AIRPORT ACCESS - A CASE STUDY APPROACH

by

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ABSTRACT

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The primary purpose of this thesis is to develop a case study concerning airport access for use in the Urban Transportation Laboratory - an undergraduate course in the Department of Civil Engineering (M.I.T.). The case study was designed to teach the fundemental properties of Transportation Systems Analysis, illustrate the use of the computer as a tool for designing and evaluating transportation alternatives, and illuminate the social choice issues involved in transportation planning.

The first step in the case study analysis is the establishment of a base case simulating the airport access movements of resident and non-resident air passengers and airport employees on the major modes serving Logan International Airport in a given reference year. This flow pattern is then tested with respect to its sensitivity to changes in the demand model parameters.

The next step in the analysis is the simulation of the projected airport-destined flow pattern in a target planning year, assuming no major changes in the access network. The projection simulation then serves as a benchmark with which to compare various policy and technology access options. One such option is evaluated in the case study. The task of designing and evaluating other alternatives is left to the students as a final assignment in the Urban Transportation Laboratory course.

The case study also raises some of the issues involved in modelling airport access. In particular, the problems of modelling airport access demand, and tracing the affects of airport accessibility on air trip generation are discussed.

Thesis Supervisor: Marvin L. Manheim
Title: Associate Professor

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Finally, I would like to express my gratitude to my parents and friends in Cambridge.

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I. INTRODUCTION

This thesis was part of a research effort to develop curriculum material for an introductory undergraduate course - the "Urban Transportation Laboratory." The course was first offered at M.I.T. in the spring term of 1970.

The Urban Transportation Laboratory is a new approach to teaching transportation systems analysis. The intent is to provide the students with an intuitive perception of the complex interactions among the components of the urban and transportation environment. The course has three basic objectives:

i. to teach the fundamental principles of transportation systems analysis [20],

ii. to illustrate the use of the computer as a tool for designing, testing and evaluating transportation alternatives,

iii. to demonstrate how the social choice issues involved in transportation planning can be systematically analyzed.

The first six weeks of the course are devoted to a series of introductory lectures designed to cover fundamental analysis principles. The lectures introduce the concepts of transportation demand and supply, and network equilibrium [20]. A set of short exercises [23] accompany the introductory lectures to acquaint the students with DODOTRANS,* a computer

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*The DODOTRANS (Decision Oriented Data Organizer for Transportation Analysis) system [36] is an extension of two previously developed systems, TRANSET II [35] and DODO [13].

software package which has been developed to analyze transportation problems. Thus the students are shown in the early stages of the course how the basic concepts of transportation systems analysis are applied in the computer environment.

The remainder of the term is devoted to three major case studies. These case studies embody the philosophy of the Urban Transportation Laboratory. It is felt that the ideal learning environment is one in which the students apply the basic concepts of analysis by formulating and testing hypotheses on simulations of real-life transportation problems. Essentially, the course has attempted to provide a laboratory experience where students perform experiments in the socio-economic arena. In the physical sciences, students are able to isolate a piece of real-world systems by performing controlled laboratory experiments. In urban transportation however, it is difficult to structure experiments because we are dealing with a system that has complex social, economic, ecological, and political interactions. The data for analysis of an urban transportation system are not readily obtainable, and the consequences of alternative actions are extremely complex.

DODOTRANS provides the student with a generalized framework that may be used to structure a wide range of transportation problems. In the computer, we can construct a simulation of the real world. Transportation systems are described in terms of demand and supply characteristics, modal data, activity system data, and a network description.* Each of these

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*The components of the DODOTRANS system will be described more fully in Section II of this thesis.

component descriptors of an urban transportation system can be modified, thereby allowing students to structure and test a variety of alternative hypotheses in a laboratory environment. Thus the computer becomes our urban transportation laboratory.

In the three DODOTRANS case studies assigned in class, the students are supplied with background descriptive material and data relevant to the problem at hand. After providing the students with a description of a "base case" transportation system, they are left with the task of formulating and testing hypotheses on the properties and consequences of alternative options. The student is encouraged to develop recommendations for changes in transportation technologies (e.g., improved service on existing modes, or introduction of new modes), and operating policies (e.g., altering fares and service frequencies) based on their DODOTRANS analysis.

The first case study - the Three-Mode Urban Corridor [24] - is meant to illustrate network flow concepts in a problem small enough to allow the details of network flow to be traced out and visualized. Although the setting for the three-mode example is based on an hypothesized, simplistic network configuration, the case study permits the impacts of transportation alternatives to be seen clearly. By illustrating the use of DODOTRANS to trace out the impacts and tradeoffs of alternative transportation systems, the students are prepared for the more complex, realistic case studies that follow.

The second major exercise - the Southeast Corridor [3] case study is designed to give the students an understanding of "the urban transportation problem." In lectures that accompany the handout material, the students are given an historical perspective on urban travel trends in Boston. The case study emphasizes the competitive and complementary relationships between public and private transport, based on actual data representing Boston's southeast corridor.

The third case study investigates airport access in Boston and is the subject of the thesis reported herein. The case study is part of a continuing research effort at M.I.T. to structuring analyses of transportation problems.* The analysis of airport access has attempted to recognize the fundamental principles of transportation systems analysis as presented by Manheim [21]. The design of the case study reflects a tradeoff between the educational and research motivations for the development of this thesis. A number of simplifying assumptions were incorporated into the DODOTRANS analysis in order to keep computer expenditures at a low level for class use. The model is presented in as aggregate a form as possible so as still to be sensitive to the basic issues of the airport access problem.**

The case study presented here, and those cited above reflect a philosophy of analyzing transportation systems. We have adopted the approach of modelling transportation according to the principles of supply-demand equilibrium. In addition, the case studies attempt to

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*A prototype DODOTRANS analysis is described in [36]. See also [22],[19],[21].

**See section 1.5 of the case study.

explicitly illustrate the nature of differential impacts on a variety of actors in the urban transportation environment.

Overview of the Airport Access Case Study

There has been a growing awareness of the existence of the "airport access problem" among airport planners in recent years. This has been an interesting development in that it reflects a shift in the emphasis of airport planning. It is now widely recognized that airport facilities are just one component of the air transport system which encompasses door-to-door travel of passengers and freight. The airport access problem is an unfortunate outgrowth of piecemeal airport planning, coupled with the extraordinarily rapid growth which commercial aviation has experienced in its short history.

Symptomatic of the airport access problem are three observations which characterize the quality of access to most major U.S. airports:

i. congestion on urban streets and arterials leading to the airport,

ii. congestion on airport access roads and parking facilities within the airport,

iii. lack of convenient public transit facilities linking the airport with the metropolitan area.

The case study was designed to illustrate the fundamental issues underlying the airport access problem, and to stimulate the students to explore alternative strategies for improving the quality of airport access.

The case study focuses attention on morning peak, inbound access movements to Boston's Logan International Airport. Despite the lack of available comprehensive origin-destination data for Logan, the Boston setting was chosen to take advantage of the students' familiarity with this area. The students are provided with a map of the analysis area, and a complete physical description of Logan facilities.

In Boston, as in other cities,* airport-destined trips exhibit a marked morning and evening peak. For example, nearly twenty percent of the total daily trips to Logan occur in the 7-9 am period. The airport peaks coincide with the urban work commuter peaks, and thus represent the periods of greatest congestion on urban arterials and transit facilities. It is during the peaks that airport access is truly a "problem," and accordingly, we have chosen 7-9 am as the time frame for the case study analysis.

In order to understand the issues underlying the airport access problem, it is essential that we determine the local origins in the Boston metropolitan area, of the travellers seeking access to the airport. The case study distinguishes between three types of airport travellers: passengers, employees, and visitors. The proportion of the total daily airport population in each of these categories was taken from the 1963 Wilbur Smith transportation inventory study [40] of the Boston metropolitan area. The data,** emphasizes the fact that the local origins of airport travellers are widely dispersed in the study area.

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*See [32] for a description of the pattern of access movements at New York's three commercial airports. [10] and [1] present similar descriptions for other cities.

**See Section 1.3.

The introductory chapter of the case study summarizes the nature of the airport access problem in Boston and other large cities in the U. S. Hopefully, this information gives the student a "feel" for the problem being dealt with. Summary data is presented on estimated daily airport populations, local origination patterns, and modal splits for fourteen U. S. airports.

After this initial statement of the problem, a base case analysis is established. The base case represents a simulation of airport access flow patterns to Logan Airport for the year in which the Boston inventory data was collected (1963). A detailed description of the input data, and DODOTRANS commands is included and the major assumptions adopted in the analysis are described. The output from the DODOTRANS base case simulation is useful in manifesting several facets of Boston's airport access problem. In particular, the base case simulation was useful in identifying the location of bottlenecks, the dominance of the auto mode, the dispersed origination pattern of air passengers, and the low level of service provided on congested freeways and the inconvenient transit facilities.

A short section on sensitivity analysis is provided to test the stability of the predicted equilibrium flow pattern in response to changes in the demand model parameters. This type of analysis is particularly relevant in light of the high degree of uncertainty involved in demand models used to predict consequences over a 12 year planning period. It is shown that the predicted volumes are, in fact, very sensitive to changes in demand model parameters.

The next step in the case study is the simulation of a 1975 null case. The null case is a projection of the airport access flow pattern in 1975 under the assumption that no major changes are made in the transportation network or the modal operating policies. The null projection forms the base against which we compare the consequences of alternative system options. An example of one alternative - the provision of a direct CBD-to-airport rail transit service - is described in detail.

After reviewing the example alternative, the students are asked to formulate and evaluate their own alternative solutions to the airport access problem. Relevant cost data for several technologies are supplied in the case study. All of the input data of the DODOTRANS simulations are stored on disks, and students were instructed on how to gain access to the files.

Section II of this thesis presents the airport access case study.* At the end of each major section of the study, the students were asked to answer questions designed to enhance their understanding of the subject matter. Throughout the month that the case study is administered, and particularly during the last phase of the study, students receive individual guidance from their instructors.

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*The reader should refer to the Urban Transportation Laboratory Workbook [23] for explanations of the DODOTRANS commands.

II. THE CASE STUDY

Preface

The exercises presented thus far in this course have developed structured analyses of the travel patterns in urban corridors. The DODOTRANS laboratory environment has been used for prediction and evaluation of technology and operating policy options. In this exercise, we investigate the issues underlying the "airport access problem." The material is presented in an open-ended form, and you will be required to structure your own analysis strategy.

Review your lecture notes on the concept of equilibrium in the network context. Be sure you understand how flows interact in a network. Can the level of service experienced by people travelling from suburban areas to the airport be influenced by the number of CBD - airport travellers? by the number of suburban to CBD travellers? Review Section 11.6 of Workbook 11. Why was it necessary to model the access links separate from the line haul links? On which links was the base case link capacity particularly crucial? Review Exercise 13. What is the definition of an elasticity? What is the difference between direct and cross elasticities? What is the meaning of a travel time direct elasticity of 0? a time cross-elasticity of 0?

1.0 Introduction

1.1 Survey of Airport Accessibility at Major U. S. Airports

There has been an increasing awareness in recent years of the existence of an airport access problem. Spectacular growth in the air transport industry has placed a strain on existing networks providing ground access to major metropolitan airports. While rapid advances in aircraft technology have increased the speed, comfort and safety of air travel, there have been virtually no improvements made in the ground access transportation systems. Thus as the popularity of air travel has grown, the quality of service on access links has steadily deteriorated.

The figure below [42] manifests a symptom of the airport access problem. In a ten year period during which jet service was introduced, average flight time on medium haul trips (600-1,000 miles) decreased by 53%, while ground access time increased by 24%. Thus, door-to-door time savings over the ten-year period (a 29% decrease) did not fully realize the potential of the faster air service. It is likely that airport accessibility will continue to deteriorate in the next few years. The growth in the number of air passengers has averaged more than 10% over the last five years, and the introduction of the jumbo jet is expected to spur even greater growth in the future. Moreover, the jumbo jets which discharge as many as 400 passengers, will compound the peaking problem at airports already choked with traffic during the morning and evening rush hours.

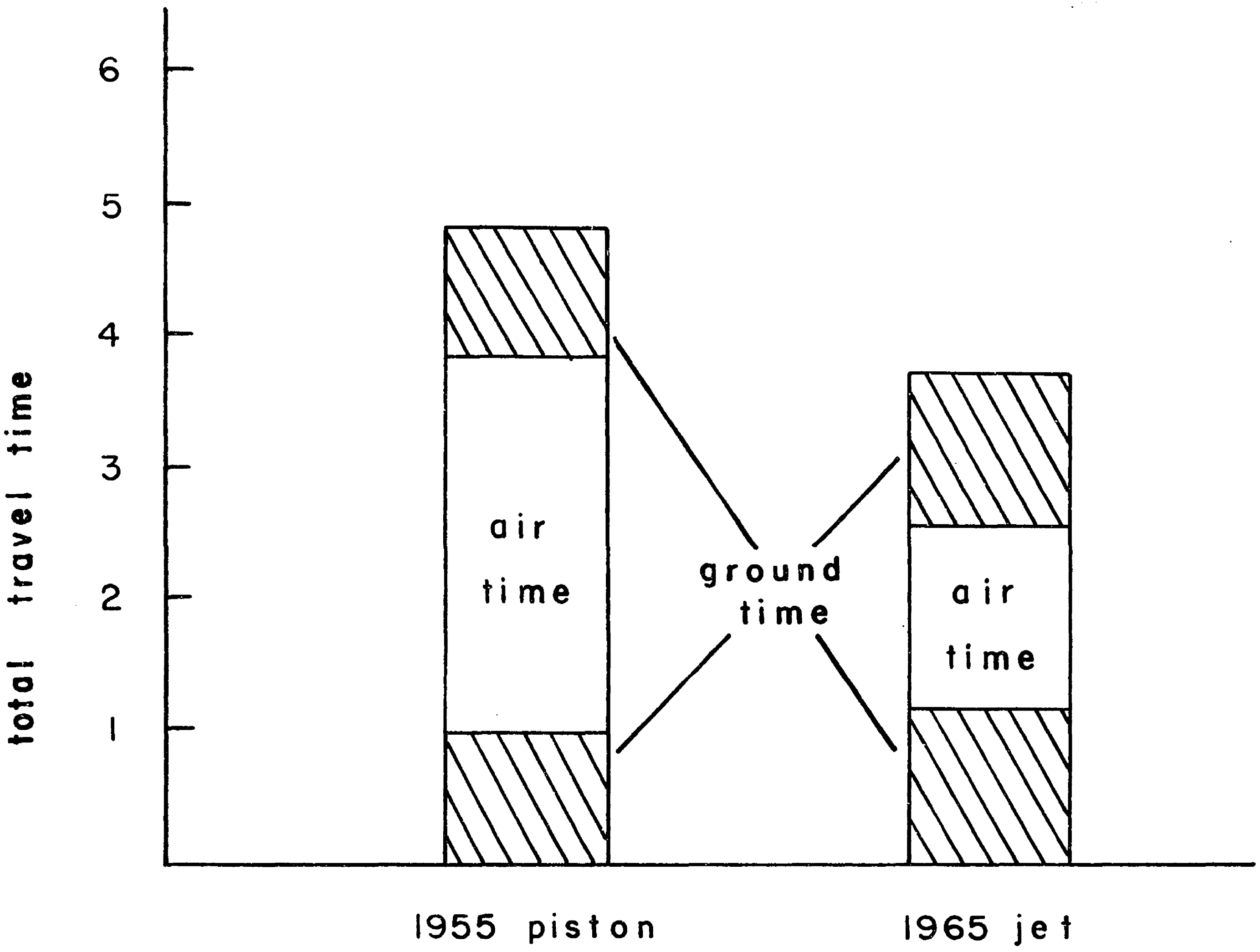
6
5
4
3
2
1
total travel time
air
time
ground
time
air
time
1955 piston
1965 jet

Figure 1.1-1

The concern about airport accessibility among airport planners has taken two distinct dimensions. First, there has been a growing recognition that an airport's <u>in</u>accessibility affects the realization of air passenger market potential. Recent studies* have indicated that the demand for air travel rises or falls as the access system provides or fails to provide service that is economical, fast, dependable and convenient. In some cities, the constraint on the growth of air travel is not limited by the capacity of airport facilities, but by the capacity of access facilities serving the airport. Thus, airport access is viewed as one subsystem in the air transport system which encompasses door-to-door travel. Schematically, the figure below illustrates how airport accessibility might affect the growth of air trip generation

The second dimension of the concern of airport planners with accessibility is related to the development of large regional airports. The projected growth of air travel (which is expected to double in the next ten years [11]) has led several large cities to plan for new regional airports located far from city centers. The provision of fast, convenient access to and from these airports is essential if passengers are to benefit from the speed of air travel. Thus the design of airport access facilities is becoming an integral part of the plans for new airport development.

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*See Section A.2. Accessibility and air trip generation is also discussed in [5], [30], [2], and [38].

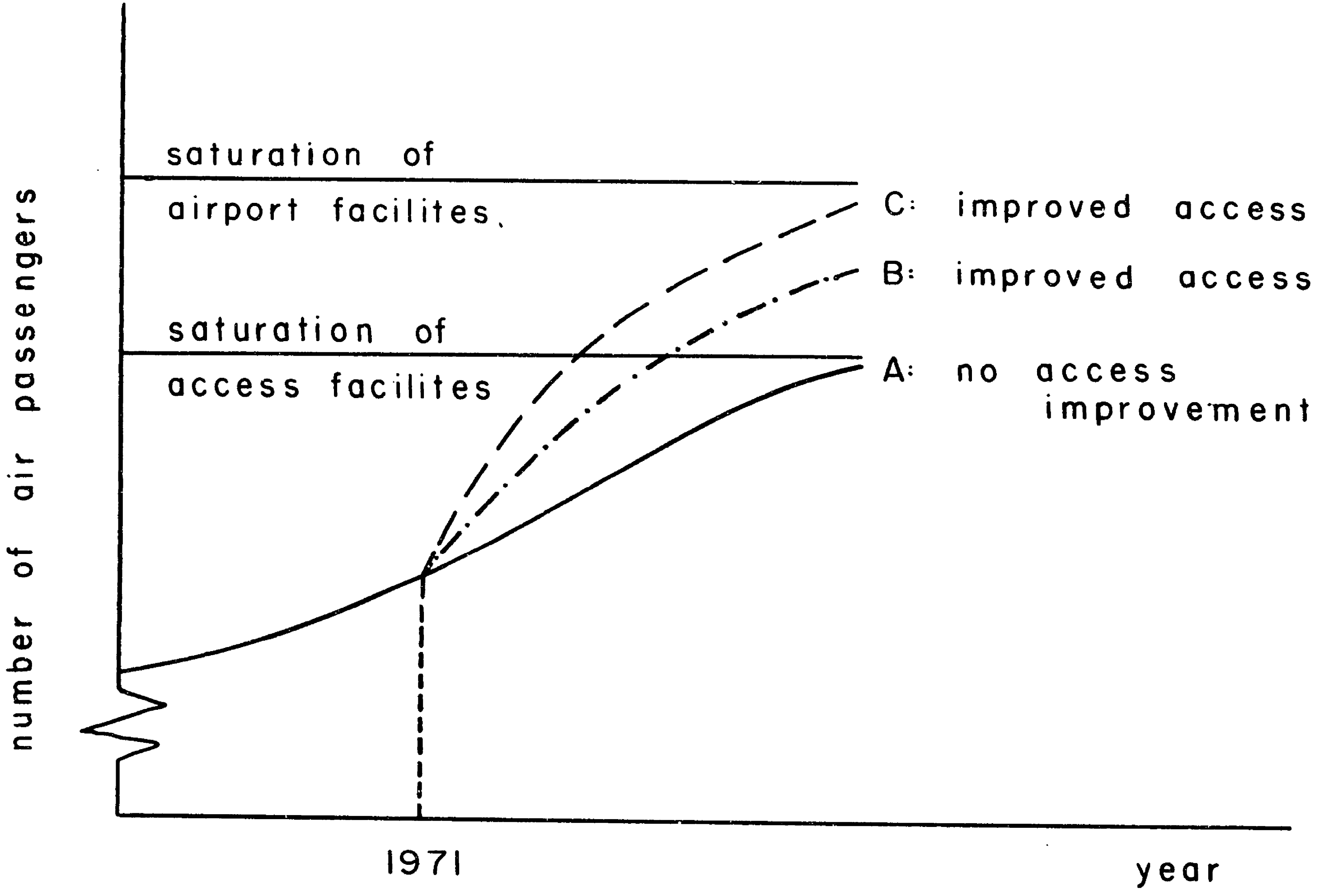
saturation of
airport facilites.
saturation of
access facilites
C: improved access
B: improved access
A: no access improvement
number of air passengers
1971
year

Figure 1.1-2

We can identify three symptoms that tend to define what has become known as the "airport access problem:"

i. congestion on urban streets and arterials leading to the airport;

ii. congestion on airport access roads and parking facilities;

iii. lack of convenient public transit facilities linking the airport with the metropolitan area.

In order to understand the basic issues underlying the airport access problem, it is essential that we relate these symptoms to the types of users requiring access, and to the local origination patterns of these user groups.

Several cities in the United States are considering implementing a direct transit service linking the Central Business District (CBD) and airport. In Cleveland, an extension of the rail rapid transit system is now operating, linking Hopkins International Airport with the CBD. Newark, New Jersey, recently announced a proposal to supplement the public bus service linking Newark International Airport to Manhattan, with rail service. At Kennedy International, plans call for the implementation of a rail-bus* service or an extension of the Long Island Railroad direct to the airport. Atlanta, Chicago (O'Hare) and Washington, D.C. (National) similarly report plans for direct CBD-airport rail rapid transit systems in the mid 1970's. Helicopter services serving the downtown areas are being planned in Los Angeles and Washington, D.C. (National).

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*A unique vehicle with retractable steel wheels. Rail-bus would travel by track to the airport periphery, and then switch to the airport road system for final distribution of passengers.

The tacit assumption underlying all these transportation proposals is that a significant number of trips destined for the airport originate from the central business district. In order to investigate this premise, it is useful to consider the groups of people requiring transportation between the airport and the surrounding community.

Three distinct types of travellers require access to airports: air passengers, employees, and visitors.* The proportion of the total airport population in each of these three categories varies from city to city (see table 1.1-1.** But on the average, airline passengers account for 45% of the daily airport population, employees 22% and visitors 33%. Note, however, that not all of the air passengers arriving at an airport require access trips to the community. For the thirteen airports in Table 1.1-1, an average of 15% of arriving passengers were on an intermediate leg of a continuing airtrip. Moreover, on a daily basis, air passengers require only one access trip to (or from) the airport while visitors and employees make two trips. Thus, whereas visitors constitute 33% of the airport population, they make 45% of the airport access trips. Air passengers are responsible for 26% of access trips, and employees, 29%.

