZ increased by 5 percent overall on weekdays and Saturdays: weeknight pedestrian traffic increased by 17 percent.
2. Sales volumes increased between 5 and 10 percent.
3. Walking to ARZ increased from 48 to 55 percents of all trips.   Auto use decreased form 11 to 6.5 percent of total trips to the ARZ.
4. Transit use to the ARZ by employees imcreased by 23 percent.

For the Nicollet Transit Mall evaluation, cordon counts for the CBD indicated no decline in auto trips.   No evidence was apparent that the mall increased total pedestrian volumes, but pedestrian circulation was improved by an increase in the sidewalk area.   Total pedestrian accidents showed no change.   Importantly, surveys after the opening of the mall showed a decline in shoppers to the CBD.   However, surveys of merchants have reported that the predominant attitude was that the mall had been a good investment.

Assessment   This study appears to be quite general   in

that no systematic effort was attempted. A sample size was relatively small. The target groups of the several surveys were not comprehensive. A more disaggregate treatment by impact group seems necessary in order to confidently judge the success or failure of project. The success or failure tends to be oriented around merchant attitude rather than various impact groups.

(ii) OECD - Gothenberg (1979)

Decision Problem and Alternatives A number of studies were carried out in order to evaluate the effect of the CBD traffic cells. The decision problem was whether or not the traffic cell schemes were beneficial in terms of their effects.

Analysis and Finding Some of the evaluations were permanant monitoring activities, others were special studies done in connection with the implementation of cells. It should be emphasized that the time of evaluation was not same for all impact categories. Thus it is difficult to judge the success or failure of the scheme with any degree of confidence. This research also suffered from a lack of data on some impact areas before the implementation. Evaluation methods employed range from interviews and questionnaire distributions to counts and surveys. Perhaps one of the most

neglected aspects of this study related to the pedestrian activities. No consideration was given to pedestrian movement before and after the implementation. The effects of various traffic cell schemes were mostly favorable. The most remarkable success of the cell schemes was the fact that no interest groups seem to be worse off. The following positive effects were stressed in the report:

1. Through the cell system and the accompanying improvements to the environment, the municipalities have given the CBD a distinctive image and indicated a future path of development.
2. The environment for people living, walking and working in the CBD has improved considerably, particularly concerning noise, pollution from car traffic and conflicts between cars and pedestrians.
3. Traffic accidents have been reduced by 36 per cent, on the average, for the CBD plus the ring road.
4. The level of service for transit has improved slightly through improved regularity, although the improvement was not as good as expected.
5. Traffic has been rerouted to the ring road without causing problems of any size.
6. The travel speed of cars has improved in the CBD and on on the ring road.

Asessment It is of particular interest to note that the ex post method employed in this study significantly contributed to the plans of traffic cell schemes through initial results of evalutions done after implementation. After the responsible authorities of Gothenberg observed increases in travel time and a negative effect on regularity, particularly in the direction of peak hour traffic, plans and actions were carried out in 1973 to remove this problem by widening the street in order to create physically separated

lanes for the tramway. The effort further opened the possibility of relocating a tramway line. The line is now giving better service to passengers due to shorter walking distances between the new stops and the main destinations in the CBD.

c. Weighting (or Scoring) Technique

(i)Transportation Research Board (1978)

Decision Problem and Alternatives Unlike previous studies examined, the objective of this study was to provide a comprehensive methodology for evaluating the social, environmental and economic benefits of pedestrian facility proposals. A comparison of alternative pedestrian facilities were performed.

Analysis This study essentially represents a extension of the cost-benefit approach, focusing primarily on hte enumeration of benefits. Thirty-six impact measures were identified in this study, and elaborate rating scales, usually normalized within a range of 1 to 10, were established for scoring projects on each of the measures. Each of the measures is given a weight according to its importance as seen by community, agency, and other interests. Because many of the variable are subjective in nature (e.g., comfort, attracitveness, noise), the calculation of benefits

is performed using an unitless scale of positive and negative values for each varialbe. Unitless scoring allows the comparison of alternatives without the need for assinging dollar values to the many noneconomic impacts of pedestrian facilities. For example, the scoring technique is illustrated by the noise impacts of motor vehicles. In this case both an appropriate formula and a corresponding graphic scale are given for value selection. The appropriate score value is selected after a series of sound readings have been taken and averaged for the facility under evaluation in Table.

Table III-A-2   Noise Level Scoring

90 db(A)	77.5 db(A)	65 db(A)	52.5 db(A)	40 db(A)
-10	-5	0	+5	+10

Any noise level over 90 db(A) scores -10

Any noise level under 40 db(A) scores +10

Total Noise Score = -10 + [(90 - observed or estimated
                             noise level) x 0.4)]

Assessment   The advantage of the scoring method employed in this study is that it allows and encourages the use of many of many benefit measures usually excluded from conventional eocnomic analysis. By reflecting community needs values that are not easily quantified, use of the method may provide adequate justification for projects not defendable previously by economic analysis alone. However, it can be faulted for the arbitrariness with which weights can be assigned and scores derived. Also, the "overall" scores by themselves are dimensionless, and offer little sisight into the merits of a particular scheme. Finally, the presentation of this list of measures in a rationalized evaluation scheme does not obviate the fact that the information required to make judgements about individual variables may be extremely difficult to obtain.