By definition, the airport is one end of an airport access trip. To determine the other trip end in the metropolitan area, we consider each

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*In this study, we identify visitors as people travelling to the airport for the purpose of delivering or retrieving air passengers, patronizing airport restaurant or retail concessions, or sightseeing.

**Tables 1.1-1 through 1.1-5 are taken from reference [8].

Table 1.1-1

ESTIMATED DAILY AIRPORT POPULATION 1966

AIRPORT	PASSENGERS	EMPLOYEES	VISITORS	TOTAL
Atlanta	29,600	12,000	36,700	78,300
Chicago-O'Hare	50,000	16,000	25,000	91,000
Denver-Stapleton	5,500	5,500	8,500	19,500
Kansas City	6,700	1,000	1,500	10,300
Los Angeles	42,000	33,000	43,700	118,700
Miami	22,000	5,000	3,000	30,000
New York - Kennedy	46,800	23,000	22,800	92,600
New York - LaGuardia	17,200	3,300	4,000	24,500
New York - Newark	14,000	3,300	4,200	21,500
Phoenix - Sky Harbor	6,000	300	8,400	14,700
San Diego	3,000	1,600	3,200	7,800
Seattle	10,000	4,000	4,700	18,700
Washington, D.C. - National	26,000	13,100	26,000	65,100

traveller type separately. Air passengers can be considered in terms of the two predominant air trip purposes - business and personal. Personal trips (e.g., visiting relatives, vacations, sightseeing, etc.) originate in most cases at the traveller's home. Obviously, then these origins are dispersed throughout the metropolitan area. This hypothesis is reinforced when it is considered that most personal air trips are made by high income travellers whose homes are, to a large extent located in suburban areas. At the destination end of their air trip, these travellers generally go to a relative's home (again, at dispersed locations), a recreational area, or a hotel. Thus, it can be generally concluded that the personal air passenger makes airport access trips to and from dispersed locations in the metropolitan area.

Business travellers begin their trip either at their office, or from their home. In cities where there has been substantial industrial suburbanization, the traveller's home and office are likely to be located out of the CBD. At the destination city, the business traveller is likely to go to a hotel (either at the airport, in the CBD, or near suburban industrial parks), or to a CBD or suburban business office. Upon return to his home city, the business traveller will probably return to his residence or office.

It is clear from the above discussion that the air passenger does not necessarily originate his trip from the CBD. This conclusion is borne out by the data in Table 1.1-2. In relatively decentralized cities like Los Angeles and San Diego, only 10 to 15% of the total air passengers

PERCENTAGE OF DAILY PASSENGER AIRPORT POPULATION ORIGINATING FROM CBD

AIRPORT	PASSENGER %
Atlanta	NA
Chicago - O'Hare	32.7
Denver - Stapleton	30.0
Kansas City	40.0
Los Angeles	15.0
Miami	NA
New York - Kennedy	33.4
New York - LaGuardia	55.9
New York - Newark	28.6
Phoenix - Sky Harbor	24.0
San Diego	10.0
Seattle	16.5
Washington, D.C. - National	23.1

Table 1.1-2

in the CBD. Even in New York and Chicago where a large amount of economic activity is located in the city center, less than half of all emplaning passengers begin their trip in the CBD.

Visitors going to the airport to deliver or retrieve air passengers, to patronize restaurant or retail concessions or to sightsee also come from origins dispersed in the metropolitan area. Visitors of the latter two categories are most likely high income families from suburban homes. Visitors providing a kiss-and-ride service to air passengers generally drive to the airport from suburban areas. Table 1.1-3 provides estimates of the percentage of airport visitors originating from the CBD. In all cases, more than 3/4 of the total number of visitor trips have non-CBD origins.

The employee population on an average day (1966) ranges from 300 at a small metropolitan airport like Sky Harbor (Phoenix), to 33,000 at Los Angeles International Airport. The types of jobs vary from physical plant maintenance staff to 747 jet captains; the income range is great. The local origins can be expected to be generally dispersed in the metropolitan area, but gravitating more towards locations near by the airport, rather than in the CBD. In Boston, for example, only 23% of the 1959 employees of Northeast Airlines lived in Boston proper, and more than a third of the employed commuted from areas outside the inner suburbs. This pattern is common to other cities as well. From Table 1.1-4, it can be seen that, in all cases, less than 1/4 of the employees originate their airport access trips in the central business district.

PERCENTAGE OF DAILY AIRPORT POPULATION ORIGINATING FROM CBD

AIRPORT	VISITOR %	EMPLOYEE %	% OF TOTAL
Atlanta	NA	NA	NA
Chicago - O'Hare	NA	NA	NA
Denver - Stapleton	NA	2.0	NA
Kansas City	NA	NA	NA
Los Angeles	14.9	6.0	12.4
Miami	NA	NA	NA
New York - Kennedy	14.5	13.9	20.7
New York - LaGuardia	15.0	6.1	35.2
New York - Newark	4.8	9.1	17.2
Phoenix	25.0	24.0	24.6
San Diego	10.0	6.0	26.0
Seattle	10.6	5.0	12.6
Washington, D.C. - National	23.1	5.0	51.2
	Table 1.1-3	Table 1.1-4	Table 1.1-5

The conclusion that can be drawn from the above discussion is clear. The origins and/or destinations of local, intraurban trips to and from airports are, to a large extent, dispersed throughout the metropolitan area. Since a large number of airport trips originate and terminate from domeciles,* this dispersion is especially evident in suburban, decentralized cities. From Table 1.1-5, it can be seen that the percentage of the total average daily airport population (passengers, visitors, and employees) originating in the CBD is, for all cities reporting (except Washington/National), less than 50%. In relatively decentralized cities like Seattle and Los Angeles, CBD originations are particularly low - on the order of 15% of the total.

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*In a recent study by Landrum and Brown [17], it was reported that 80% of local Los Angeles air passengers have their home as their local point of origin, 83% have their home as their local point of destination, and 71% start and end their air trips at home.

1.2 The Airport Traveller - Modal Choice

In several large U. S. cities, there are as many as seven modes serving the airport. In Boston, for example, transportation services to Logan include auto, taxi, limousine, rental car, and subway (with bus transfer). Other cities (New York, Los Angeles, Seattle-Tacoma) provide helicopter services in addition to the common ground access modes, and Newark Airport is served by a public bus carrier in addition to the privately owned Carey Bus Lines. The extent to which each of these modes is used for airport access trips in a particular city depends on the travellers' perception of the relative merits (i.e., the level of service (LOS) offered) of each mode. Specifically, we can identify the LOS variables influencing the modal choice decision as:

1. availability of the mode at the travellers' local point of origin;
2. number of transfers needed to complete a trip from door-to-door (i.e., from the local point of origin to the airport office, departure gate or recreational/retail facility;
3. total access trip cost;
4. total access trip time;
5. frequency/schedule delay;
6. time reliability;
7. comforts and amenities.

Each of these factors is discussed separately below.

1. modal availability

The previous section discussed the dispersed origin pattern of airport access trips. Most of the modes serving metropolitan airports are CBD oriented. Thus the suburban dweller or office worker is limited in his choice of modes. Of the six modes serving Logan, only auto, rental car, and taxi provide access from the Boston suburbs. Employees, visitors and personal air travellers can be expected to almost exclusively rely on the automobile from suburban locations. The business travellers starting from a non-CBD origin will patronize the taxi or rental car modes (especially if he is not in his home city) in addition to private (or company chauffeured) auto. Only travellers originating from the CBD may choose from all modes serving the airport.

2. number of transfers

Auto, taxi, and rental car are considered to be flexible - in the sense that they provide no-transfer, door-to-door service. The other modes leave from specific terminal locations in the CBD, and typically require the traveller to take a transfer mode connecting his local point of origin and the downtown terminal facility. (The transfer mode might be taxi or transit.) Those travellers using the MBTA/bus mode to Logan will typically make 3 or 4 transit transfers before reaching the airport. For the air passenger burdened by baggage, the subway/bus mode is usually considered too inconvenient, if there is any other alternative.

3. trip cost

The total cost of an airport access trip includes the sum of the costs of all the modes used in going from door-to-door. For business trips access cost is usually of little or no concern to the air passenger, since his company pays for travel expenses. This explains the relatively high patronage of taxi and rental car services by business travellers. Even the modal choices of personal air passengers and visitors are often relatively fare insensitive. Only the modal-choice decisions of low-income personal air passengers (e.g., students and armed forces personnel), and low-income airport employees can be expected to be significantly affected by access trip cost.

4. trip time

Travel time appears to be an important factor in determining the modal choices for the majority of travellers to the airport. The relevant measure of this factor takes account of the total time consumed in traveling from the local point of origination to the airline terminal building. Often, a substantial fraction of the total trip time is consumed during the non line-haul portions of the access trip. Auto drivers parking at the airport may be forced to walk as far as one half mile to their airline terminal. Limousine and bus users face the problem of getting to downtown terminal buildings. And subway riders may have to make frequent, time-consuming transfers. Only taxi and kiss-and-ride auto passengers receive direct door-to-door service.

5. frequency/schedule delay

Airport employees and air passengers have a specific preferred time of arrival at the airport. In choosing their access mode, these travellers must take account of the frequency of service offered by the various modes. Consider the case of an air passenger whose plane departs Logan at 9 AM, and has his local origin in downtown Boston. The traveller is considering two modes - taxi and limousine which offer him the following levels of service:

	(1) travel time	(2) cost	(3) desired arrival time	(4) expected arrival	(5)=(3)-(4) schedule delay
TAXI	30 minutes	$2.50	8:30	8:30	0 minutes
LIMOUSINE	35 minutes	$1.25	8:30	8:10	20 minutes

Notice that the two modes provide approximately the same travel time. Taxi is twice as costly as limousine, but delivers the traveller to the airport at his desired time of arrival. Limousine, because of its fixed schedule, gets the air passenger to the terminal 20 minutes early.* Many air passengers are willing to pay a premium price to minimize their schedule delay, and thus in this instance would choose taxi service. Thus large schedule delays on modes characterized by limited frequency of service (limousine, bus, helicopter) have a negative effect on ridership.

6. time reliability

In addition to the schedule delay characteristic, consideration of

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*It is assumed that the traveller takes the last scheduled limousine that will deliver him to the airport before his desired time of arrival.

a mode's time reliability plays a crucial role in the modal choice decisions of travellers who have a preferred arrival time at the airport. Air passengers (and especially those who are not in their home city), tend to shy away from modes with which they are not familiar. The business traveller in downtown Boston might well be able to reach Logan by subway in less time than by taxi - and at a fraction of the cost - but as he perceives it, the subway system is time unreliable (if he perceives a high risk of getting lost!), and he is willing to pay a premium price for a risk-free time of arrival. Many air passengers who are relatively insensitive to fare will take taxis rather than troubling to inquire about the specifics of subway, limousine or bus services.*

7. comfort and amenities

Since a large majority of air passengers and airport visitors are from high income groups,they tend to prefer modes that offer privacy, comfort and convenience. Many air passengers seem more than willing to pay the premium price for taxi service, when limousine or bus service offers similar service at lower cost. For this reason, subway service is particularly unattractive to air passengers and airport visitors.

The preceding discussion allows us to draw some general conclusions concerning the modal split of airport access trips. The relatively dispersed origin pattern tends to favor use of autos (private and rented) and

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*Although in many cities, airlines officially sanction private limousine service, and furnish information about limousine service on airline ticket jackets.

taxis for airport trips. For trips originating from the CBD, business and personal air passengers, and airport visitors are relatively fare insensitive - and tend to choose modes offering speed, reliability, frequent service and comfort. In general then, these travellers prefer auto and taxi to limousine, bus or subway.

These conclusions are corroborated by the figures in Tables 1.2-1 and 1.2-2.* In Table 1.2-1, the percentage usage by air passengers of each of seven modes is displayed for thirteen airports. It is clear that the principal means of transport to the airport is by auto and taxi. The combined percentage of these two modes ranges from a low of 64% in Newark (where an extremely high interstate taxi fare is charged for trips crossing the New York/New Jersey border) to a high of 93% in Atlanta and Denver. In general, cities with highly centralized urban cores have relatively lower auto usage than suburban cities. But for all airports (except Newark), more than half of the air passengers arrive at the airport by private auto.

In Table 1.2-2, the percentage of air passengers from the CBD using each of the seven modes is displayed. In most cities taxi is the dominant mode of travel - attracting ridership from the high proportion of business travellers with offices in the CBD. Private bus/limousine and auto also attract a significant fraction of CBD-airport travellers. However, in all but two cities, the bus/limousine services carry fewer passengers than autos and taxis.

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*Tables 1.2-1 through 1.2-4 are from reference [8].

GROUND ACCESS MODAL CHOICES OF AIRLINE PASSENGERS BETWEEN AIRPORTS AND ALL ORIGINS (INCLUDING CENTRAL BUSINESS DISTRICTS), AS A PERCENTAGE

Table 1.2-1

Airports (1)	Airport bus or limo. (2)	Heli-copter (3)	Public bus (4)	Subway-bus transfer (5)	Taxi (6)	Private autos (7)	Rental cars (8)	Taxi+private auto + rental car (9)
Atlanta	5.0	-	2.0	-	9.0	84.0	-	93.0
Chicago - O'Hare	18.7	-	-	-	25.3	49.9	5.1	75.3
Denver - Stapleton	5.0	-	2.0	-	25.0	68.0	-	93.0
Kansas City Municipal	NA	-	-	-	NA	58.0	8.0	NA
Los Angeles	4.5	2.0	0.5	-	5.0	85.8	2.5	93.0
Miami	10.4	-	0.0	-	24.3	46.0	19.3	89.6
New York - Kennedy	20.0	2.0	-	3.0	29.0	46.0	-	75.0
New York - LaGuardia	12.0	0.0	-	3.0	47.0	38.0	-	85.0
New York - Newark	25.0	1.0	10.0	-	10.0	54.0	-	64.0
Phoenix - Sky Harbor	9.0	-	4.0	-	11.0	61.0	15.0	87.0
San Diego	-	-	5.0	-	15.0	65.0	15.0	95.0
Seattle - Tacoma	20.0	1.0	2.0	-	5.0	62.0	-a	67.0
Washington, D.C. - (National)	12.0	-	3.0	-	38.7	39.4	5.9	85.0

GROUND ACCESS MODAL CHOICES OF AIRLINE PASSENGERS BETWEEN AIRPORTS AND CENTRAL BUSINESS DISTRICTS, AS A PERCENTAGE

Table 1.2-2

Airports (1)	Airport bus or limo. (2)	Heli-copter (3)	Public bus (4)	Subway-bus transfer (5)	Taxi (6)	Private autos (7)	Rental cars (8)	Taxi+private auto + rental car (9)
Atlanta	6.0	-	1.0	-	10.0	70.0	13.0	93.0
Chicago - O'Hare	39.6	-	-	-	35.9	17.8	6.0	60.4
Denver - Stapleton	15.0	-	1.0	-	35.0	45.0	5.0	75.0
Kansas City Municipal	NA	-	-	-	NA	NA	NA	NA
Los Angeles	30.0	-	1.0	-	15.0	40.0	14.0	69.0
Miami	NA	-	0.0	-	NA	NA	NA	NA
New York - Kennedy	30.0	1.0	-	3.0	44.0	22.0	-	66.0
New York - LaGuardia	16.0	0.0	-	3.0	65.0	16.0	-	81.0
New York - Newark	64.0	1.0	13.0	-	9.0	13.0	-	22.0
Phoenix - Sky Harbor	25.0	-	5.0	-	40.0	17.0	13.0	70.0
San Diego	-	-	10.0	-	80.0	10.0	-	90.0
Seattle-Tacoma	54.0	3.0	1.0	-	15.0	27.0	-	42.0
Washington, D.C. - National	19.2	-	1.6	-	64.0	11.9	3.3	79.2

Tables 1.2-3 and 1.2-4 present estimated figures on the modal choice of airport visitors and employees respectively. It is clear that these traveller groups rely almost exclusively on the private auto.

Table 1.2-3

PERCENTAGE OF VISITORS USING EACH ACCESS MODE

City-Airport	Auto	Taxi	Limo/Bus
New York - Kennedy	100%	-	-
New York - LaGuardia	100%	-	-
New York - Newark	100%	-	-
Baltimore - Friendship	100%	-	-
Washington, D.C. - National	100%	-	-
Washington, D.C. - Dulles	100%	-	-

PERCENTAGE OF EMPLOYEES USING EACH ACCESS MODE

City-Airport	Auto	Taxi	Limo/Bus	Other
Boston-Logan	93%	7%		
Minn.-St. Paul	89%	6%		5%
New York - Kennedy	87%	9%	3%	1%
San Francisco	74%[a]	17%	9%	

[a] drive alone - 46%, carpool - 28%

Table 1.2-4

1.3 Airport Access Trips in Boston

The purpose of this section is to compare Boston's airport access trip patterns with the trip patterns of the thirteen selected airports discussed earlier. The data presented here was collected as part of the Comprehensive Traffic and Transportation Inventory [40] conducted by Wilbur Smith and Associates in 1963. The comprehensive survey was designed to obtain complete information on a regional basis, of present travel characteristics, and patterns, and use of existing transportation facilities. The data on airport access was merely a by-product of the regional home-interview study. As such, it does not include some of the important stratifications (e.g., business vs. personal air passenger trips) which are particularly relevant to an airport access study. Nonetheless, the available (in fact, the only existing origin/destination airport access data for the Boston metropolitan area) data does permit some important observations.

The Wilbur Smith study conducted the dwelling-unit survey between June 1, 1963 and June 1, 1964. Interviews were recorded at approximately three percent of the 741,000 dwelling units located within Route 128, and seven percent of the 348,000 dwelling units located outside of Route 128. From the interviews, trips to logan were classified into three trip purposes: air passenger, employee, and visitor.* Furthermore, each trip was stratified by income level and mode.

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*The visitor category includes social, recreational,shopping and car-chauffeur trips.

It is important to note that since the source of this data is a home interview survey, reported air passenger trips represent only resident air trips. The other two trip purposes - employee and visitor - recorded by the survey should accurately reflect the true totals, since the bulk of these trips begin from domeciles.

Trip data was tabulated for each of the towns within the study area. (See Figure 1.3-1; the study area is comprised of all towns within the heavy black line.) In Table 1.3-1, we present the number of trips* by trip purpose for each town in the study area. Tables 1.3-2, 1.3-3, 1.3-4, and 1.3-5 further stratify this data, showing the trip totals of each trip purpose by each mode (auto drive, auto passenger, taxi, and transit respectively).

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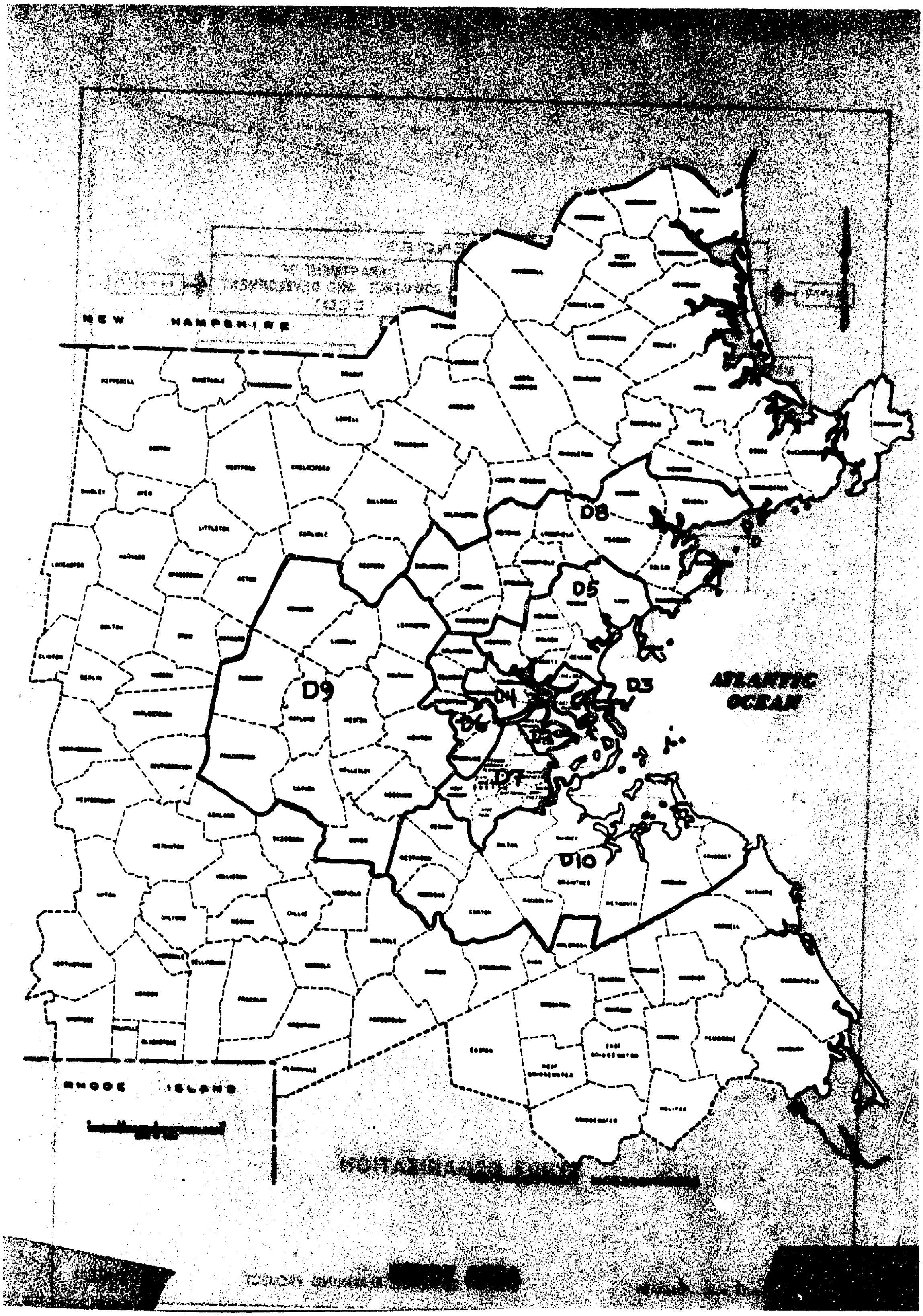
*Trip totals represent 24 hour weekday volumes.



Source: reference [40]   Figure 1.3-1

TOWNS .VS. TO_PURSE

	AIR_PAX	EMPLOYEE	VISITOR	TOTAL
FRSTN	93.	591.	166.	850.
CHASTN	0.	53.	0.	53.
BOSPR	379.	222.	177.	778.
SBOS	0.	15.	33.	49.
ROXBURY	112.	78.	37.	227.
DORCH	0.	123.	0.	123.
MATAPN	39.	78.	39.	156.
HYDPK	0.	38.	0.	38.
RSLNDL	0.	39.	0.	39.
JAMPL	292.	78.	92.	462.
BRITON	175.	39.	0.	214.
BRKLINE	181.	0.	0.	181.
NEWTON	193.	37.	37.	266.
WESTON	37.	39.	0.	76.
WLSLY	70.	0.	0.	70.
NEEDHM	16.	0.	0.	16.
WALTHAM	179.	39.	139.	356.
WTRTN	109.	53.	0.	163.
BELMNT	77.	0.	0.	77.
LXGTN	74.	0.	0.	74.
BURLTN	0.	0.	0.	0.
WOBURN	0.	36.	0.	36.
READING	70.	0.	0.	70.
STONEHM	40.	0.	0.	40.
WINCTR	0.	0.	0.	0.
ARLNTN	0.	0.	0.	0.
CAMB	175.	74.	78.	327.
SOMRVL	47.	44.	0.	91.
MEDFD	162.	59.	0.	221.
EVERET	0.	17.	196.	213.
CHLSEA	0.	82.	0.	82.
REVERE	42.	171.	42.	255.
WINTHP	275.	330.	0.	605.
MALDEN	97.	106.	0.	203.
MELROSE	0.	81.	0.	81.
WILMTN	17.	17.	0.	34.
WAKEFD	78.	39.	0.	116.
LYNFLD	0.	0.	0.	0.
SAUGUS	82.	75.	0.	157.
LYNN	76.	173.	38.	287.
NAHANT	0.	0.	0.	0.
SWMSCT	165.	41.	124.	330.
MARBHD	81.	41.	41.	163.
SALEM	0.	40.	0.	40.
PEABODY	41.	133.	0.	174.
DANVERS	0.	35.	0.	35.
BEVERLY	34.	107.	34.	175.
CONCORD	53.	57.	0.	110.
LINCOLN	36.	0.	0.	36.
WAYLAND	57.	18.	77.	152.
NATICK	31.	17.	0.	49.
SUDBURY	32.	0.	0.	32.
FRAMHM	134.	32.	0.	166.
DOVER	17.	0.	0.	17.
WESTWD	0.	0.	0.	0.
NORWOOD	75.	37.	0.	112.
CANTON	35.	0.	0.	35.
RANDOLF	16.	0.	0.	16.
DEDHAM	34.	34.	102.	170.
MILTON	0.	0.	0.	0.
QUINCY	0.	79.	0.	79.
BRNTREE	74.	74.	0.	148.
WEYMTH	37.	0.	0.	37.
HINGM	0.	16.	17.	33.
COHST	17.	0.	0.	17.
TOTAL	4159.	3589.	1467.	9215.

Table 1.3-1

```
        MODE   AUTO_DIV

        TOWNS .VS. TO_PURSE

                AIR_PAX EMPLOYEE   VISITOR     TOTAL

   EBSTN          0.       465.        83.      548.
  CHASTN          0.        37.         0.       37.
   BOSPR         91.       155.        16.      262.
    SBOS          0.        15.        17.       32.
 ROXBURY        112.        41.         0.      153.
   DORCH          0.        81.         0.       81.
  MATAPN          0.        39.         0.       39.
   HYDPK          0.         0.         0.        0.
  RSLNDL          0.        39.         0.       39.
   JAMPL         69.        78.         0.      147.
  BRITON          0.        39.         0.       39.
 BRKLINE        181.         0.         0.      181.
  NEWTON        119.        37.         0.      156.
  WESTON         37.        39.         0.       76.
   WLSLY          0.         0.         0.        0.
  NEEDHM         16.         0.         0.       16.
 WALTHAM         85.        39.         0.      124.
   WTRTN         72.        53.         0.      126.
  BELMNT         77.         0.         0.       77.
   LXGTN         74.         0.         0.       74.
  BURLTN          0.         0.         0.        0.
  WOBURN          0.        36.         0.       36.
 READING         70.         0.         0.       70.
 STONEHM         40.         0.         0.       40.
  WINCTR          0.         0.         0.        0.
  ARLNTN          0.         0.         0.        0.
    CAMB         68.        39.        39.      146.
  SOMRVL          0.         0.         0.        0.
   MEDFD         54.        59.         0.      113.
  EVERET          0.        17.        48.       66.
  CHLSEA          0.        42.         0.       42.
  REVERE         42.        84.         0.      126.
  WINTHP        196.       236.         0.      432.
  MALDEN         48.       106.         0.      154.
 MELROSE          0.        81.         0.       81.
  WILMTN         17.        17.         0.       34.
  WAKEFD         39.        39.         0.       78.
  LYNFLD          0.         0.         0.        0.
  SAUGUS         41.        38.         0.       79.
    LYNN         38.       173.         0.      211.
  NAHANT          0.         0.         0.        0.
  SWMSCT         82.        41.         0.      124.
  MARBHD         81.        41.         0.      122.
   SALEM          0.        40.         0.       40.
 PEABODY         41.        92.         0.      133.
 DANVERS          0.        35.         0.       35.
 BEVERLY         34.       107.         0.      141.
 CONCORD         53.        57.         0.      110.
 LINCOLN         18.         0.         0.       18.
 WAYLAND         57.        18.         0.       75.
  NATICK         16.        17.         0.       33.
 SUDBURY         32.         0.         0.       32.
  FRAMHM         86.        32.         0.      118.
   DOVER         17.         0.         0.       17.
  WESTWD          0.         0.         0.        0.
 NORWOOD          0.        37.         0.       37.
  CANTON         35.         0.         0.       35.
 RANDOLF         16.         0.         0.       16.
  DEDHAM         34.         0.         0.       34.
  MILTON          0.         0.         0.        0.
  QUINCY          0.        79.         0.       79.
 BRNTREE         74.        74.         0.      148.
  WEYMTH          0.         0.         0.        0.
   HINGM          0.        16.         0.       16.
   COHST         17.         0.         0.       17.

   TOTAL       2281.      2811.       203.     5295.
```

Table 1.3-2

```
     MODE  AUTO_PAX

     TOWNS .VS. TC_PURSE

              AIR_PAX  EMPLOYEE  VISITOR    TOTAL

   EBSTN        37.       40.       83.      160.
  CHASTN         0.        0.        0.        0.
   BOSPR       138.        0.      161.      298.
    SBOS         0.        0.       17.       17.
 ROXBURY         0.       37.       37.       73.
   DORCH         0.        0.        0.        0.
  MATAPN        39.        0.       39.       78.
   HYDPK         0.        0.        0.        0.
  RSLNDL         0.        0.        0.        0.
   JAMPL       223.        0.       92.      315.
  BRITON       175.        0.        0.      175.
 BRKLINE         0.        0.        0.        0.
  NEWTON        74.        0.       37.      111.
  WESTON         0.        0.        0.        0.
   WLSLY         0.        0.        0.        0.
  NEEDHM         0.        0.        0.        0.
 WALTHAM        94.        0.      139.      232.
   WTRTN        37.        0.        0.       37.
  BELMNT         0.        0.        0.        0.
   LXGTN         0.        0.        0.        0.
  BURLTN         0.        0.        0.        0.
  WOBURN         0.        0.        0.        0.
 READING         0.        0.        0.        0.
 STONEHM         0.        0.        0.        0.
  WINCTR         0.        0.        0.        0.
  ARLNTN         0.        0.        0.        0.
    CAMB        18.       35.       39.       92.
  SOMRVL        47.        0.        0.       47.
   MEDFD       108.        0.        0.      108.
  EVERET         0.        0.      148.      148.
  CHLSEA         0.        0.        0.        0.
  REVERE         0.       44.       42.       86.
  WINTHP        79.       94.        0.      173.
  MALDEN        48.        0.        0.       48.
 MELROSE         0.        0.        0.        0.
  WILMTN         0.        0.        0.        0.
  WAKEFD        39.        0.        0.       39.
  LYNFLD         0.        0.        0.        0.
  SAUGUS        41.       38.        0.       79.
    LYNN        38.        0.       38.       76.
  NAHANT         0.        0.        0.        0.
  SWMSCT        82.        0.      124.      206.
  MARBHD         0.        0.       41.       41.
   SALEM         0.        0.        0.        0.
 PEABODY         0.       41.        0.       41.
 DANVERS         0.        0.        0.        0.
 BEVERLY         0.        0.       34.       34.
 CONCORD         0.        0.        0.        0.
 LINCOLN         0.        0.        0.        0.
 WAYLAND         0.        0.       77.       77.
  NATICK        16.        0.        0.       16.
 SUDBURY         0.        0.        0.        0.
  FRAMHM        48.        0.        0.       48.
   DOVER         0.        0.        0.        0.
  WESTWD         0.        0.        0.        0.
 NORWOOD        75.        0.        0.       75.
  CANTON         0.        0.        0.        0.
 RANDOLF         0.        0.        0.        0.
  DEDHAM         0.       34.      102.      136.
  MILTON         0.        0.        0.        0.
  QUINCY         0.        0.        0.        0.
 BRNTREE         0.        0.        0.        0.
  WEYMTH        37.        0.        0.       37.
   HINGM         0.        0.       17.       17.
   COHST         0.        0.        0.        0.

   TOTAL      1492.      363.     1265.     3120.
```

Table 1.3-3

```
MODE   TAXI_PAX

TOWNS .VS. TO_PURSE

          AIR_PAX EMPLOYEE  VISITOR    TOTAL

   EBSTN      0.        0.       0.       0.
  CHASTN      0.        0.       0.       0.
   BOSPR     18.        0.       0.      18.
    SBOS      0.        0.       0.       0.
 ROXBURY      0.        0.       0.       0.
   DORCH      0.        0.       0.       0.
  MATAPN      0.        0.       0.       0.
   HYDPK      0.        0.       0.       0.
  RSLNDL      0.        0.       0.       0.
   JAMPL      0.        0.       0.       0.
  BRITON      0.        0.       0.       0.
 BRKLINE      0.        0.       0.       0.
  NEWTON      0.        0.       0.       0.
  WESTON      0.        0.       0.       0.
   WLSLY     70.        0.       0.      70.
  NEEDHM      0.        0.       0.       0.
 WALTHAM      0.        0.       0.       0.
   WTRTN      0.        0.       0.       0.
  BELMNT      0.        0.       0.       0.
   LXGTN      0.        0.       0.       0.
  BURLTN      0.        0.       0.       0.
  WOBURN      0.        0.       0.       0.
 READING      0.        0.       0.       0.
 STONEHM      0.        0.       0.       0.
  WINCTR      0.        0.       0.       0.
  ARLNTN      0.        0.       0.       0.
    CAMB     42.        0.       0.      42.
  SOMRVL      0.        0.       0.       0.
   MEDFD      0.        0.       0.       0.
  EVERET      0.        0.       0.       0.
  CHLSEA      0.        0.       0.       0.
  REVERE      0.        0.       0.       0.
  WINTHP      0.        0.       0.       0.
  MALDEN      0.        0.       0.       0.
 MELROSE      0.        0.       0.       0.
  WILMTN      0.        0.       0.       0.
  WAKEFD      0.        0.       0.       0.
  LYNFLD      0.        0.       0.       0.
  SAUGUS      0.        0.       0.       0.
    LYNN      0.        0.       0.       0.
  NAHANT      0.        0.       0.       0.
  SWMSCT      0.        0.       0.       0.
  MARBHD      0.        0.       0.       0.
   SALEM      0.        0.       0.       0.
 PEABODY      0.        0.       0.       0.
 DANVERS      0.        0.       0.       0.
 BEVERLY      0.        0.       0.       0.
 CONCORD      0.        0.       0.       0.
 LINCOLN     18.        0.       0.      18.
 WAYLAND      0.        0.       0.       0.
  NATICK      0.        0.       0.       0.
 SUDBURY      0.        0.       0.       0.
  FRAMHM      0.        0.       0.       0.
   DOVER      0.        0.       0.       0.
  WESTWD      0.        0.       0.       0.
 NORWOOD      0.        0.       0.       0.
  CANTON      0.        0.       0.       0.
 RANDOLF      0.        0.       0.       0.
  DEDHAM      0.        0.       0.       0.
  MILTON      0.        0.       0.       0.
  QUINCY      0.        0.       0.       0.
 BRNTREE      0.        0.       0.       0.
  WEYMTH      0.        0.       0.       0.
   HINGM      0.        0.       0.       0.
   COHST      0.        0.       0.       0.

   TOTAL    149.        0.       0.     149.
```

Table 1.3-4

```
        MODE  SUB_BUS

        TOWNS .VS. TO_PURSE

              AIR_PAX EMPLOYEE  VISITOR    TOTAL

     EBSTN       57.       85.       0.     142.
    CHASTN        0.        0.       0.       0.
     BOSPR      133.       67.       0.     200.
      SBOS        0.        0.       0.       0.
   ROXBURY        0.        0.       0.       0.
     DORCH        0.       42.       0.      42.
    MATAPN        0.       39.       0.      39.
     HYDPK        0.       38.       0.      38.
    RSLNDL        0.        0.       0.       0.
     JAMPL        0.        0.       0.       0.
    BRITON        0.        0.       0.       0.
   BRKLINE        0.        0.       0.       0.
    NEWTON        0.        0.       0.       0.
    WESTON        0.        0.       0.       0.
     WLSLY        0.        0.       0.       0.
    NEEDHM        0.        0.       0.       0.
   WALTHAM        0.        0.       0.       0.
     WTRTN        0.        0.       0.       0.
    BELMNT        0.        0.       0.       0.
     LXGTN        0.        0.       0.       0.
    BURLTN        0.        0.       0.       0.
    WOBURN        0.        0.       0.       0.
   READING        0.        0.       0.       0.
   STONEHM        0.        0.       0.       0.
    WINCTR        0.        0.       0.       0.
    ARLNTN        0.        0.       0.       0.
      CAMB       47.        0.       0.      47.
    SOMRVL        0.       44.       0.      44.
     MEDFD        0.        0.       0.       0.
    EVERET        0.        0.       0.       0.
    CHLSEA        0.       40.       0.      40.
    REVERE        0.       44.       0.      44.
    WINTHP        0.        0.       0.       0.
    MALDEN        0.        0.       0.       0.
   MELROSE        0.        0.       0.       0.
    WILMTN        0.        0.       0.       0.
    WAKEFD        0.        0.       0.       0.
    LYNFLD        0.        0.       0.       0.
    SAUGUS        0.        0.       0.       0.
      LYNN        0.        0.       0.       0.
    NAHANT        0.        0.       0.       0.
    SWMSCT        0.        0.       0.       0.
    MARBHD        0.        0.       0.       0.
     SALEM        0.        0.       0.       0.
   PEABODY        0.        0.       0.       0.
   DANVERS        0.        0.       0.       0.
   BEVERLY        0.        0.       0.       0.
   CONCORD        0.        0.       0.       0.
   LINCOLN        0.        0.       0.       0.
   WAYLAND        0.        0.       0.       0.
    NATICK        0.        0.       0.       0.
   SUDBURY        0.        0.       0.       0.
    FRAMHM        0.        0.       0.       0.
     DOVER        0.        0.       0.       0.
    WESTWD        0.        0.       0.       0.
   NORWOOD        0.        0.       0.       0.
    CANTON        0.        0.       0.       0.
   RANDOLF        0.        0.       0.       0.
    DEDHAM        0.        0.       0.       0.
    MILTON        0.        0.       0.       0.
    QUINCY        0.        0.       0.       0.
   BRNTREE        0.        0.       0.       0.
    WEYMTH        0.        0.       0.       0.
     HINGM        0.        0.       0.       0.
     COHST        0.        0.       0.       0.

     TOTAL      237.      399.       0.     635.
```

Table 1.3-5

With respect to the information contained in these tables, we can make the following observations:

1. The local origins of resident air passengers are widely dispersed in the Boston metropolitan area. Based on the district boundaries shown in Figure 1.3-1, the Boston CBD (district D2) accounted for only 379 trips or 9% of the area total.
2. In fact, except for districts 10 (7%) and 4 (5%), the Boston CBD generated the smallest percentage of resident air passengers. The percentages of resident air passenger trips for all districts is shown below in Table 1.3-6.

PERCENTAGE OF TOTAL RESIDENT AIR PASSENGER TRIPS ORIGINATING FROM EACH DISTRICT IN THE BOSTON STUDY AREA

DISTRICT	PERCENTAGE
2	9%
3	9%
4	5%
5	11%
6	13%
7	12%
8	12%
9	22%
10	7%

Table 1.3-6

3. Visitor trips are also dispersed widely throughout the metropolitan area. The origins of airport employees tend to gravitate towards locations near Logan, on the North Shore. The populous Roxbury-Mattapan-Dorchester area (district 7) also generates a relatively large proportion of the airport employees.

This data is summarized below in Table 1.3-7.

PERCENTAGE OF TOTAL RESIDENT AIR PASSENGER TRIPS ORIGINATING FROM EACH DISTRICT IN THE BOSTON STUDY AREA

DISTRICT	PERCENTAGE OF VISITORS	PERCENTAGE OF EMPLOYEES
2	14%	7%
3	11%	28%
4	5%	5%
5	19%	19%
6	0%	2%
7	12%	12%
8	14%	13%
9	17%	7%
10	8%	7%

Table 1.3-7

4. Resident air passengers, employees, and visitors rely predominantly on the automobile as a means of going to Logan Airport. Of all the resident air passengers, 57% drive to the airport, 37% are driven, and 6% use the MBTA.* In effect then, 94% of the resident air passengers arrived at Logan in an automobile. Visitors made exclusive use of the automobile for airport trips - 14% driving, and 86% being driven. In the employee category, 79% of the total drove to Logan, 10% were driven, and 11% used public transportation.

---

*The sample size of resident air passenger taxi trips was too small to be considered as a reliable indicator of total taxi trips. A total of only eight dwelling units reported use of taxi for a Logan-destined trip. Hence the taxi mode is neglected in the above discussion. As a result, the above percentages will tend to be overestimates of the true modal split.

5. As might be expected,use of transit by resident air passengers and employees was limited to origins in Boston proper and the inner suburbs.

6. It is dangerous to draw conclusive inferences from the data concerning the effects of income on modal choice, because of the large number of interviews in which income was not reported. However, from Table 1.3-8 it can be noted that high income resident air passengers were more likely to drive than be driven to the airport as compared to low income air passengers.* This can be explained by the fact that the car ownership rate for high income residents is higher than for low income residents. Thus, it is more likely that the high income resident air passengers had an automobile available which they could drive and park at the airport for the duration of their air trip.

MODAL SPLIT BY INCOME LEVEL FOR RESIDENT AIR PASSENGERS

	AUTO-DRV	AUTO-PAX	SUB-BUS	TOTAL
LOW-INCOME	811	738	55	1604
HIGH-INCOME	1425	298	134	1857
INCOME NOT REPORTED	608	595	47	1250
	2844	1631	236	4711

Table 1.3-8

---

*The cutoff point between "high" and "low" income was considered to be $10,000.

7. The home interview survey does not allow us to draw any inferences about the local origins of non-resident air passengers. However, in another survey,* Wilbur Smith and Associates collected trip data for a selected sample of taxis registered in their planning area. The taxi survey involved the examination of the logs of about 370 taxis (a 10% randomly selected sample), which, taken together, accounted for about 88,000 24 hour weekday trips. Taxi trips to Logan Airport are displayed in Table 1.3-9 by origin town and taxi occupancy.

Since taxi is usually the preferred mode for non-resident air passengers,** Table 1.3-9 can give us at least a rough indication of the local origins of this group of travellers. The Boston CBD accounted for a full 44% of the total area taxi trips. Given the high concentration of business activity located in the CBD, the data indicates that a relatively high percentage of non-resident business air passengers use taxi from a local origin in the downtown Boston area. It should be remembered here that only 9% of the resident air passengers had a local origin in the Boston CBD.

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*Reference [40], page 97.

**For example, the Port of New York Authority study [32] of New York's Domestic Air Passenger Market (1963) reported that 58% of the non-resident air passengers patronized taxis to get to LaGuardia Airport. This was more than twice the modal share of any of the other modes patronized.

TOWNS.VS.OCCUPANCY

	1 PAX	2 PAX	3 PAX	4 PAX	TOTAL
EBSTN	55	33	0	0	88
CHASTN	0	0	0	0	0
BOSPR	357	111	22	0	491
SBOS	11	0	0	0	11
ROXBUR	0	0	11	0	11
DIRCH	0	0	0	0	0
MATAPN	0	0	0	0	0
HYDPK	11	0	0	0	11
RSLNDL	0	0	0	0	0
JAMPL	88	11	0	0	99
BRITON	11	0	0	0	11
BRKLIN	31	11	10	0	52
NEWTON	32	0	10	10	52
WESTON	0	0	0	0	0
WLSLY	0	0	0	0	0
NEEDHM	24	0	0	0	24
WALTHM	10	0	0	0	10
WTRTN	0	0	0	0	0
BELMNT	10	0	0	0	10
LXNGTN	18	0	0	0	18
BURLTN	0	0	0	0	0
WOBURN	0	0	0	0	0
READNG	0	0	0	0	0
STONHM	10	0	0	0	10
WINCTR	0	0	0	0	0
ARLNTN	0	0	0	0	0
CAMB	38	38	0	0	76
SOMRVL	22	7	0	0	29
MEDFD	8	0	0	0	8
EVERET	0	0	0	0	0
CHLSEA	0	0	0	0	0
REVERE	11	0	0	0	11
WINTHP	16	0	0	0	16
MALDEN	28	0	0	0	28
MELRSE	0	0	0	0	0
WILMTN	0	0	0	0	0
WAKEFD	0	0	0	0	0
LYNFLD	0	0	0	0	0
SAUGUS	0	0	0	0	0
LYNN	0	9	0	0	9
NAHANT	0	0	0	0	0
SWMSCT	0	0	0	0	0
MARBHD	0	0	0	0	0
SALEM	0	0	0	0	0
PEABDY	0	0	0	0	0
DANVRS	9	0	0	0	9
BVERLY	0	0	0	0	0
CNCORD	0	0	0	0	0
LNCOLN	0	0	0	0	0
WAYLND	0	0	0	0	0
NATICK	0	0	0	0	0
SDBURY	0	0	0	0	0
FRAMHM	0	0	0	0	0
DOVER	0	0	0	0	0
WESTWD	0	0	0	0	0
NORWOD	0	0	0	0	0
CANTON	0	0	0	0	0
RNDOLF	0	0	0	0	0
DEDHAM	0	0	0	0	0
MILTON	0	0	0	0	0
QUINCY	11	0	0	0	11
BRNTRE	0	0	0	0	0
WEYMTH	0	0	0	0	0
HINGM	0	0	0	0	0
COHST	0	0	0	0	0
TOTAL	817	221	53	10	1102

Table 1.3-9

1.4 Summary of Airport Access Trip Patterns

In summary, we can conclude that in Boston, as well as in other major cities, the airport access problem is very much imbedded in the metropolitan transportation problem. Their almost exclusive reliance on rubber-tired vehicles make airport travellers subject to the same congestion delays that afflict commuters and shoppers on city streets and urban arterials. The complementarity of these two flow patterns is all the more evident when it is noted that the peak period for airport trips coincides with the peak of other urban trip purposes (most notably work trips).

The second salient conclusion we can reach based on the data presented earlier is that the local origins of airport travellers are widely dispersed in the metropolitan area. The origins of non-resident air passengers, employees, and especially resident air passengers and visitors are not heavily concentrated in the downtown area. Thus, "solutions" to the airport access problem which call for improvements only in the transportation services offered between the CBD and airport, are not likely to be effective.

Finally, in passing, we note that there are a whole range of problems in the area of air transportation other than airport access that are equally deserving of attention. Though we cannot address these issues within the scope of this case study, it is important to recognize the existence of the following problems:

1. noise pollution:

The areal expansion of airports, combined with the ever increasing size of jet aircraft, have created a situation of excessive noise in communities surrounding major metropolitan airports.

2. airport capacity:

The rapid growth of the air transportation industry has placed a strain on the capacity of existing airports. The noise problem has made airports "bad neighbors." Thus, the problem of finding a location of a politically acceptable site for new airports has become increasingly difficult.

3. air space congestion:

The growth of the air industry has also put a strain on the air traffic control equipment which provides safe passage of aircraft in controlled corridors. Despite rapid advances in technology, the dangers of near misses and in-flight collisions remain as a major threat to airlines.

4. terminal congestion:

The introduction of the jumbo jets (Boeing 747, Douglas DC-10, and Lockheed L-1011) has created major problems in the area of passenger handling. Most airports have not been able to make the necessary terminal improvements to handle efficiently the passenger and baggage movement required by the new 400-seat aircraft.

Question 1.4-1

In the preceding discussion no mention was made of the delays the air passenger encounters once he arrives at the air terminal. At large metropolitan airports ticketing and baggage check-in delays coupled with the time consumed while the passenger's aircraft taxis and waits for takeoff clearance, may amount to as much as two hours. Will terminal delays affect the passenger's choice of access mode to the airport? Might it affect his decision whether or not to fly at all?

Answer 1.4-1

Terminal delays affect all air passengers equally, regardless of their mode of arrival to the airport. Consequently, we can expect passengers to make their access modal choice independent of the magnitude of ticketing, baggage check-in, and in-plane, pre-takeoff delays. However, as air terminal delays increase, air transport's competitive advantage over other intercity modes diminishes. Thus, terminal delays may influence travellers' choices of intercity service (i.e., between air, bus, rail, and auto).

Question 1.4-2

While, in most cities, the majority of airport access trips originate outside the CBD, the slowest average (auto or taxi) speeds are experienced by CBD-airport travellers. What does this suggest about the interaction between intraurban flows and airport access flows?

Study Tables 1.1-1, 1.1-2, 1.1-3, and 1.1-4. Which group - air passenger, visitor, or employee is most predominantly affected by CBD - airport access delays?

Answer 1.4-2

The degree of interaction between general urban flows, and airport access flows depends on the particular geography of a city. In cities where the major arterial providing access to the airport is also heavily used for urban work trips (e.g., Van Wyck Expressway near New York's Kennedy International Airport), we can expect the delays incurred airport travellers to be primarily attributable to non-airport trip makers. Airport travel is a small percentage of intraurban movements. There are cases however where special limited access highway facilities are provided exclusively for airport trips (e.g., Dulles International Airport Road) which essentially eliminates the flow interaction. In general, it is the non-airport travellers that are mainly responsible for congestion in urban areas. This congestion is greatest in the CBD. From Tables 1.1-2, 1.1-3, and 1.1-4, it can be seen that air passengers are more adversely affected by CBD congestion than airport visitors or employees. For the cities represented in the tables, an average of 28.2% of the air passengers originated their airport trip in the CBD as compared to 14.7% of the visitors and 8.6% of the employees.

1.5 Objectives of the Case Study

This analysis focuses attention on the network providing access to Boston's Logan International Airport. We are specifically interested in the morning peak* intraurban trips originating at various points in the metropolitan Boston area (e.g., home, office, or hotel), and terminating at the airport terminal or office buildings.

Before embarking on an analysis strategy it is extremely important to: 1) state the objectives of the study, and 2) identify the basic issues to be explored. The choice of a model, data requirements, and degree of detail in the analysis depend entirely on the scope of the study. Since this study was designed primarily for educational purposes, no attempt was made to work with a microscopically detailed network representation of the Boston area. Rather, the model is presented in as aggregate a form as possible so as still to be sensitive to the basic issues we wish to investigate.

In particular, we would like to address the following issues with our analysis:

a. What is the extent of the airport access problem?
   What is the present level of congestion?

b. Who are the relevant actors? What are the major types of flows (by user group) which should be analyzed?

c. What is the nature of the existing transportation facilities?

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*For the purpose of this case study, the morning peak is considered to extend from 7:00 am to 9:00 am.

Which facilities in the present network are particularly congested?

d. Which alternatives should be considered as part of the solution to the airport access problem?

2.0 Analysis Framework

DODOTRANS provides the analyst with a generalized framework that may be used to structure a wide range of transportation problems. In workbook exercise 14 [3], DODOTRANS was used to simulate the travel patterns of two income groups in Boston's southeast corridor. In this study, a larger geographic area is considered. Although we are primarily interested in predicting the impacts of various alternatives on airport access flows, it was imperative also to consider the morning peak work commuter flows to downtown Boston. Since work commuters and airport travellers use the same limited road space, changes in the transportation or activity system will clearly affect both groups mutually. This flow interaction is implicitly modelled in the analysis.

The study area is shown in Figure 1.3-1 on page 43. The ten districts defined in the figure were chosen because together they account for the majority of airport and commuter trips in the Boston area. The towns and communities included are:

District 1	Airport	-Logan International Airport
District 2	Boston CBD	-Boston Proper, South Boston
District 3	Logan Community	- Chelsea, East Boston, Winthrop
District 4	River Basin Communities	-Cambridge, Charlestown, Somerville
District 5	North Shore	-Everett, Lynn, Malden, Medford, Melrose, Nahant, Revere, Saugus
District 6	Inner Suburbs	-Arlington, Belmont, Brighton, Brookline, Watertown

District 7	Southern Boston Communities	-Dorchester, Fenway-Jamaica Plain, Hyde Park, Mattapan, Roslindale, Roxbury, West Roxbury
District 8	Northern Suburbs	-Beverly, Burlington, Danvers, Lynfield, Marblehead, Peabody, Reading, Salem, Swampscott, Stoneham, Wakefield, Winchester, Woburn
District 9	Western Suburbs	-Concord, Dover, Lexington, Lincoln, Natick, Needham, Newton, Framingham, Sudbury, Wayland, Waltham, Wellesley, Weston
District 10	Southern Suburbs	-Braintree, Canton, Cohasset, Dedham, Hingham, Milton, Norwood, Randolph, Quincy, Westwood, Weymouth

The network focuses attention on inbound, radial travel, because it is on these directed links that CBD commuter and airport trips primarily interact. The five modes in the base case analysis - air passenger auto drive, air passenger auto passenger, taxi, public transit, and employee auto drive - account for the majority of trips inbound to Logan International and the CBD. A detailed description of the network is presented in Section 5.2.

3.0 Actors

In this analysis, we distinguish between three airport traveller groups - resident air passenger,* non-resident air passenger, and airport employee. The first two traveller groups were considered separately for two reasons. One consideration is that the available modes for providing access to Logan are quite different for residents and non-residents. In general, resident air passengers have an automobile available in which they can drive or be driven. Non-residents, on the other hand, are generally limited to the public modes - taxi, limousine, or rail rapid transit. The second reason for considering these two traveller groups separately is that they tend to have a dichotomous origination pattern. Non-resident air passengers are relatively heavily concentrated in the CBD, whereas resident air passengers have origins spread widely throughout the metropolitan area.

We have purposely neglected consideration of airport visitors as a separate traveller group. The reason for this omission is that a very large percentage** of visitors arriving at Logan in the morning peak accompany air passengers in private autos. Thus in modelling the auto passenger mode for resident air passengers, we are explicitly accounting for the overwhelming majority of airport visitor trips in the morning peak.

Three transportation operator groups were considered in the base

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*That is, air passengers whose home or office is within the study area shown in Figure 1.3-1.

**The Wilbur Smith survey data indicated that about 99% of the morning peak airport visitors' trips were made for the stated purpose of delivering an air passenger to Logan.

case DODOTRANS simulation - namely the operators of public transit, taxis, and the airport garages. It was not deemed relevant to consider explicitly the operator revenues for the auto passenger and employee auto drive modes. In effect then, we are neglecting the opportunity cost associated with the provision of temporary terminal curb spaces, and the sunk cost of employee parking lots. The impacts of the alternatives explored in this case study on other actors in the urban environment cannot be represented quantitatively in the DODOTRANS simulations. It will be up to the student to think qualitatively through the expected impacts on government and various non (transportation)-user groups.

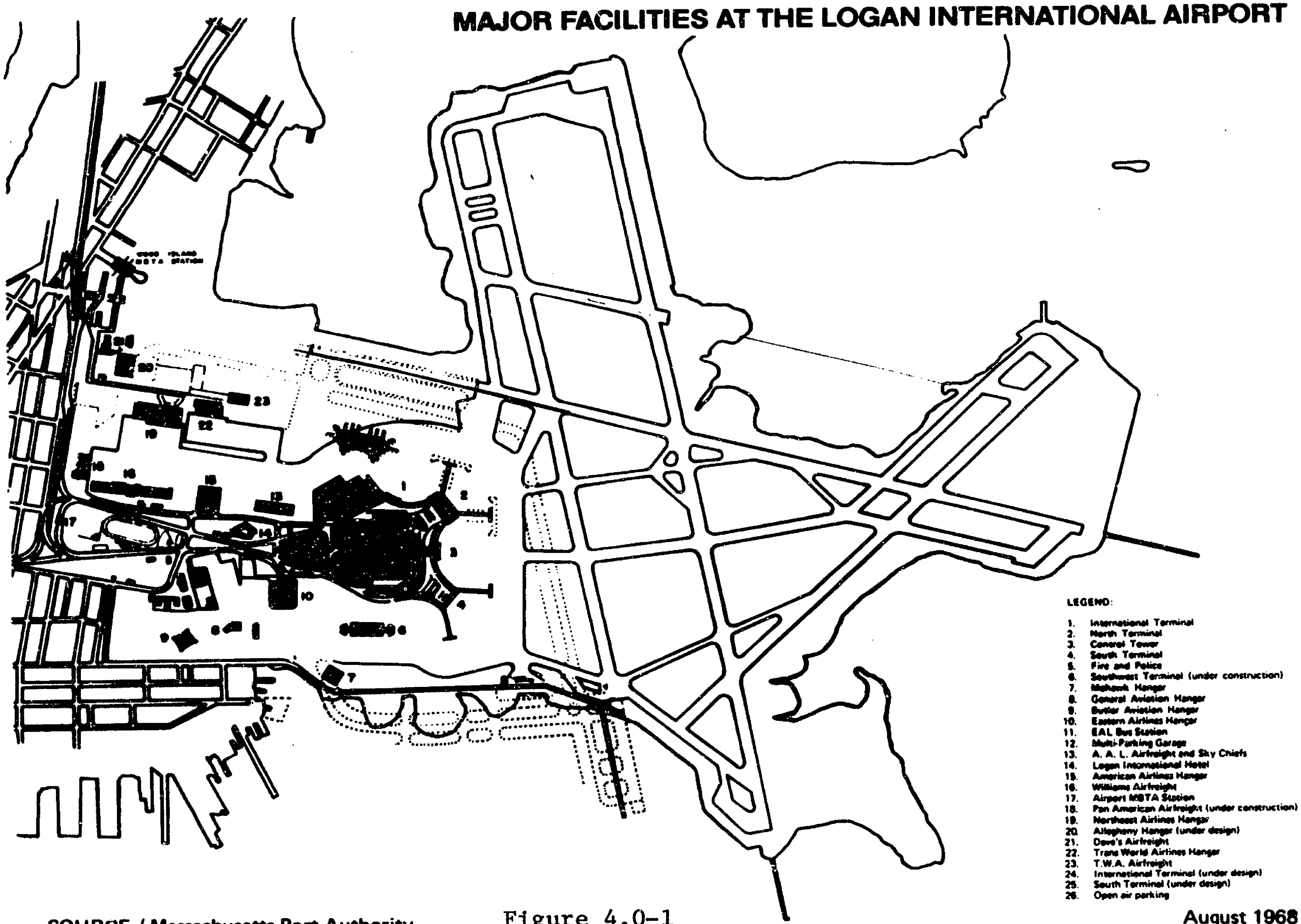
4.0 Airport Access to Logan International Airport - A Physical Description

Logan International is the eighth busiest airport in the world. In 1966, 3,002,000 passengers emplaned at Logan, and the Federal Aviation Administration (FAA) forecasts over six million passengers for 1975 [16]. Employment at Logan has been growing steadily over recent years. At present, there are approximately 10,000 Logan employees earning yearly wages in excess of sixty million dollars. The Wilbur Smith home interview survey indicates that nearly one fourth of the air passengers and employee trips to Logan occur in the morning peak. Thus, it is estimated that on a typical 1970 weekday between seven and nine in the morning, 2,800 air passengers and 2,500 employees made trips to the airport.

Logan Airport is situated at the eastern extreme of East Boston. Except for communities on the North Shore, auto access trips to the airport must pass through the Callahan Tunnel (a 25¢ toll facility). The airline terminal buildings are situated around a horseshoe shaped access road as shown in Figure 4.0-1. A centrally located multi-level garage (presently being expanded to a capacity of 6,500 cars) provides parking spaces for airport passengers and visitors. Air passengers are required to walk as much as half a mile from the garage to their departure gate. Most companies provide free parking facilities for their employees in lots near the office and terminal buildings.

Logan is presently undertaking a large construction program, which, within ten years should markedly alter the present layout of the airport.

MAJOR FACILITIES AT THE LOGAN INTERNATIONAL AIRPORT



SOURCE / Massachusetts Port Authority

Figure 4.0-1

August 1968

Plans call for the construction of four unit terminals* (two of these terminals, the Southwest and the North Terminal, are already completed), a new tower, addition of a parallel 15-33 runway, expanded cargo facilities built on land fill, and expanded parking and access roadway facilities and a people-mover system. The new construction should improve the flow of traffic around the airport.

At present, three public modes serve Logan Airport. Limousine service is available only from downtown Boston.** These eight-passenger vehicles depart from major hotels in the Boston CBD every fifteen minutes and charge a fare of $1.25. The limousines disembark passengers at all of the major airline terminal complexes.

Subway service to Logan is provided by the Blue Line of the MBTA. A bus transfer is required to complete the one mile trip from the airport subway stop to the airline terminal buildings. The subway and bus fare from Boston to Logan is 45¢.

Taxi service to Logan is offered from all communities in the metropolitan area. While it is the most convenient of all the public modes, it is also the most expensive. The present taxi fares are on the order of 50¢ fixed charge plus 50¢ per mile (in addition to which the passenger

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*The unit terminals house car parking lots, ticketing and baggage handling facilities, and plane gates for one or more airlines.

**Limousine service is also offered from Nashua, Manchester, and Dover, New Hampshire on a limited basis. There is no suburban Boston limousine service. Because it accounts for a very small fraction of airport trips, this mode was not modelled in the present case study.

must pay the 25¢ tunnel toll).

5.0 DODOTRANS Simulation: Logan Airport Access - 1963

5.1 The Analysis Framework and DODOTRANS

The base case network was modelled to predict the flow patterns of airport-destined trips on the major modes serving Logan. In order to represent separately the flow patterns of resident air passengers, non-resident air passengers, and employees, each of the ten analysis districts shown in Figure 1.3-1 had to be programmed as three DODOTRANS districts. Thus, the resulting DODOTRANS network is relatively large - involving 30 districts and 180 zones.*

We have already mentioned that the airport access problem is very much imbedded in the urban transportation problem, in that both airport and non-airport travellers are vying for use of limited urban motorways and public transit facilities. There are two ways to model this interaction in DODOTRANS.

> The explicit approach would be to model the transportation movements of the entire metropolitan community, focusing our attention on the resulting congestion delays faced by airport travellers. This type of analysis would require a large amount of data, and a very costly-to-run, unwieldy network representation.

> The implicit approach, which we have adopted here due to budget and

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*In addition to the five base case modes mentioned in Section 2.0, a sixth "dummy" mode was modelled in the base case. While this mode has no physical significance in the base case analysis, it is included to permit the simulation of the introduction of a new mode (e.g., V/STOL service) later in the case study.

time constraints, accepts the level of urban congestion caused by non-airport travellers (i.e., the work commuter flow pattern) as an exogenous input to the analysis. Thus, the supply functions used in the implicit analysis are adjusted so that the "free-speed" travel times already reflect the network loading of non-airport travellers.

Even with the simplifying assumptions inherent in the implicit analysis, it was found that the cost of each DODOTRANS run exceeded the limit allowed by our budget. In an effort to bring down the computer simulation costs, a further assumption concerning supply functions was made. By using horizontal supply functions, we were able to employ a 100% assignment increment, thus minimizing the number of required iterations in the incremental assignment procedure of DODOTRANS. In Figure 5.1-1, the implications of horizontal supply function assumption are shown diagrammatically. The supply function for a particular link in the network is labelled S_1. The demand function for airport travellers, D_1, and for work commuters, D_2, sum horizontally to yield the composite demand function, D_3. The equilibrium point is shown as point A in the figure. Note, that if we use the horizontal supply function S_2, the same equilibrium flow pattern is determined. However, the two supply functions S_1 and S_2 will result in very different equilibria if the demand functions shift from the positions as shown in the figure.

In the sections that follow, the data input for the DODOTRANS simulation of the base case are described. The data sets are organized into

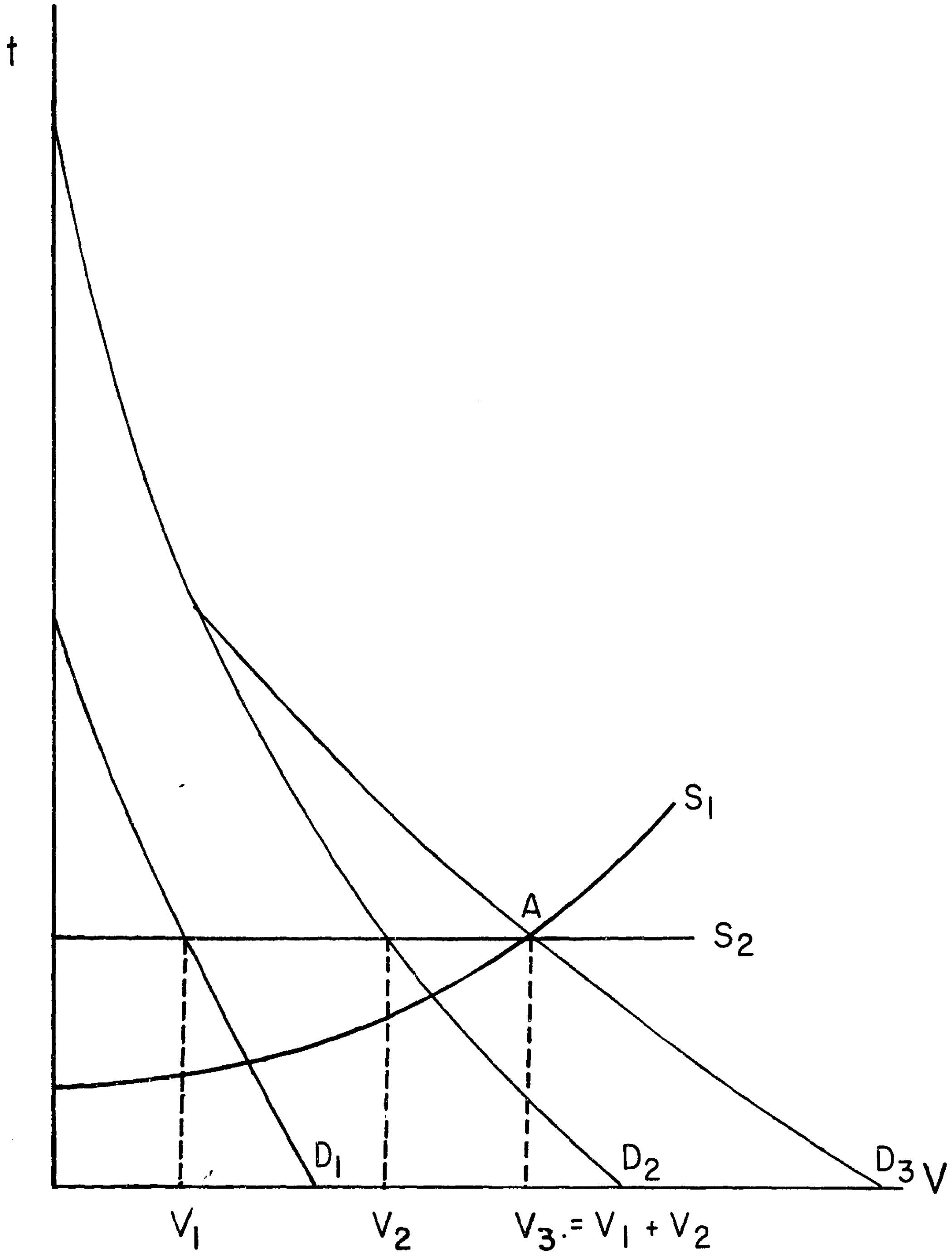


Figure 5.1-1

five components as shown below.

1. NETWORK DATA - list of link characteristics:
    - distance
    - number of lanes
    - appropriate supply function - termed Volume Delay (V/D) function
2. MODAL DATA - description of transportation technologies
    - interzonal fares and frequencies
    - fixed and operating costs of each mode
3. V/D DATA - list of V/D functions
    - piecewise linear description of relationship between volume and travel time
4. ACTIVITY DATA - description of the attributes of each district
    - district populations and incomes
5. DEMAND MODEL PARAMETERS

Question 5.1

Discuss the implications of the use of horizontal supply functions. In particular, how can we take account of the increasing congestion caused by a growth in non-airport travel, in the context of the implicit approach adopted in this case study?

Answer 5.1

By employing horizontal supply curves, we are neglecting the effects of congestion on equilibrium flow patterns. Refer to figure 5.1-2 where D_1, D_2, and D_3 represent the demand functions in some base year for airport trips, work-commuter trips, and total trips (the horizontal summation of D_1 and D_2) respectively. The supply function for a particular set of links in the network is shown as S_1. The resulting equilibrium flows are V_1 (airport trips), V_2 (work commuter trips), and V_3 (total trips, equal to $V_1 + V_2$). If S_1 were modelled as the horizontal supply function S_2, the same equilibrium flow pattern would result.

Consider now some future year where increasing population and employment opportunities have shifted the demand for work trips outward to D_2'. Assume that the demand for airport travel remains unchanged. The new demand function for total trips is shown as D_3', equal to the horizontal summation of D_2' and D_1. Whereas in the base year, S_1 and S_2 yielded the same equilibrium flow pattern, it is clear from the figure that in the

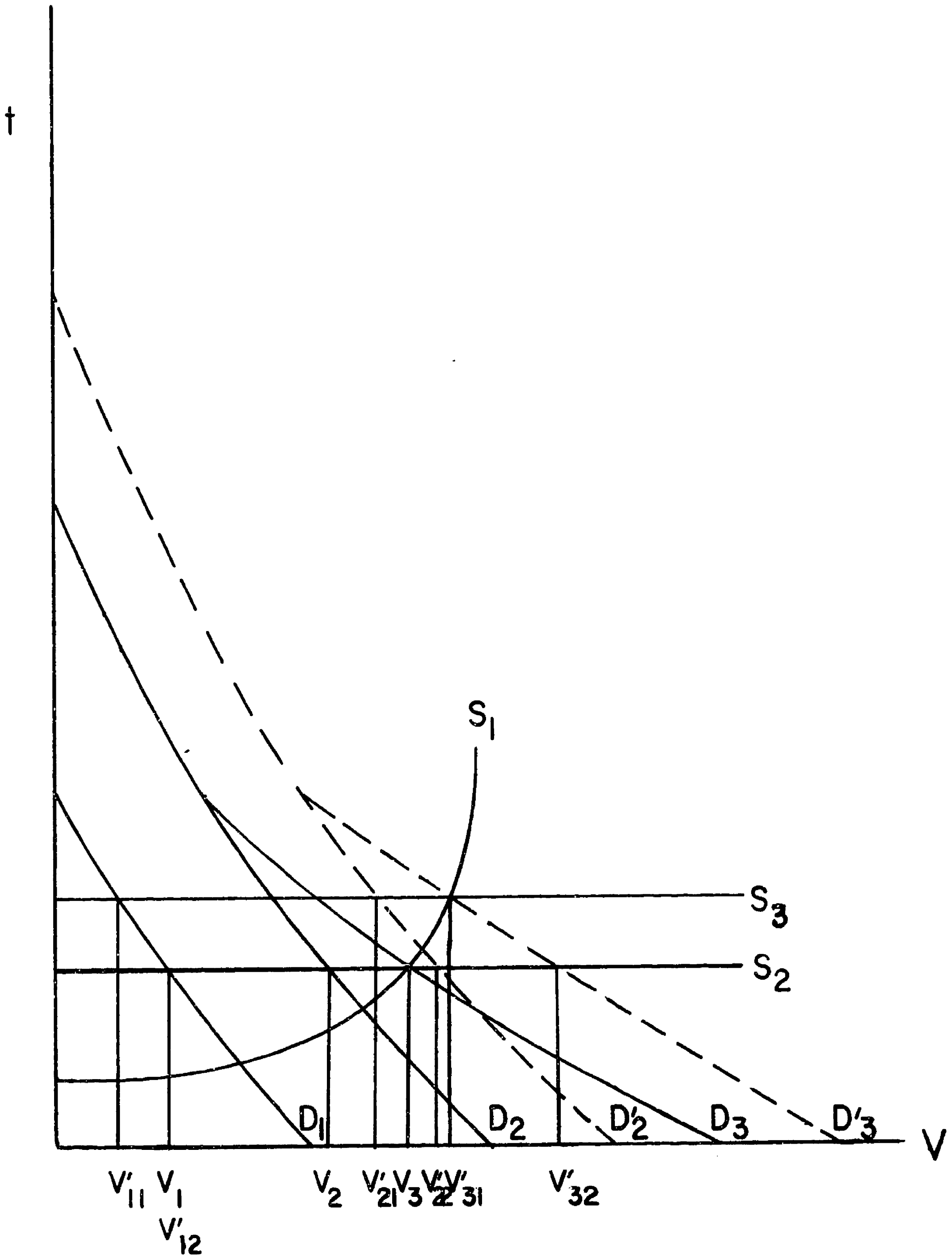


Figure 5.1-2

future year, the horizontal supply function S_z will tend to overestimate the flows resulting from the outward shift in demand. This can be seen by noting that

$$V'_{32} > V'_{31}$$

$$V'_{22} > V'_{21}$$

$$V'_{12} > V'_{11}$$

where V'_{ij} is defined as the volume resulting from the flow equilibrium between demand D'_i and supply S_j.

This case study adopts an implicit modelling approach where the congestion caused by urban work commuter trips are exogenously input to the analysis. In order to account for the additional congestion caused by the expected growth in total travel over the planning period (1963-1975), it is necessary to shift the base case horizontal supply functions upward for the projection year analysis. In Figure 5.1-2, S_3 represents the shifted horizontal supply function. Note that the equilibrium flow pattern resulting from demand D'_3 and supply S_1 and S_3 are the same.

5.2 The Network

The network is modelled to represent each trip in three segments - collection at the origin, line-haul, and distribution at the destination. For all modes, the access portion of the trip is modelled as one link. For rail trips, this link represents an aggregate measure of the time consumed in getting from a local point of origin to the rail station. The auto and taxi access links represent the average time travellers spend on the local street network.

Highway line haul links were coded to represent the most probable arterials used by airport travellers in the analysis area. For each district, one aggregate line haul link was coded. For example, the line haul link for origins on the south shore represents the Southeast Expressway. The length of the line haul links were determined from the location of the population centroid of each analysis district. Transit line haul links were measured from the stations closest to the population centroids of the analysis districts.

The analysis rendered a more detailed description of the distributor links at the airport. For example, air passengers driving to the airport were routed over two distributor links - one representing the time spent on the airport access road, and the other representing the time consumed in parking and walking to the terminals. The network representation for transit access to Logan includes a transfer link at the airport subway station and a bus access link to the terminal buildings.

The base case network with dummy links* omitted is presented in Figure 5.2.1. The links connecting zones of mode 6 (i.e., zone numbers ending with 5) were coded merely to conform to the DODOTRANS convention** of network connectivity since this mode is not used in the base case analysis (see footnote, page 69).

Note that each analysis districted is coded as three DODOTRANS districts - one for each traveller group (resident air passenger, non-resident air passenger, and employee). Each DODOTRANS district includes a zone for each mode in the analysis. Thus, modelling the ten analysis districts, three traveller groups, and six modes results in 180 DODOTRANS zones.

The zones are numbered according to the code described below:

Zone number = $n_1 n_2 n_3$

where, n_1 = 1-10 - district number

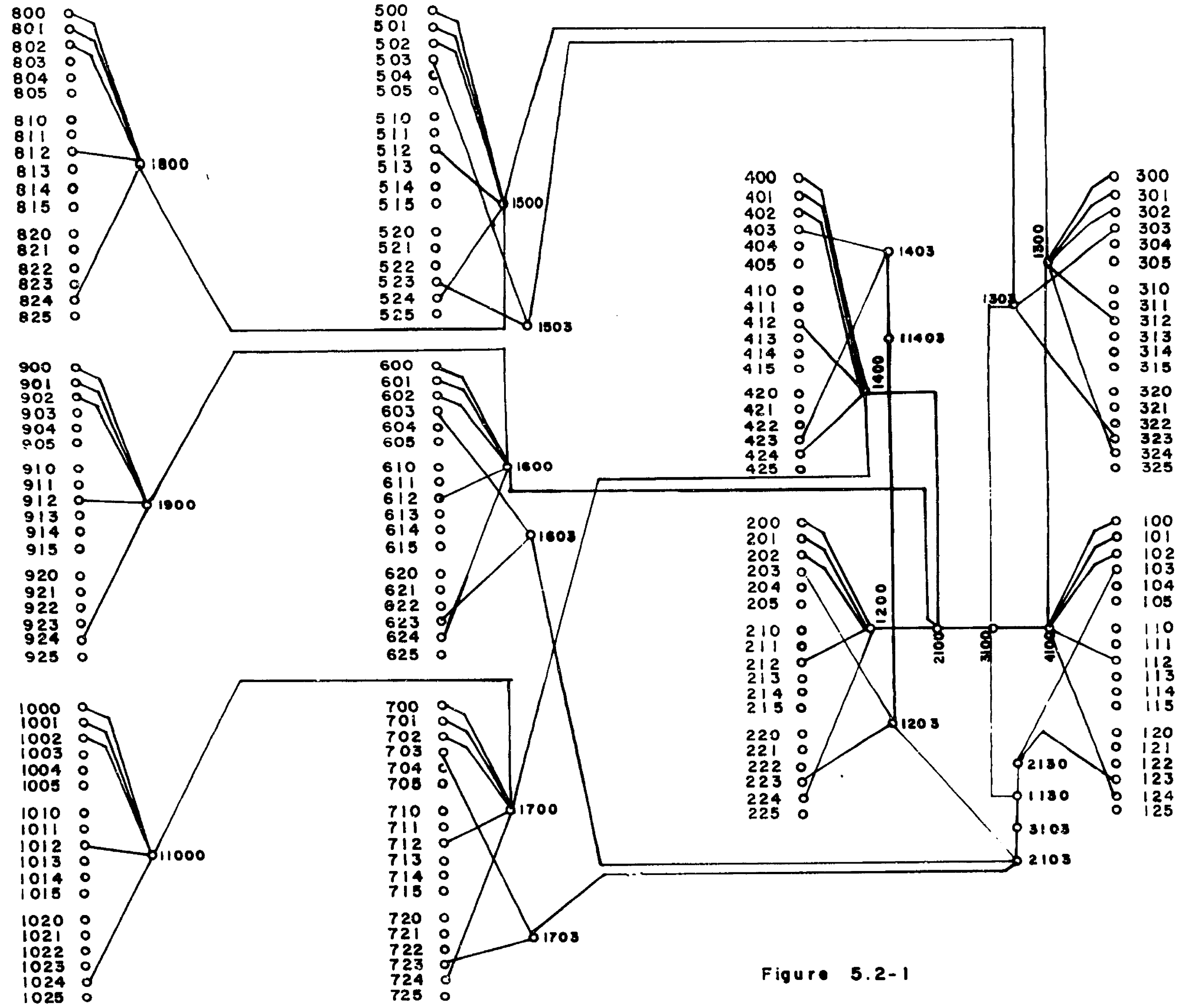
0 resident air passenger
n_2 = 1 non-resident air passenger district
2 employee

0 auto drive (air passenger)
n_3= 1 auto passenger (air passenger) zone
2 taxi

---

*Dummy links have ny physical significance. They are inserted into the network in order to provide a connection between all the DODOTRANS zones.

**See reference [24], page 19.



800
801
802
803
804
805
810
811
812
813
814
815
820
821
822
823
824
825
1800
900
901
902
903
904
905
910
911
912
913
914
915
920
921
922
923
924
925
1900
1000
1001
1002
1003
1004
1005
1010
1011
1012
1013
1014
1015
1020
1021
1022
1023
1024
1025
11000
500
501
502
503
504
505
510
511
512
513
514
515
520
521
522
523
524
525
1500
1503
600
601
602
603
604
605
610
611
612
613
614
615
620
621
622
623
624
625
1600
1603
700
701
702
703
704
705
710
711
712
713
714
715
720
721
722
723
724
725
1700
1703
400
401
402
403
404
405
410
411
412
413
414
415
420
421
422
423
424
425
1400
1403
11403
200
201
202
203
204
205
210
211
212
213
214
215
220
221
222
223
224
225
1200
1203
2100
3100
4100
1300
1303
300
301
302
303
304
305
310
311
312
313
314
315
320
321
322
323
324
325
100
101
102
103
104
105
110
111
112
113
114
115
120
121
122
123
124
125
2130
1130
3103
2103

Figure 5.2-1

3 subway/bus

$n_3 =$ 4 auto drive (employee) zone

5 new mode

An annotated listing of the network follows.

```
READ NETWORK 'BASE' ZONES 180 VOLUME DELAY SET 'BASE'
$ LINK ORDERING FOR DODOTRANS CONVENTION OF MODE/ZONE ASSIGNMENT
LINK 1     100   101   1 1 1
LINK 2     110   111   1 1 1
LINK 3     120   121   1 1 1
LINK 4     200   201   1 1 1
LINK 5     210   211   1 1 1
LINK 6     220   221   1 1 1
LINK 7     300   301   1 1 1
LINK 8     310   311   1 1 1
LINK 9     320   321   1 1 1
LINK 10    400   401   1 1 1
LINK 11    410   411   1 1 1
LINK 12    420   421   1 1 1
LINK 13    500   501   1 1 1
LINK 14    510   511   1 1 1
LINK 15    520   521   1 1 1
LINK 16    600   601   1 1 1
LINK 17    610   611   1 1 1
LINK 18    620   621   1 1 1
LINK 19    700   701   1 1 1
LINK 20    710   711   1 1 1
LINK 21    720   721   1 1 1
LINK 22    800   801   1 1 1
LINK 23    810   811   1 1 1
LINK 24    820   821   1 1 1
LINK 25    900   901   1 1 1
LINK 26    910   911   1 1 1
LINK 27    920   921   1 1 1
LINK 28    1000  1001  1 1 1
```

```
LINK 29   1010  1011  1 1 1
LINK 30   1020  1021  1 1 1
LINK 31   101   102   1 1 1
LINK 32   111   112   1 1 1
LINK 33   121   122   1 1 1
LINK 34   201   202   1 1 1
LINK 35   211   212   1 1 1
LINK 36   221   222   1 1 1
LINK 37   301   302   1 1 1
LINK 38   311   312   1 1 1
LINK 39   321   322   1 1 1
LINK 40   401   402   1 1 1
LINK 41   411   412   1 1 1
LINK 42   421   422   1 1 1
LINK 43   501   502   1 1 1
LINK 44   511   512   1 1 1
LINK 45   521   522   1 1 1
LINK 46   601   602   1 1 1
LINK 47   611   612   1 1 1
LINK 48   621   622   1 1 1
LINK 49   701   702   1 1 1
LINK 50   711   712   1 1 1
LINK 51   721   722   1 1 1
LINK 52   801   802   1 1 1
LINK 53   811   812   1 1 1
LINK 54   821   822   1 1 1
LINK 55   901   902   1 1 1
LINK 56   911   912   1 1 1
LINK 57   921   922   1 1 1
LINK 58   1001  1002  1 1 1
```

```
LINK 59   1011  1012  1 1 1
LINK 60   1021  1022  1 1 1
LINK 61   102   103   1 1 1
LINK 62   112   113   1 1 1
LINK 63   122   123   1 1 1
LINK 64   202   203   1 1 1
LINK 65   212   213   1 1 1
LINK 66   222   223   1 1 1
LINK 67   302   303   1 1 1
LINK 68   312   313   1 1 1
LINK 69   322   323   1 1 1
LINK 70   402   403   1 1 1
LINK 71   412   413   1 1 1
LINK 72   422   423   1 1 1
LINK 73   502   503   1 1 1
LINK 74   512   513   1 1 1
LINK 75   522   523   1 1 1
LINK 76   602   603   1 1 1
LINK 77   612   613   1 1 1
LINK 78   622   623   1 1 1
LINK 79   702   703   1 1 1
LINK 80   712   713   1 1 1
LINK 81   722   723   1 1 1
LINK 82   802   803   1 1 1
LINK 83   812   813   1 1 1
LINK 84   822   823   1 1 1
LINK 85   902   903   1 1 1
LINK 86   912   913   1 1 1
LINK 87   922   923   1 1 1
LINK 88   1002  1003  1 1 1
```

```
LINK 89   1012  1013  1 1 1
LINK 90   1022  1023  1 1 1
LINK 91   103   104   1 1 1
LINK 92   113   134   1 1 1
LINK 93   123   124   1 1 1
LINK 94   203   204   1 1 1
LINK 95   213   214   1 1 1
LINK 96   223   224   1 1 1
LINK 97   303   304   1 1 1
LINK 98   313   314   1 1 1
LINK 99   323   324   1 1 1
LINK 100  403   404   1 1 1
LINK 101  413   414   1 1 1
LINK 102  423   424   4 1 1
LINK 103  503   504   1 1 1
LINK 104  513   514   1 1 1
LINK 105  523   524   4 1 1
LINK 106  603   604   1 1 1
LINK 107  613   614   1 1 1
LINK 108  623   624   4 1 1
LINK 109  703   704   4 1 1
LINK 110  713   714   4 1 1
LINK 111  723   724   4 1 1
LINK 112  803   804   1 1 1
LINK 113  813   814   1 1 1
LINK 114  823   824   4 1 1
LINK 115  903   904   1 1 1
LINK 116  913   914   1 1 1
LINK 117  923   924   4 1 1
LINK 118  1003  1004  4 1 1
```

```
LINK 119  1013  1014  4 1 1
LINK 120  1023  1024  4 1 1
LINK 121  104   105   1 1 1
LINK 122  114   115   1 1 1
LINK 123  124   125   1 1 1
LINK 124  204   205   1 1 1
LINK 125  214   215   1 1 1
LINK 126  224   225   1 1 1
LINK 127  304   305   1 1 1
LINK 128  314   315   1 1 1
LINK 129  324   325   1 1 1
LINK 130  404   405   1 1 1
LINK 131  414   415   1 1 1
LINK 132  424   425   1 1 1
LINK 133  504   505   1 1 1
LINK 134  514   515   1 1 1
LINK 135  524   525   1 1 1
LINK 136  604   605   1 1 1
LINK 137  614   615   1 1 1
LINK 138  624   625   1 1 1
LINK 139  704   705   4 1 1
LINK 140  714   715   4 1 1
LINK 141  724   725   1 1 1
LINK 142  804   805   1 1 1
LINK 143  814   815   1 1 1
LINK 144  824   825   1 1 1
LINK 145  904   905   1 1 1
LINK 146  914   915   1 1 1
LINK 147  924   925   1 1 1
LINK 148  1004  1005  4 1 1
```

```
LINK 149  1014  1015  4 1 1
LINK 150  1024  1025  1 1 1
LINK 151  105   110   1 1 1
LINK 152  115   120   1 1 1
LINK 153  125   100   1 1 1
LINK 154  205   210   1 1 1
LINK 155  215   220   1 1 1
LINK 156  225   200   1 1 1
LINK 157  305   310   1 1 1
LINK 158  315   320   1 1 1
LINK 159  325   300   1 1 1
LINK 160  405   410   1 1 1
LINK 161  415   420   1 1 1
LINK 162  425   400   1 1 1
LINK 163  505   510   1 1 1
LINK 164  515   520   1 1 1
LINK 165  525   500   1 1 1
LINK 166  605   610   1 1 1
LINK 167  615   620   1 1 1
LINK 168  625   600   1 1 1
LINK 169  705   710   1 1 1
LINK 170  715   720   1 1 1
LINK 171  725   700   1 1 1
LINK 172  805   810   1 1 1
LINK 173  815   820   1 1 1
LINK 174  825   800   1 1 1
LINK 175  905   910   1 1 1
LINK 176  915   920   1 1 1
LINK 177  925   900   1 1 1
LINK 178  1005  1010  1 1 1
```

```
LINK 179  1015  1020  1 1 1
LINK 180  1025  1000  1 1 1
$ ALT3 DRIVE ACCESS LINKS AT LOCAL ORIGINS
LINK 181  200   1200  1.5 1 2
LINK 182  224   1200  1.5 1 2
LINK 183  300   1300  1 1 2
LINK 184  324   1300  1 1 2
LINK 185  400   1400  2 1 2
LINK 186  424   1400  2 1 2
LINK 187  500   1500  2 1 2
LINK 188  524   1300  2 1 2
LINK 189  600   1600  1.5 1 2
LINK 190  624   1600  1.5 1 2
LINK 191  700   1700  1.5 1 2
LINK 192  724   1700  1.5 1 2
LINK 193  800   1300  2 1 2
LINK 194  8241  800   2 1 2
LINK 195  900   1900  2 1 2
LINK 196  924   1900  2 1 2
LINK 197  1000  11000 2.5 1 2
LINK 198  1024  11000 2.5 1 2
$ ALT3 PASSENGER ACCESS LINKS AT LOCAL ORIGINS
LINK 199  201   1200  1.5 1 2
LINK 200  301   1300  1 1 2
LINK 201  401   1400  2 1 2
LINK 202  501   1500  2 1 2
LINK 203  601   1600  1.5 1 2
LINK 204  701   1700  1.5 1 2
LINK 205  801   1800  2 1 2
LINK 206  901   1900  2 1 2
```

```
$ TAXI ACCESS LINKS AT LOCAL ORIGINS
LINK 207  1001  11000 2.5 1 2
LINK 208  202   1200  1.5 1 2
LINK 209  302   1300  1 1 2
LINK 210  402   1400  2 1 2
LINK 211  502   1500  2 1 2
LINK 212  602   1600  1.5 1 2
LINK 213  702   1700  1.5 1 2
LINK 214  802   1800  2 1 2
LINK 215  902   1900  2 1 2
LINK 216  1002  11000 2.5 1 2
LINK 217  212   1200  1.5 1 2
LINK 218  312   1300  1 1 2
LINK 219  412   1400  2 1 2
LINK 220  512   1500  2 1 2
LINK 221  612   1600  1.5 1 2
LINK 222  712   1700  1.5 1 2
LINK 223  812   1800  2 1 2
LINK 224  912   1900  2 1 2
LINK 225  1012  11000 2.5 1 2
$ TRANSIT ACCESS AT LOCAL ORIGINS
LINK 226  203   1203  1.6 1 2
LINK 227  303   1303  2 1 2
LINK 228  403   1403  1.5 1 2
LINK 229  503   1503  3.33 1 2
LINK 230  603   1603  3.33 1 2
LINK 231  703   1703  2.5 1 2
LINK 232  803   1803  6 1 2
LINK 233  903   1903  4.18 1 2
LINK 234  1003  1703  6 1 2
```

```
LINK 235  213   1203  1.5 1 2
LINK 236  313   1303  2 1 2
LINK 237  413   1403  1.5 1 2
LINK 238  513   1503  3.33 1 2
LINK 239  613   1603  3.33 1 2
LINK 240  713   1703  2.5 1 2
LINK 241  813   1803  6 1 2
LINK 242  913   1903  4.18 1 2
LINK 243  1013  1703  6 1 2
LINK 244  223   1203  1.6 1 2
LINK 245  323   1303  2 1 2
LINK 246  423   1403  1.5 1 2
LINK 247  523   1503  3.33 1 2
LINK 248  623   1603   3.33 1 2
LINK 249  723   1703  2.5 1 2
LINK 250  823   1803  6 1 2
LINK 251  923   1903  4.18 1 2
LINK 252  1023  1703  6 1 2
LINK 253  205   1204  1.6 1 2
LINK 254  305   1304  2.5 1 2
$ NEW MODE ACCESS LINKS AT LOCAL ORIGINS
LINK 255  405   1404  2.5 1 2
LINK 256  505   1504  3 1 2
LINK 257  605   1604  3 1 2
LINK 258  705   1704  3 1 2
LINK 259  805   1804  3.33 1 2
LINK 260  905   1904  3.33 1 2
LINK 261  1005  11004 3.33 1 2
LINK 262  215   1204  1.6 1 2
LINK 263  315   1304  2.5 1 2
```

```
LINK 264  415   1404  2.5 1 2
LINK 265  515   1504  3 1 2
LINK 266  615   1604  3 1 2
LINK 267  715   1704  3 1 2
LINK 268  815   1804  3.33 1 2
LINK 269  915   1904  3.33 1 2
LINK 270  1015  11004 3.33 1 2
$ SUBWAY/BUS LINE HAUL AND TRANSFER LINKS
LINK 271  1503  1303  2.0 1 10
LINK 272  1303  1130  2.8 1 10
LINK 273  1903  1603  8.25 1 10
LINK 274  1603  2103  5.8 1 9
LINK 275  1703  2103  7.6 1 10
LINK 276  1403  11403 2.9 1 10
LINK 277  11403 1203 .04 1 11
LINK 278  1203  2103  1.5 1 9
LINK 279  2103  3103  .25 1 1
LINK 280  3103  1130  2 1 9
LINK 281  1130  2130  .25 1 1
$ NEW MODE LINE HAUL LINKS--THESE ARE DUMMY LINKS IN THE BASE CASE
LINK 282  1204  1200  .04 1 11
LINK 283  1304  1300  .04 1 11
LINK 284  1404  1400  .04 1 11
LINK 285  1504  1500  .04 1 11
LINK 286  1604  1600  .04 1 11
LINK 287  1704  1700  .04 1 11
LINK 288  1804  1800  .04 1 11
LINK 289  1904  1900  .04 1 11
LINK 290  11004 11000 .04 1 11
$ AUTO DRIVE, AUTO PASSENGER, AND TAXI LINE HAUL LINKS
```

```
LINK 291  1800  1300  5.82 3 3
LINK 292  2500  2300  5.72 3 4
LINK 293  1300  4100  .67 3 5
LINK 294  1900  1600  8.18 3 6
LINK 295  1600  2100  5.80 3 5
LINK 296  11000 1700 6.18 3 6
LINK 297  1700  1400  2.17 3 7
LINK 298  1400  2100  2.65 3 5
LINK 299  1200  2100  1 3 8
$ LINKS AT THE AIRPORT
LINK 300  2100  3100  1 2 12
LINK 301  3100  4100  1 2 13
LINK 302  4100  100   .5 1 1
LINK 303  4100  101   .04 1 11
LINK 304  4100  102   .04 1 11
LINK 305  4100  112   .04 1 11
LINK 306  4100  124   .25 1 1
LINK 307  3100  2130  .04 1 11
LINK 308  2130  103   .5 1 1
LINK 309  2130  105   .5 1 1
LINK 310  2130  113   .5 1 1
LINK 311  2130  115   .5 1 1
LINK 312  2130  123   .5 1 1
$ ADDITIONAL DUMMY LINKS CODED TO SATISFY DODOTRANS NETWORK CONNECTIVITY
LINK 313  125   200   1 1 1
LINK 314  125   300   1 1 1
LINK 315  125   400   1 1 1
LINK 316  125   500   1 1 1
LINK 317  125   600   1 1 1
LINK 318  125   700   1 1 1
```

```
LINK 319  125   800   1 1 1
LINK 320  125   900   1 1 1
LINK 321  125   1000  1 1 1
LINK 322  225   300   1 1 1
LINK 323  225   400   1 1 1
LINK 324  225   500   1 1 1
LINK 325  225   600   1 1 1
LINK 326  225   700   1 1 1
LINK 327  225   800   1 1 1
LINK 328  225   900   1 1 1
LINK 329  225   1000  1 1 1
LINK 330  325   200   1 1 1
LINK 331  325   400   1 1 1
LINK 332  325   500   1 1 1
LINK 333  325   600   1 1 1
LINK 334  325   700   1 1 1
LINK 335  325   800   1 1 1
LINK 336  325   900   1 1 1
LINK 337  325   1000  1 1 1
LINK 338  425   200   1 1 1
LINK 339  425   300   1 1 1
LINK 340  425   500   1 1 1
LINK 341  425   600   1 1 1
LINK 342  425   700   1 1 1
LINK 343  425   800   1 1 1
LINK 344  425   900   1 1 1
LINK 345  425   1000  1 1 1
LINK 346  525   200   1 1 1
LINK 347  525   300   1 1 1
LINK 348  525   400   1 1 1
```

```
LINK 349  525   500   1 1 1
LINK 350  525   700   1 1 1
LINK 351  525   800   1 1 1
LINK 352  525   900   1 1 1
LINK 353  525   1000  1 1 1
LINK 354  625   200   1 1 1
LINK 355  625   300   1 1 1
LINK 356  625   400   1 1 1
LINK 357  625   500   1 1 1
LINK 358  625   700   1 1 1
LINK 359  625   800   1 1 1
LINK 360  625   900   1 1 1
LINK 361  625   1000  1 1 1
LINK 362  725   200   1 1 1
LINK 363  725   300   1 1 1
LINK 364  725   400   1 1 1
LINK 365  725   500   1 1 1
LINK 366  725   600   1 1 1
LINK 367  725   800   1 1 1
LINK 368  725   900   1 1 1
LINK 369  725   1000  1 1 1
LINK 370  825   200   1 1 1
LINK 371  825   300   1 1 1
LINK 372  825   400   1 1 1
LINK 373  825   500   1 1 1
LINK 374  825   600   1 1 1
LINK 375  825   700   1 1 1
LINK 376  825   900   1 1 1
LINK 377  825   1000  1 1 1
LINK 378  925   200   4 1 1
```

```
LINK 379  925   300   4 1 1
LINK 380  925   400   4 1 1
LINK 381  925   500   1 1 1
LINK 382  925   600   1 1 1
LINK 383  925   700   1 1 1
LINK 384  925   800   1 1 1
LINK 385  925   1000  1 1 1
LINK 386  1025  200   1 1 1
LINK 387  1025  300   1 1 1
LINK 388  1025  400   1 1 1
LINK 389  1025  500   1 1 1
LINK 390  1025  600   1 1 1
LINK 391  1025  700   1 1 1
LINK 392  1025  800   1 1 1
LINK 393  1025  900   1 1 1

EDIT NETWORK

THERE ARE     0  SEQUENCE ERRORS



THERE ARE    214 NODES AND    394 LINKS IN NETWORK BASE

NETWORK BASE     HAS BEEN READ

STORE NETWORK

NETWORK BASE     HAS BEEN STORED ON DISK
```

Question 5.2

Consider a typical trip profile encountered by an air passenger travelling by subway from the CBD to the airport as shown in the table below:

ACTION	TIME IN MINUTES	DISTANCE IN MILES
1. walk to subway	5	1/4
2. wait for train	3	0
3. ride in train	3	3/4
4. transfer to another platform	2	0
5. wait for train	3	0
6. ride in train	5	1-1/4
7. transfer to bus platform	2	0
8. wait for bus	5	0
9. ride in bus to terminal	7	1
	35	3-1/4 Total

Construct a time-distance plot to show this trip profile diagrammatically. Put time on the horizontal axis and distance on the vertical axis. Note each action as a point on your plot and connect the points.

What is the significance of a line drawn from the origin to the point representing the final action?

What is the average speed of this trip?

What percentage of the trip is spent in a train?

What does this suggest about the effectiveness of an improvement of train speed from 15 mph to 30 mph as a means of reducing overall trip time?

Answer 5.2

Figure 5.2-2 displays a time-distance plot of a typical airport access trip by public transportation. The horizontal sections of this plot represent out-of-vehicle transfer times. A line drawn from the origin to the traveller's destination (point 9) gives the average trip speed (5.6 miles per hour). Only 23% of the total trip time is spent on board a train. Thus a doubling of train speed produces only an 11-1/2% decrease in total trip time.

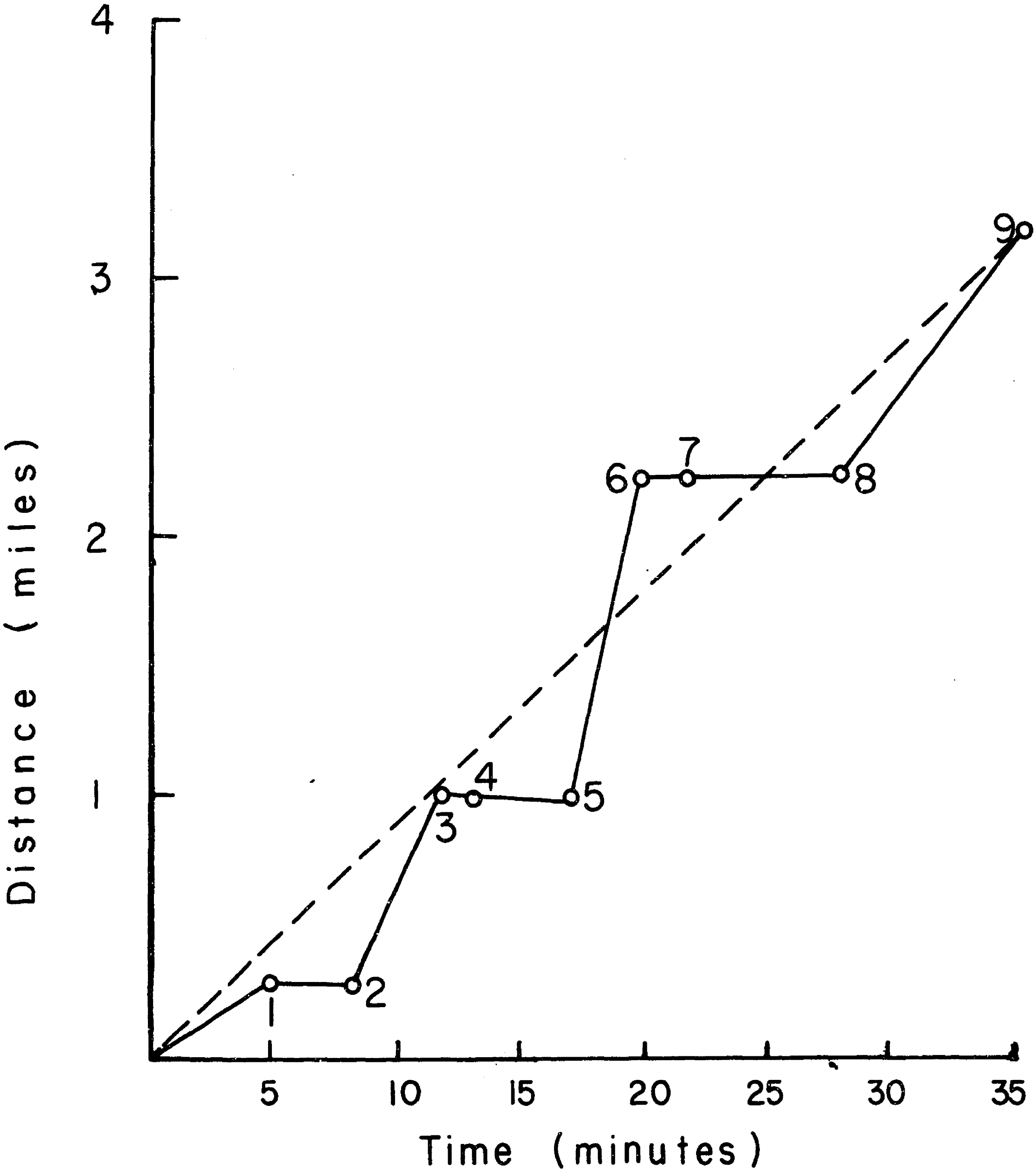

4
3
2
1
Distance (miles)
5
10
15
20
25
30
35
Time (minutes)
1
2
3
4
5
6
7
8
9

Figure 5.2-2

5.3 Volume-Delay Functions

As discussed in Section ....5.1, the present analysis makes use of horizontal supply functions. Essentially this assumption implies that the number of airport travellers has an imperceptibly small effect on the level of congestion on urban streets and arterials. To the extent that airport traffic accounts for a very small percentage of total urban traffic, this assumption is quite valid. On links near and within the Logan complex (e.g., the Callahan Tunnel and airport access roads), it is airport travellers that make up the predominant share of total traffic. On these links, the volume delay functions were adjusted to reflect not only the congestion caused by work commuter traffic, but by air passengers and Logan employees as well.

In all, thirteen volume delay functions were coded. These functions represent the various line haul links (V/D 3 - V/D 8), access links (V/D 2 and V/D 13), transfer links (V/D 11) and dummy links (V/D 1) described in Section 5.2.

```
READ VOL/DELAY 'BASE' FUNCTIONS 13 POINTS/FUNCTION 3
$ DUMMY LINKS
V/D 1 LO CAPACITY POINT 2 0 20 1000 20 2000 20
$ AUTO ACCESS AT LOCAL ORIGINS
V/D 2 LO CAPACITY POINT 2 0 6 1000 6 2000 6
$ AUTO LINE HAUL LINKS (V/D FUNCTIONS 3 THROUGH 8)
V/D 3 EX CAPACITY POINT 2 0 2 1000 2 1000 2 2000 2
V/D 4 EX CAPACITY POINT 2 0 2.4 1000 2.4 2000 2.4
V/D 5 EX CAPACITY POINT 2 0 4 1000 4 2000 4
V/D 6 EX CAPACITY POINT 2 0 1.715 1000 1.715 2000 1.715
V/D 7 EX CAPACITY POINT 2 0 3 1000 3 2000 3
V/D 8 EX CAPACITY POINT 2 0 6 1000 6 2000 6
$ LOW SPEED TRANSIT (I.E. STREET CAR SERVICE)
V/D 9 AR CAPACITY POINT 2 0 6 1000 6 2000 6
$ RAPID TRANSIT
V/D 10 AR CAPACITY POINT 2 0 4 1000 4 2000 4
$ DUMMY LINKS
V/D 11 LO CAPACITY POINT 2 0 1 1000 1 2000 1
$ CALLAHAN TUNNEL
V/D 12 LO CAPACITY POINT 2 0 10 1000 10 2000 10
$ AIRPORT ACCESS ROAD AT LOGAN INTERNATIONAL
V/D 13 LO CAPACITY POINT 2 0 7 1000 7 2000 7
EDIT VOLUME DELAY
```

5.4 Modal Service Data

The modal data set described the transportation technologies in terms of fares, frequencies, and system policy options. Frequency data was specified as a zero-one variable. Defined as such, the frequency data is used as a "switch" to control the assignment of interzonal volumes, rather than as an explicit explanatory variable in the demand model. For all inter-district pairs not serviced by a particular mode, a frequency of zero is assigned.* Conversely, a frequency of one was assigned between inter-district pairs served by each mode.

The data for interzonal fares is described for each mode below:

a. air passenger auto drive - The operating cost of the auto drive mode is assumed to be 10¢/mile in this case study. Estimates of auto operating expenses in urban areas range from 5¢/mile to 20¢/mile. Thus, the choice of the 10¢/mile figure represents a compromise between these two extremes. The auto fare also includes a garage parking charge and the 25¢ Callahan Tunnel toll.

The Port of New York Authority's study on New York's Domestic Air Passenger Market** reports that the most frequently observed air trip duration is two nights. By applying this figure to Logan, the $2.50/day parking fee results in an average parking charge of five

---

*During the prediction process, DODOTRANS automatically assigns zero volume to all modes whose frequency of service between a pair of districts is zero.

**Reference [32], page 10.

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---

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**Reference [32], page 10.

dollars. Thus the total air passenger auto drive fare is $5.25 plus 10¢/mile.

b. auto passenger - Auto passenger trips to Logan were charged twice the one-way cost of an auto trip to the airport. No attempt was made to assign a cost reflecting the value of time expended by the chauffeur of the auto.

c. taxi - Taxi trips to Logan were assigned a 25¢ tunnel toll in addition to the fare of 25¢ plus 35¢ per mile.

d. public transit - Transit fares were assigned to approximate the fare structure of the MBTA. These user costs represent the average of the fares on the combination of public transit modes used by airport travellers. The fares assigned were as follows:

FROM	FARE
D2	.30
D3	.40
D4	.35
D5	.45
D6	.50
D7	.35

e. employee auto drive - Employee auto dirve trips to Logan were assigned a fare of 10¢/mile plus the 25¢ tunnel toll. No parking charge was assessed since most employees have free parking privileges.

Very little information was available from which to derive the operator cost data for the five modes considered in this analysis. At present, we are primarily interested in actual operating costs rather than the foregone investments in fixed facilities. Later in the analysis, when we consider the implementation of new transportation technologies, the capital outlays for the construction of new facilities will be considered in more detail.

In the base case analysis, the data entered under the System Policy commands were input in units of dollars per passenger mile as shown below:

MODE	OPERATOR	COST IN DOLLARS PER PASSENGER MILE
auto driver	MASSPORT: Airport garage operator	0.00*
auto passenger	......	0.00
taxi	taxi operator	0.10**
subway/bus	MBTA	0.03

---

*Assuming negligible maintenance cost and neglecting sunk capital cost.

**Based on 10¢/mile operating cost.

```
READ MODAL SERVICE DATA SET 'BASE' DISTRICTS 30 MODES 6
DATA FOR MODE 1 'AUTODRIV'
FARE FROM  4 TO 1 5.75
FARE FROM  7 TO 1 5.75
FARE FROM 10 TO 1 5.90
FARE FROM 13 TO 1 6.25
FARE FROM 16 TO 1 5.20
FARE FROM 19 TO 1 6.10
FARE FROM 22 TO 1 6.85
FARE FROM 25 TO 1 7.05
FARE FROM 28 TO 1 6.75
FREQ FROM  4 TO 1 1
FREQ FROM  7 TO 1 1
FREQ FROM 10 TO 1 1
FREQ FROM 13 TO 1 1
FREQ FROM 16 TO 1 1
FREQ FROM 19 TO 1 1
FREQ FROM 22 TO 1 1
FREQ FROM 25 TO 1 1
```

```
FREQ FROM 28 TO 1 1
DATA FOR MODE 2 'AUTOPAX'
FARE FROM  4 TO 1 1.10
FARE FROM  7 TO 1 1.05
FARE FROM 10 TO 1 1.45
FARE FROM 13 TO 1 2.20
FARE FROM 16 TO 1 2.05
FARE FROM 19 TO 1 1.90
FARE FROM 22 TO 1 3.30
FARE FROM 25 TO 1 3.70
FARE FROM 28 TO 1 3.10
FREQ FROM  4 TO 1 1
FREQ FROM  7 TO 1 1
FREQ FROM 10 TO 1 1
FREQ FROM 13 TO 1 1
FREQ FROM 16 TO 1 1
FREQ FROM 19 TO 1 1
FREQ FROM 22 TO 1 1
FREQ FROM 25 TO 1 1
FREQ FROM 28 TO 1 1
DATA FOR MODE 3 'TAXI'
FARE FROM  4 TO 1 1.55
FARE FROM  5 TO 2 1.55
FARE FROM  7 TO 1 1.45
FARE FROM  8 TO 2 1.45
FARE FROM 10 TO 1 2.10
FARE FROM 11 TO 2 2.10
FARE FROM 13 TO 1 3.45
FARE FROM 14 TO 2 3.45
FARE FROM 16 TO 1 3.60
```

```
FARE FROM 17 TO 2 3.60
FARE FROM 19 TO 1 3.40
FARE FROM 20 TO 2 3.40
FARE FROM 22 TO 1 5.50
FARE FROM 23 TO 2 3.50
FARE FROM 25 TO 1 6.10
FARE FROM 26 TO 2 6.10
FARE FROM 28 TO 1 3.05
FARE FROM 29 TO 2 3.05
FREQ FROM  4 TO 1 1
FREQ FROM  5 TO 2  1
FREQ FROM  7 TO 1 1
FREQ FROM  8 TO 2 1
FREQ FROM 10 TO 1 1
FREQ FROM 11 TO 2 1
FREQ FROM 13 TO 1 1
FREQ FROM 14 TO 2 1
FREQ FROM 16 TO 1 1
FREQ FROM 17 TO 2 1
FREQ FROM 19 TO 1 1
FREQ FROM 20 TO 2 1
FREQ FROM 22 TO 1 1
FREQ FROM 23 TO 2 1
FREQ FROM 25 TO 1 1
FREQ FROM 26 TO 2 1
FREQ FROM 28 TO 1 1
FREQ FROM 29 TO 2 1
DATA FOR MODE 4 'SUB/BUS'
FARE FROM  4 TO 1 .30
FARE FROM  6 TO 3 .30
```

```
FARE FROM  7 TO 1 .40
FARE FROM  9 TO 3 .40
FARE FROM 10 TO 1 .35
FARE FROM 12 TO 3 .35
FARE FROM 13 TO 1 .45
FARE FROM 15 TO 3 .45
FARE FROM 16 TO 1 .50
FARE FROM 18 TO 3 .50
FARE FROM 19 TO 1 .30
FARE FROM 21 TO 3 .30
FREQ FROM  4 TO 1 1
FREQ FROM  6 TO 3 1
FREQ FROM  7 TO 1 1
FREQ FROM  9 TO 3 1
FREQ FROM 10 TO 1 1
FREQ FROM 13 TO 3 1
FREQ FROM 13 TO 1 1
FREQ FROM 15 TO 3 1
FREQ FROM 16 TO 1 1
FREQ FROM 18 TO 3 1
FREQ FROM 19 TO 1 1
FREQ FROM 21 TO 3 1
DATA FOR MODE 5 'EMPADRIV'
FARE FROM  6 TO 3 .55
FARE FROM  9 TO 3 .50
FARE FROM 12 TO 3 .70
FARE FROM 15 TO 3 1.10
FARE FROM 18 TO 3 1.00
FARE FROM 21 TO 3 .95
FARE FROM 24 TO 3 1.05
```

```
FARE FROM 27 TO 3 1.65
FARE FROM 30 TO 3 1.55
FREQ FROM  6 TO 3 1
FREQ FROM  9 TO 3 1
FREQ FROM 12 TO 3 1
FREQ FROM 15 TO 3 1
FREQ FROM 18 TO 3 1
FREQ FROM 21 TO 3 1
FREQ FROM 24 TO 3 1
FREQ FROM 27 TO 3 1
FREQ FROM 30 TO 3 1
DATA FOR MODE 6 'SUBURBAN'
FARE FROM  4 TO 1 100
FARE FROM  5 TO 2 100
FARE FROM  6 TO 3 100
FARE FROM  7 TO 1 100
FARE FROM  8 TO 2 100
FARE FROM  9 TO 3 100
FARE FROM 10 TO 1 100
FARE FROM 11 TO 2 100
FARE FROM 12 TO 3 100
FARE FROM 13 TO 1 100
FARE FROM 14 TO 2 100
FARE FROM 15 TO 3 100
FARE FROM 16 TO 1 100
FARE FROM 17 TO 2 100
FARE FROM 18 TO 3 100
FARE FROM 19 TO 1 100
FARE FROM 20 TO 2 100
FARE FROM 21 TO 3 100
```

```
FARE FROM 22 TO 1 100
FARE FROM 23 TO 2 100
FARE FROM 24 TO 3 100
FARE FROM 25 TO 1 100
FARE FROM 26 TO 2 100
FARE FROM 27 TO 3 100
FARE FROM 28 TO 1 100
FARE FROM 29 TO 2 100
FARE FROM 30 TO 3 100
FARE FROM  4 TO 1 0
EDIT MODAL DATA SET
SYSTEM POLICIES MODE 'AUTODRIV' 0 0 0.10 0
SYSTEM POLICIES MODE 'AUTOPAX' 0 0 0.10 0
SYSTEM POLICIES MODE 'TAXI' 0 0 0.10 0
SYSTEM POLICIES MODE 'SUB/BUS' 0 0 0.03 0
SYSTEM POLICIES MODE 'EMPADRIV' 0 0 0.10 0
SYSTEM POLICIES MODE 'SUBURBAN' 0 0 0 0
STORE MODAL 'BASE'
```

5.5 Activity System Data

The activity system commands characterize the districts in the network by population, income, and holding capacity. The first two descriptions - population and income - are used as explanatory variables in the DODOTRANS demand models. Holding capacity - the measure of potential growth in a district - is used for predicting regional growth patterns. Since predictions of district growth are not considered in this analysis, an arbitrary value of holding capacities is specified for each of the ten districts.

As discussed in the following section, a special modal share formulation of the McLynn demand model is used for our case study. In this formulation, the total trips generated from a district are distributed among the various modes according to the relative impedances of each mode. Accordingly, the activity system data for the analysis is of a rather different form than that described in Workbook 14 [3]. The population variable characterizes the total number of airport travellers originating in each district. More specifically, since we have divided each analysis district into three DODOTRANS districts, the activity data describes the total number of:

a. resident air passengers

b. non-resident passengers

c. employees

originating from each district in the base case morning peak period. This data was derived from the Wilbur Smith home-interview and taxi survey described earlier.

The income variable of the activity system data is not used in the base case analysis. Later, in the DODOTRANS projection simulation of 1975, the income variable will be used to describe the relative growth of air passengers and employees between the districts in the analysis area.

An annotated listing of the activity system data commands is shown on the following pages. There are thirty DODOTRANS districts in the case study. Districts 1, 2, and 3 refer to the three traveller groups in analysis district 1 (see Section 2.0), districts 4, 5, and 6 describe analysis district 2, and so on.

```
READ ACTIVITY SYSTEM DATA SET 'BASE' DISTRICTS 30
DISTRICT  1    1 1 1 'AP1'
DISTRICT  2    1 1 1 'AP2'
DISTRICT  3    1 1 1 'AP3'
DISTRICT  4   97 1 1 'D21'
DISTRICT  5  264 1 1 'D22'
DISTRICT  6   59 1 1 'D23'
DISTRICT  7  102 1 1 'D31'
DISTRICT  8  110 1 1 'D32'
DISTRICT  9  217 1 1 'D33'
DISTRICT 10   49 1 1 'D41'
DISTRICT 11  105 1 1 'D42'
DISTRICT 12   30 1 1 'D43'
DISTRICT 13  131 1 1 'D51'
DISTRICT 14  111 1 1 'D52'
DISTRICT 15  146 1 1 'D53'
DISTRICT 16  141 1 1 'D61'
DISTRICT 17  135 1 1 'D62'
DISTRICT 18   23 1 1 'D63'
DISTRICT 19  121 1 1 'D71'
DISTRICT 20  131 1 1 'D72'
DISTRICT 21   99 1 1 'D73'
DISTRICT 22  130 1 1 'D81'
DISTRICT 23   23 1 1 'D82'
DISTRICT 24  108 1 1 'D83'
DISTRICT 25  216 1 1 'D91'
DISTRICT 26   37 1 1 'D92'
DISTRICT 27   60 1 1 'D93'
DISTRICT 28   74 1 1 'D101'
DISTRICT 29    3 1 1 'D102'
DISTRICT 30   52 1 1 'D103'
EDIT ACTIVITY DATA SET
```

5.6 Demand Model and Parameters

Several formulations of alternative demand models were tested before a modified form of the McLynn model was selected for the present analysis. Demand prediction of airport access trips presents some thorny problems. For one thing, we are dealing with a rather limited number of total trips. The use of a direct demand model (such as the Kraft-Sarc model used in the Southeast Corridor Case Study) is best suited to predicting aggregate travel behavior of a large number of travellers where individual anomalies in trip decisions have little effect on the total flow. The smaller the flow pattern, the more we can expect the predictions of direct demand models to be erratic.

Another particular problem in choosing an acceptable demand model for the prediction of airport access trips results from the fact that the flow pattern includes a wide range of trip purposes. In the Southeast Corridor Case Study [3], the morning peak movements consisted primarily of urban work commuter trips. In that analysis, it was necessary to distinguish between low and high income travellers, since these two traveller groups exhibited significantly different travel behavior. For airport access analysis, the demand model that predicts employee trips must also be able to predict the flow patterns of resident and non-resident air passengers as well. It is unlikely that the elasticity of air passenger demand with respect to time or cost is the same as the employee demand elasticities.

Of course, one could stratify the demand equations according to trip purpose and traveller characteristics. It may be hypothesized that trip behavior varies according to the following traveller classifications:

air passengers	airport employees	airport visitor
- resident	- high income	- passenger-related
- non-resident	- low income	- recreational visit
- business trip		
- personal trip		
- high income		
- low income		

However, the limited number of observations in the data set limits our ability to calibrate large numbers of demand equations. Moreover, in DODOTRANS each stratification must be coded by adding districts to the analysis. Thus, a large number of traveller group stratifications leads to a large and unwieldy network representation. As discussed in Section 3.0, this case study stratifies airport travellers into three groups - resident air passengers, non-resident air passengers, and airport employees.

A third problem in the choice of a suitable demand model for predicting airport access trips arises from the nature of air passenger trips. It is reasonable to assume that air passengers on short-haul flights will be more sensitive to the quality of access than long-haul air trip passengers.* Improvements in a particular access mode, will clearly affect but will not greatly influence the basic decision of whether to fly at all (except on short flights). Thus, our demand model should reflect this behavior.

---

*This premise is discussed in detail in Appendix 2 of the case study.

Lastly, since our analysis considers the introduction of a new mode into the access network, we had to choose a demand model that would realistically predict the resulting changes in the flow pattern.

In light of the problems discussed above, it was found that the Kraft-Sarc demand model was not suitable for the prediction of airport access trips. Rather, a modified form of the McLynn demand model* was calibrated and used here. The form of the McLynn model is shown on the following page.

---

*The McLynn model itself is a special form of the generalized conductivity demand model. It was developed by J. M. McLynn in 1969 as part of the Northeast Corridor Project. See Reference [22], page 117.

$$V_{ijk} = \frac{a_o P_i^{a_1} P_j^{a_2} Y_i^{a_3} Y_j^{a_4} n_k t_{ijk}^{b_1^k} c_{ijk}^{b_2^k} \left(1-e^{-cf_{ijk}}\right)^{b_3^k}}{\left[\sum_m n_m t_{ijm}^{b_1^m} c_{ijm}^{b_2^m} \left(1-e^{-cf_{ijm}}\right)^{b_3^m}\right]^{1-d}}$$

where:

i = origin zone

j = destination zone

k,m = mode k, mode m

V_{ijk} = volume on mode k between zones i and j

P = population

Y = income

or some other relevant description of the activity system (see section 5.5)

t_{ijk} = travel time on mode k between zones i and j

c_{ijk} = fare on mode k between zones i and j

f_{ijk} = frequency of mode k between zones i and j

c,d = constants

e = the natural number e

b_1^k = the exponent of travel time of mode k

b_2^k = the exponent of fare of mode k

b_3^k = the exponent of frequency of mode k

n_k = coefficient for mode k

The basic assumption of this model is that the demand for transportation on a particular mode is a function of the trip generating potential at an origin zone, the trip attracting potential at a destination zone, and the conductivity (expressed as the product of travel time, fare, and the frequency function, each raised to a mode-specific exponent) of the particular mode relative to the sum of the conductivities of all modes. The separate sets of demand parameters (one for each mode) represents the hypothesis that travellers employ different values in evaluating the level of service offered by each mode.

Unlike the Kraft-Sarc model, the exponents of time, cost and frequency in the McLynn model do not have a one-to-one correspondance with the elasticities of the LOS variables. To see this, we derive the direct time elasticity below:

Let $K_{ij} = a_o P_i^{a_1} P_j^{a_2} Y_i^{a_3} Y_j^{a_4}$

and $C_{ijk} = n_k t_{ijk}^{b_1^k} C_{ijk}^{b_2^k} (1-e^{-cf_{ijk}})^{b_3^k}$ conductivity of mode k.

Then $V_{ijk} = \dfrac{K_{ij} C_{ijk}}{\left[\sum_m C_{ijm}\right]^{1-d}}$

The direct time elasticity of mode k, E_{k,t_k} is defined as:

$$E_{k,t_k} = \frac{\partial V_{ijk}}{\partial t_{ijk}} \cdot \frac{t_{ijk}}{V_{ijk}}$$

$$= \frac{\partial}{\partial t_{ijk}} \left[K_{ij} \left[\frac{C_{ijk}}{\sum_m C_{ijm}} \right]^{1-d} \right] \cdot \frac{t_{ijk}}{V_{ijk}}$$

Evaluating the partial derivative, we get

$$E_{k,t_k} = b_1^k(1-[1-d]\Omega_k)$$

where Ω_k is defined as the ratio of the conductivity of mode k to the sum of the conductivities of all modes. Before explaining this result, we point out the simplifications we have employed with regard to the use of the McLynn model. First, we have assumed that the parameter, d, is equal to zero. Secondly, we have directly input the total trips (i.e., by all modes) from district i, V_i, as the population for each district in the analysis area.* Finally, since we are considering only one destination (the airport), we can drop the subscript j from the demand equation.

With these simplifications, the McLynn model reduces to:

$$V_{ik} = \frac{V_i C_{ik}}{\sum_m C_{im}}$$

and the direct elasticity reduces to:

$$E_k, t_k = b_1^k \, (1-\Omega_k)$$

where Ω_k now can be seen to represent the modal share (i.e., of the total

---

*Furthermore, the exponent of population at the origin zone, a_1, is assumed to be 1 in this analysis.

volume V_i)of mode k. Thus, it is evident that the structure of the McLynn model implies that the direct elasticities are a function of the percentage share of the mode in question. The greater the share, Ω_k, the less sensitive will be the demand for a mode k with respect to its own level of service. Conversely, as Ω_k approaches zero, the direct elasticity approaches its negative limiting value of b_1^k. It will be left as an exercise to the reader to derive the expression for cross elasticities consistent with the structure of the McLynn model.

The determination of the set of demand parameters used in this case study was heavily based on judgement. Calibration of the model required a trial-and-error process in order to bring the predicted flow pattern in close agreement with the known base-case volumes and trip times. The results are shown as a listing of the parameter set for the base case DODOTRANS simulation and are given on page 121.

Question 5.6.1

As described in this section, the simplified form of the McLynn demand model can be expressed as:

$$V_{ik} = \frac{V_i C_{ik}}{\sum_m C_{im}}$$

Will the total number of trips (by all modes) from district i change if the level of service offered by mode k is improved? if the level of service offered by all modes is improved? If the travel time on mode k decreases by 10%, will the volume on mode k change? If so, by what percentage?

Answer 5.6.1

The total number of trips by all modes from district i is defined as

$$V_i = \sum_{\text{all } k} V_{ik} = \sum_{\text{all } k} \frac{V_i C_{ik}}{{}_m C_{im}} = V_i$$

Thus, the total trips from any district is independent of changes in the level of service of one or all modes. If the travel time on mode k is decreased by 10%, the volume on mode k will increase by $(10E_k, t_k)$ percent.

Question 5.6.2

Derive the cross-elasticity of demand for mode k with respect to a change in the travel time of mode 1. Discuss your result. What does it imply about the change of volume on all modes k (k ≠ 1) due to a change in the travel time on mode 1?

Answer 5.6.2

Defining $E_{k,t_1} = \frac{\partial V_k}{\partial t_1} \cdot \frac{t_1}{V_k}$, we get

$$E_{k,t_1} = -b_1^1 \Omega_1$$

From the above, it can be seen that

1. The cross elasticities of demand of mode k with respect to travel time (or cost) of mode 1 is the same for all modes k ≠ 1
2. The cross elasticities of all modes k ≠ 1 increase as the market share of mode 1 increases.

5.7 Consequences

The following pages give the DODOTRANS printout of the action described in Sections 5.2, 5.3, 5.4, and 5.5, with the parameter set as described in Section 5.6. These consequences represent the flow pattern during a typical morning peak hour on a 1963 weekday.

```
DODOTRANS

LOAD MODAL 'BASE'

DEMAND MODEL PARAMETERS 'BASE' FOR CONDUCTIVITY MODEL

GENERAL PARAMETERS 1000 1 0 0 0 0 0 0 0 1000

MODE 1 PARAMETERS 50 -1.5 -.5 1

MODE 2 PARAMETERS 20 -1.5 -.5 1

MODE 3 PARAMETERS 10 -1.5 -.5 1

MODE 4 PARAMETERS 1.8 -1.0 -.33 1

MODE 5 PARAMETERS 10 -1.0 -.5 1

MODE 6 PARAMETERS 6 -1.5 -.5 1

INCREMENT 100 PERCENT

END

 ******  END OF CURRENT DEFINITION OF PARAMETER BASE


ACTION 'BASE'

NETWORK 'BASE'

DISTRICT DATA 'BASE'

MODE DATA 'BASE'

VOLUME/DELAY 'BASE'

STOP DEFINITION OF ACTION

 ******  END OF CURRENT DEFINITION OF ACTION BASE


GENERAL CONDUCTIVITY DEMAND MODEL CONSEQUENCES 'BASE' -
 OF ACTION 'BASE' PARAMETER 'BASE'

STOP

 ******  END OF DEFINITION OF CONSEQUENCE BASE


                              THE NETWORK IS COMPLETELY ASSIGNED AFTER  5220 ITERATIONS

                                   TIME USED SINCE START OF RUN IS   2.45 MINUTES


                         DATA HAS BEEN STORED ON DISK IN DATA FILE BASE
```

```
                                  COST SUMMARIES FOR FLOW PATTERN BASE

                                              NETWORK BASE


                                                     DAILY USER DATA BY MODE AND ORIGIN

                          TOTAL        USER FARES        USER TRAVEL TIME       USER WAIT TIME       WEIGHTED COSTS
                          TRIPS
 MODE       ORIGIN                 TOTAL      AVERAGE      TOTAL   AVERAGE     TOTAL    AVERAGE       TOTAL       AVERAGE
           DISTRICT (PASS/DAY)     ($)       ($/TRIP)    (HOURS) (MIN/TRIP)  (HOURS)  (MIN/TRIP)      ($)        ($/TRIP)


AUTODRIV AP1          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV AP2          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV AP3          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D21         26   1.49500E 02      5.75    1.84253E 01     43.     0.0              0.0    1.49500E 02        5.75
AUTODRIV D22          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D23          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D31         26   1.49500E 02      5.75    1.56520E 01     36.     0.0              0.0    1.49500E 02        5.75
AUTODRIV D32          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D33          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D41         15   8.85000E 01      5.90    1.24900E 01     50.     0.0              0.0    8.85000E 01        5.90
AUTODRIV D42          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D43          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D51         42   2.62500E 02      6.25    3.90880E 01     56.     0.0              0.0    2.62500E 02        6.25
AUTODRIV D52          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D53          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D61         48   2.97600E 02      6.20    4.77760E 01     60.     0.0              0.0    2.97600E 02        6.20
AUTODRIV D62          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D63          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D71         39   2.37900E 02      6.10    3.48140E 01     54.     0.0              0.0    2.37900E 02        6.10
AUTODRIV D72          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D73          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D81         64   4.38400E 02      6.85    7.19359E 01     67.     0.0              0.0    4.38400E 02        6.85
AUTODRIV D82          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D83          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D91        111   7.82550E 02      7.05    1.41710E 02     77.     0.0              0.0    7.82550E 02        7.05
AUTODRIV D92          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D93          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D101        36   2.43000E 02      6.75    4.20720E 01     70.     0.0              0.0    2.43000E 02        6.75
AUTODRIV D102         0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTODRIV D103         0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0


AUTOPAX  AP1          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  AP2          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  AP3          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D21         36   3.96000E 01      1.10    1.92960E 01     32.     0.0              0.0    3.96000E 01        1.10
AUTOPAX  D22          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D23          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D31         41   4.30500E 01      1.05    1.76027E 01     26.     0.0              0.0    4.30500E 01        1.05
AUTOPAX  D32          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D33          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D41         17   2.46500E 01      1.45    1.12200E 01     40.     0.0              0.0    2.46500E 01        1.45
AUTOPAX  D42          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D43          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
AUTOPAX  D51         38   8.36000E 01      2.20    2.88040E 01     45.     0.0              0.0    8.36000E 01        2.20
AUTOPAX  D52          0   0.0              0.0     0.0              0.0    0.0              0.0    0.0                0.0
```

```
AUTOPAX  D53      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D61     45   9.22500E 01   2.05  3.70200E 01   49.   0.0          0.0   9.22500E 01   2.05
AUTOPAX  D62      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D63      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D71     39   7.41000E 01   1.90  2.80800E 01   43.   0.0          0.0   7.41000E 01   1.90
AUTOPAX  D72      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D73      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D81     47   1.55100E 02   3.30  4.47126E 01   57.   0.0          0.0   1.55100E 02   3.30
AUTOPAX  D82      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D83      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D91     76   2.81200E 02   3.70  8.39040E 01   66.   0.0          0.0   2.81200E 02   3.70
AUTOPAX  D92      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D93      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D101    27   8.37000E 01   3.10  2.68920E 01   60.   0.0          0.0   8.37000E 01   3.10
AUTOPAX  D102     0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
AUTOPAX  D103     0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0


TAXI     AP1      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     AP2      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     AP3      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D21     15   2.32500E 01   1.55  8.03999E 00   32.   0.0          0.0   2.32500E 01   1.55
TAXI     D22    264   4.09200E 02   1.55  1.41504E 02   32.   0.0          0.0   4.09200E 02   1.55
TAXI     D23      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D31     17   2.46500E 01   1.45  7.29866E 00   26.   0.0          0.0   2.46500E 01   1.45
TAXI     D32    110   1.59500E 02   1.45  4.72267E 01   26.   0.0          0.0   1.59500E 02   1.45
TAXI     D33      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D41      7   1.47000E 01   2.10  4.62000E 00   40.   0.0          0.0   1.47000E 01   2.10
TAXI     D42    105   2.20500E 02   2.10  6.92999E 01   40.   0.0          0.0   2.20500E 02   2.10
TAXI     D43      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D51     15   5.17500E 01   3.45  1.13700E 01   45.   0.0          0.0   5.17500E 01   3.45
TAXI     D52    111   3.82950E 02   3.45  8.41380E 01   45.   0.0          0.0   3.82950E 02   3.45
TAXI     D53      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D61     17   6.12000F 01   3.60  1.39853E 01   49.   0.0          0.0   6.12000E 01   3.60
TAXI     D62    135   4.86000E 02   3.60  1.11060E 02   49.   0.0          0.0   4.86000E 02   3.60
TAXI     D63      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D71     15   5.10000E 01   3.40  1.08000E 01   43.   0.0          0.0   5.10000E 01   3.40
TAXI     D72    131   4.45400E 02   3.40  9.43200E 01   43.   0.0          0.0   4.45400E 02   3.40
TAXI     D73      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D81     18   9.90000E 01   5.50  1.71240E 01   57.   0.0          0.0   9.90000E 01   5.50
TAXI     D82     23   1.26500E 02   5.50  2.18806E 01   57.   0.0          0.0   1.26500E 02   5.50
TAXI     D83      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D91     30   1.83000E 02   6.10  3.31200E 01   66.   0.0          0.0   1.83000E 02   6.10
TAXI     D92     37   2.25700E 02   6.10  4.08480E 01   66.   0.0          0.0   2.25700E 02   6.10
TAXI     D93      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
TAXI     D101    11   5.55500E 01   5.05  1.09560E 01   60.   0.0          0.0   5.55500E 01   5.05
TAXI     D102     3   1.51500E 01   5.05  2.98800E 00   60.   0.0          0.0   1.51500E 01   5.05
TAXI     D103     0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0


SUB/BUS  AP1      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  AP2      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  AP3      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  D21     20   6.00000E 00   0.30  1.53867E 01   46.   0.0          0.0   6.00000E 00   0.30
SUB/BUS  D22      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  D23      8   2.40000E 00   0.30  6.15466E 00   46.   0.0          0.0   2.40000E 00   0.30
SUB/BUS  D31     17   6.80000E 00   0.40  1.08800E 01   38.   0.0          0.0   6.80000E 00   0.40
SUB/BUS  D32      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  D33     26   1.04000E 01   0.40  1.66400E 01   38.   0.0          0.0   1.04000E 01   0.40
SUB/BUS  D41     10   3.50000E 00   0.35  1.03400E 01   62.   0.0          0.0   3.50000E 00   0.35
SUB/BUS  D42      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  D43      4   1.40000E 00   0.35  4.13600E 00   62.   0.0          0.0   1.40000E 00   0.35
SUB/BUS  D51     36   1.62000E 01   0.45  3.45120E 01   58.   0.0          0.0   1.62000E 01   0.45
SUB/BUS  D52      0   0.0           0.0   0.0           0.0   0.0          0.0   0.0           0.0
SUB/BUS  D53     26   1.17000E 01   0.45  2.49253E 01   58.   0.0          0.0   1.17000E 01   0.45
SUB/BUS  D61     31   1.55000E 01   0.50  4.24493E 01   82.   0.0          0.0   1.55000E 01   0.50
```

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SUB/BUS  D62        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D63        3  1.50000E 00   0.50  4.10800E 00   82.  0.0      0.0  1.50000E 00   0.50
SUB/BUS  D71       28  8.40000E 00   0.30  3.40480E 01   73.  0.0      0.0  8.40000E 00   0.30
SUB/BUS  D72        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D73       14  4.20000E 00   0.30  1.70240E 01   73.  0.0      0.0  4.20000E 00   0.30
SUB/BUS  D81        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D82        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D83        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D91        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D92        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D93        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D101       0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D102       0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUB/BUS  D103       0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0

EMPADRIV AP1        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV AP2        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV AP3        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D21        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D22        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D23       51  2.80500E 01   0.55  3.13820E 01   37.  0.0      0.0  2.80500E 01   0.55
EMPADRIV D31        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D32        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D33      191  9.55000E 01   0.50  9.71553E 01   31.  0.0      0.0  9.55000E 01   0.50
EMPADRIV D41        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D42        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D43       26  1.82000E 01   0.70  1.92227E 01   44.  0.0      0.0  1.82000E 01   0.70
EMPADRIV D51        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D52        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D53      120  1.32000E 02   1.10  1.00480E 02   50.  0.0      0.0  1.32000E 02   1.10
EMPADRIV D61        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D62        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D63       20  2.00000E 01   1.00  1.80400E 01   54.  0.0      0.0  2.00000E 01   1.00
EMPADRIV D71        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D72        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D73       85  8.07500E 01   0.95  6.79433E 01   48.  0.0      0.0  8.07500E 01   0.95
EMPADRIV D81        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D82        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D83      108  1.78200E 02   1.65  1.11312E 02   62.  0.0      0.0  1.78200E 02   1.65
EMPADRIV D91        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D92        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D93       60  1.11000E 02   1.85  7.10000E 01   71.  0.0      0.0  1.11000E 02   1.85
EMPADRIV D101       0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D102       0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
EMPADRIV D103      52  8.06000E 01   1.55  5.59173E 01   65.  0.0      0.0  8.06000E 01   1.55

SUBURBAN AP1        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN AP2        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN AP3        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D21        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D22        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D23        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D31        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D32        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D33        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D41        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D42        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D43        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D51        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D52        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D53        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D61        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D62        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
SUBURBAN D63        0  0.0           0.0   0.0           0.0  0.0      0.0  0.0           0.0
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SUBURBAN D71	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D72	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D73	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D81	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D82	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D83	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D91	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D92	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D93	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D101	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D102	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D103	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
                                          DAILY USER DATA BY MODE

               TOTAL       USER FARES           USER TRAVEL TIME        USER WAIT TIME          WEIGHTED COSTS
               TRIPS
  M O D E                TOTAL        AVERAGE      TOTAL     AVERAGE      TOTAL     AVERAGE       TOTAL        AVERAGE
             (PASS/DAY)   ($)        ($/TRIP)    (HOURS)   (MIN/TRIP)   (HOURS)   (MIN/TRIP)       ($)        ($/TRIP)

  AUTODRIV       407   2.64945E 03     6.51    4.23963E 02    63.     0.0                0.0     2.64945E 03    6.51
  AUTOPAX        366   8.77249E 02     2.40    2.97531E 02    49.     0.0                0.0     8.77249E 02    2.40
  TAXI          1064   3.03500E 03     2.85    7.30579E 02    41.     0.0                0.0     3.03560E 03    2.85
  SUB/BUS        223   8.80000E 01     0.39    2.20604E 02    59.     0.0                0.0     8.80000E 01    0.39
  FMPADRIV       713   7.44299E 02     1.04    5.72452E 02    48.     0.0                0.0     7.44299E 02    1.04
  SUBURBAN         0   0.0             0.0     0.0             0.0    0.0                0.0     0.0            0.0

T O T A L S     2773   7.39399E 03     2.67  . 2.24513E 03    49.     0.0                0.0     7.39399E 03    2.67


                                      YEARLY COSTS AND REVENUES BY MODE

M O D E     TOTAL       USER        TOTAL USER     OPERATOR'S    GOVERNMENT  OPERATOR'S PROFIT  GOVT. REVENUE
            TRIPS       FARES         COSTS          PROFIT       REVENUE      PER PASSENGER    PER PASSENGER

AUTODRIV    148555   9.67049E 05   9.67049E 05   7.72843E 05   0.0               5.20              0.0
AUTOPAX     133590   3.20196E 05   3.20196E 05   1.69651E 05   0.0               1.27              0.0
TAXI        388360   1.10777E 06   1.10777E 06   7.96040E 05   0.0               2.05              0.0
SUB/BUS      81395   3.21200E 04   3.21200E 04   9.09741E 03   0.0               0.11              0.0
FMPADRIV    260245   2.71669E 05   2.71669E 05   2.71669E 05   0.0               1.04              0.0
SUBURBAN         0   0.0           0.0           0.0           0.0               0.0               0.0

TOTALS     1012145   2.69880E 06   2.69880E 06   2.01930E 06   0.0               2.00              0.0
```

5.8 Analysis of the Base Case

The base case analysis was designed to simulate airport access movements to Logan International Airport in 1963. It serves to indicate the extent of the present "problem." The purpose of this section is to explore the validity of the DODOTRANS simulation.

Question 5.8.1

Several simplifying assumptions were incorporated into the base case analysis. Itemize the most crucial assumptions and discuss their significance in the base case simulation.

Answer 5.8.1

Although the analysis was calibrated to reproduce existing, observed travel patterns, the ultimate purpose of the simulation is to serve as a planning tool with which to test changes in the airport access system. The major assumptions in the analysis have been discussed in previous sections.

a. As described in Section 2.0, we have adopted a very aggregate network representation. Each district in the analysis is composed of several towns and communities, for which average access characteristics are modelled.

b. The implicit approach neglects explicit consideration of non-airport travel in the analysis area. Consequently, the level of congestion has to be estimated exogenously in the analysis. The use of horizontal supply functions represents the crucial assumption that airport travellers contribute insignificantly to the congestion on urban streets and arterials.

c. The classification of airport trips into three traveller groups neglects other, possibly significant stratifications.

d. Finally, the modified McLynn demand model assumes that total airport trip-making is independent of the quality of airport access.

Despite the limiting assumptions described above, it is felt that the base case analysis serves to illustrate the basic nature of the airport access problem. The necessity for making these assumptions was dictated by the budget constraint on computer expenditures. It is of particular importance here to emphasize that the base case analysis attempts to simulate a very large, complex urban system. A more detailed analysis would require data that is unavailable for the Boston area, and an extremely large DODOTRANS network which would have a computer cost far in excess of the class budget.

6.0 Projection

A projection represents an attempt to predict the consequences of a null (i.e., do-nothing) action in some future year. In the context of our case study, the projection simulation describes the changes in the base case flow pattern resulting from changing activity system characteristics. The usefulness of a projection is that it forms the basis with which to compare various policy and technology alternatives.

We have all heard statements like: "provision of a balanced transportation system requires that we improve mass transit," or "there is a clear and obvious need to expand our highway facilities to alleviate the strangle-hold of congestion." Such statements are quite natural reactions to the human desire to do something in the face of the steadily deteriorating condition of urban transportation.

The role of the transportation planner, however, is to test empirically the relative benefits of a wide range of alternatives. It might well be the case that the status quo - i.e., the null alternative - is the most politically, socially, and economically justifiable alternative of all the actions considered. Therefore, the "null" or "do-nothing" action must always be explicitly analyzed.

6.1 Airport Access in 1975 - A Projection Framework

In Section 5.7, we presented the flow pattern of airport access trips for a typical 1963 weekday morning peak. Projections by the FAA and the Massachusetts Port Authority (MASSPORT) indicate that air trip generation and Logan employment will show marked increases through the year 1975. The impacts of the "jet-age" in the years immediately following 1963 caused a tremendous growth of activity at Logan. For example, in 1966 alone, air passenger movements* increased by over 1.5 million (25%), employment increased by 1300 (19%), and total wages paid at Logan increased by $25 million (74%). While the growth in air travel and Logan employment is not expected to be as rapid in the years 1970-1975 as it was over the 1963-1970 period, there are indications that steady growth will still persist. The increased activity at Logan and the growth in the study area population and income over the period 1963-1975 are shown in Table 6.1.1 below.

	1963	1975	percent increase
emplaning passengers	2,157,000	6,335,000	194%
Logan employment	3,590	11,000	206%
study area population	2,525,002	2,537,700	.5%
study area employment	956,932	1,031,800	8%

Table 6.1.1**

---

*Air passenger movements equal the sum of arriving and departing air passengers.

**Source: references [16], [26], and [43].

In order to stimulate the flow pattern of airport access trips to Logan in 1975, it is necessary to determine the relative growth of airport trip generation from each of the districts in the analysis area. It is reasonable to expect that those districts which experience a relatively large increase in population and employment over the twelve year planning period will also experience a higher than average increase in airport trip generation. Similarly, districts characterized by a decline in population and economic activity will experience a change in the number of airport trips lower than the area-wide average.

This hypothesis was modelled by defining an indicator for each of the three traveller groups which characterizes the relative growth of each district. For example, for resident air passenger trips, let G_{ri} be a measure of the relative growth in resident air passenger trips in district i:

$$G_{ri} = \frac{K_r \dfrac{P_{n_i} E_{n_i}}{P_{o_i} E_{o_i}}}{\sum\limits_j \dfrac{P_{n_j} E_{n_j}}{P_{o_j} E_{o_j}}}$$

where: K_r = scaling constant for resident air passenger trips

P_{n_i} = 1975 population of district i

E_{n_i} = 1975 employment of district i

P_{o_i} = 1963 population of district i

E_{o_i} = 1963 employment of district i

Thus we hypothesize that the number of resident air passenger trips in a district will increase in proportion to the growth of its population and income relative to the area-wide growth in population and income.

The scaling constant K_r is chosen to constrain the sum of the growths of resident air passengers in each district to equal the area-wide growth. The constraint takes the form:

$$\sum_i G_{ri} \cdot V_{ri} = G_r V_r$$

$$K_r \sum_i \frac{\dfrac{P_{n_i} E_{n_i}}{P_{o_i} E_{o_i}}}{\sum_j \dfrac{P_{n_j} E_{n_j}}{P_{o_j} E_{o_j}}} \cdot V_{ri} \equiv G_r V_r$$

Thus,

$$K_r \sum_i V_{ri} = G_r V_r$$

or

$$K_r = \frac{G_r V_r}{\sum_i V_{ri}} = G_r$$

where V_{ri} = number of resident air passengers originating in district i in 1963

V_r = number of resident air passengers in the entire study area in 1963

G_r = the average area-wide growth in the number of resident air passengers (as given in Table 6.1.1).

In a similar fashion, the relative growth of non-resident air passenger and Logan employee trips are measured by the indicators G_{ni} and G_{ei}:

$$G_{ni} = K_n \frac{\dfrac{P_{n_i} E_{n_i}}{P_{o_i} E_{o_i}}}{\sum_j \dfrac{P_{n_j} E_{n_j}}{P_{o_j} E_{o_j}}}$$

and $$G_{ei} = K_e \frac{\dfrac{P_{n_i}}{P_{o_i}}}{\sum_j \dfrac{P_{n_j}}{P_{o_j}}}$$

Notice that the growth in the number of airport employee trips is distributed among the individual districts as a function only of the relative changes in population over the planning period. Thus, it is hypothesized that population is the most relevant description of a district's trip generating potential for employee trips.

The population and employment forecasts of the Boston Regional Planning Project were used to determine the relative growth factors (G_{ri}, G_{ni}, and G_{ei}) for each of the analysis districts as summarized in Table 6.1.2 on the following page. This data was input to the projection simulation as the income variable in the activity system data set 'PROJ75'. In addition, the area-wide growth factors of resident air passenger, non-resident air passenger, and employee trip generations were input as the population variables of the three DODOTRANS airport districts.

DISTRICT	1963 POPULATION	1975 POPULATION	1963 EMPLOYMENT	1975 EMPLOYMENT	G_{ri}	G_{ni}	G_{ei}
D2	156,814	138,000	237,739	261,000	0.800	0.800	0.919
D3	96,789	82,300	25,792	26,300	0.717	0.717	0.888
D4	220,880	191,400	106,982	99,000	0.636	0.636	0.905
D5	366,130	352,500	95,774	97,200	0.809	0.809	1.003
D6	240,906	220,800	74,765	71,000	0.720	0.720	0.957
D7	406,854	355,800	126,665	121,000	0.691	0.691	0.914
D8	338,122	382,000	83,328	98,100	1.100	1.100	1.178
D9	371,559	441,000	128,523	205,800	1.571	1.571	1.242
D10	327,048	373,000	77,364	108,700	1.326	1.326	1.187

Table 6.1.2

The resulting demand equations used in our DODOTRANS projection simulation take the form:

$$V'_{rijk} = a_o G_{ri} G_r V_{ri} \frac{C_{ijk}}{\sum_m C_{ijm}}$$

where V'_{rijk} = 1975 volume of resident air passengers from districts i on mode k

V_{ri} = the number of resident air passengers originating in district i in 1963

G_{ri} = relative growth factor of district i

G_r = area-wide resident air passenger growth factor

C_{ijk} = conductivity of mode k between districts i and the airport

The components of the action used in the DODOTRANS projection simulation are summarized below:

a. NETWORK 'BASE'

The 1975 network is identical to the base case (1963) network, consistent with our notion that a projection represents the null alternative.

b. ACTIVITY SYSTEM DATA SET 'PROJ75'

The relative and area-wide growth factors were input as population and income variables (as described above) in the projection activity data set.

c. VOLUME/DELAY SET 'PROJ75'

The volume delay set used in the projection run has to reflect the congestion expected on the urban streets and arterials in the study area. The increasing use of private auto, and the growth of area-wide population over the twelve year planning period are expected to result in increased trip generation and higher travel times on the 1975 road network. The volume delay set 'PROJ75' reflects this trend.

The base case link travel times were increased for the projection run as described in Table 6.1-3.

Link Type	% Travel Time Increase
line haul access links	5%
suburban line haul links	5%
inner suburb and CBD line haul links	10%
Callahan Tunnel link	20%
transit line haul links	5%

Table 6.1-3

d. MODAL DATA SET 'PROJ75'

The fares on public transit and taxi have increased from their 1963 levels. The fare data in MODAL DATA SET 'PROJ75' was adjusted accordingly. Table 6.1-4 presents the 1975 fare data for these two modes.

District	1975 Transit Fare	1975 Taxi Fare
2	.45	2.25
3	.60	2.10
4	.50	3.05
5	.60	4.95
6	.60	4.60
7	.50	4.85
8	-	7.85
9	-	8.75
10	-	8.25

Table 6.1-4

Operator cost data was left unchanged, with one exception. The airport garage operator was charged an amortized value of the construction cost of the new three-level parking garage. The five million dollar structure was amortized at 6% over 35 years, resulting in a yearly cost of $314,000.

The following pages present listings of data sets used in the DODOTRANS projection simulation.

```
READ VOL/DELAY 'PROJ75' FUNCTIONS 13 POINTS/FUNCTION 3
$ DUMMY LINKS
V/D 1 LO CAPACITY POINT 2 0 20 1000 20 2000 20
$ AUTO ACCESS AT LOCAL ORIGINS
V/D 2 LO CAPACITY POINT 2 0 6.3 1000 6.3 2000 6.3
$ AUTO LINE HAUL LINKS (V/D FUNCTIONS 3 THROUGH 8)
V/D 3 EX CAPACITY POINT 2 0 2.1 1000 2.1 2000 2.1
V/D 4 EX CAPACITY POINT 2 0 2.6 1000 2.6 2000 2.6
V/D 5 EX CAPACITY POINT 2 0 4.4 1000 4.4 2000 4.4
V/D 6 EX CAPACITY POINT 2 0 1.8 1000 1.8 2000 1.8
V/D 7 EX CAPACITY POINT 2 0 3.3 1000 3.3 2000 3.3
V/D 8 EX CAPACITY POINT 2 0 6.6 1000 6.6 2000 6.6
$ LOW SPEED TRANSIT (I.E. STREET CAR SERVICE)
V/D 9 AR CAPACITY POINT 2 0 6 1000 6 2000 6
$ RAPID TRANSIT
V/D 10 AR CAPACITY POINT 2 0 4 1000 4 2000 4
$ DUMMY LINKS
V/D 11 LO CAPACITY POINT 2 0 1 1000 1 2000 1
$ CALLAHAN TUNNEL
V/D 12 LO CAPACITY POINT 2 0 12 1000 12 2000 12
$ AIRPORT ACCESS ROAD AT LOGAN
V/D 13 LO CAPACITY POINT 2 0 7 1000 7 2000 7
```

```
MODIFY MODAL 'BASE' FORMING 'PROJ75'
MODE 3 FARE O  4 D 1 N 2.25
MODE 3 FARE O  5 D 2 N 2.25
MODE 3 FARE O  7 D 1 N 2.10
MODE 3 FARE O  8 D 2 N 2.10
MODE 3 FARE O 10 D 1 N 3.05
MODE 3 FARE O 11 D 2 N 3.05
MODE 3 FARE O 13 D 1 N 4.95
MODE 3 FARE O 14 D 2 N 4.95
MODE 3 FARE O 16 D 1 N 4.60
MODE 3 FARE O 17 D 2 N 4.60
MODE 3 FARE O 19 D 1 N 4.85
MODE 3 FARE O 20 D 2 N 4.85
MODE 3 FARE O 22 D 1 N 7.85
MODE 3 FARE O 23 D 2 N 7.85
MODE 3 FARE O 25 D 1 N 8.75
MODE 3 FARE O 26 D 2 N 8.75
MODE 3 FARE O 28 D 1 N 8.25
MODE 3 FARE O 29 D 2 N 8.25
MODE 4 FARE O  4 D 1 N .45
MODE 4 FARE O  6 D 3 N .45
MODE 4 FARE O  7 D 1 N .60
```

```
MODE 4 FARE 0  9 C 3 N .60
MODE 4 FARE 0 10 C 1 N .50
MODE 4 FARE 0 12 C 3 N .50
MODE 4 FARE 0 13 C 1 N .60
MODE 4 FARE 0 15 C 3 N .60
MODE 4 FARE 0 16 C 1 N .60
MODE 4 FARE 0 18 C 3 N .60
MODE 4 FARE 0 19 C 1 N .50
MODE 4 FARE 0 21 C 3 N .50
EDIT MODAL
SYSTEM POLICIES MODE 'AUTODRIV' 75000 0 0.10 0
SYSTEM POLICIES MODE 'AUTOPAX' 0 0 0.10 0
SYSTEM POLICIES MODE 'TAXI' 0 0 0.10 0
SYSTEM POLICIES MODE 'SUB/BUS' 0 0 0.03 0
SYSTEM POLICIES MODE 'EMPADRIV' 0 0 0.10 0
SYSTEM POLICIES MODE 'SUBURBAN' 0 0 0 0
STORE MODAL 'PMOD73'
```

```
READ ACTIVITY SYSTEM DATA SET 'PROJ75' DISTRICTS 30
DISTRICT  1   3 1 1 'AP1'
DISTRICT  2   3 1 1 'AP2'
DISTRICT  3   3 1 1 'AP3'
DISTRICT 4  57  800 1 'D21'
DISTRICT  5 264  800 1 'D22'
DISTRICT  6  55  949 1 'D23'
DISTRICT  7 102  717 1 'D31'
DISTRICT  8 110  717 1 'D32'
DISTRICT  9 217  688 1 'D33'
DISTRICT 10  45  636 1 'D41'
DISTRICT 11 105  636 1 'D42'
DISTRICT 12  30  505 1 'D43'
DISTRICT 13 131 809  1 'D51'
DISTRICT 14 111  809 1 'D52'
DISTRICT 15 146 1003 1 'D53'
DISTRICT 16 141  720 1 'D61'
DISTRICT 17 135  720 1 'D62'
DISTRICT 18  23  557 1 'D63'
DISTRICT 19 121  691 1 'D71'
DISTRICT 20 131  691 1 'D72'
DISTRICT 21  55  524 1 'D73'
DISTRICT 22 130 1100 1 'D81'
DISTRICT 23  22 1100 1 'D82'
DISTRICT 24 138 1178 1 'D83'
DISTRICT  5 216 1571 1 'D91'
DISTRICT 26  37 1571 1 'D92'
DISTRICT 27  60 1242 1 'D93'
DISTRICT 28  74 1326 1 'D101'
DISTRICT 29   3 1326 1 'D102'
DISTRICT 30  52 1187 1 'D103'
EDIT ACTIVITY DATA SET
```

6.2 Consequences - DODOTRANS Projection Simulation

The following pages give the DODOTRANS printout of the action 'PROJ75' discussed in the previous section. The demand parameters calibrated for the base case are also used for the projection simulation.

```
OOOOTRANS

LOAD MODAL 'PROJ75'

DEMAND MODEL PARAMETERS 'PROJ75' FOR CONDUCTIVITY MODEL

GENERAL PARAMETERS 1000 1 1 1 0 0 9 0 0 1000

MODE 1 PARAMETERS 50 -1.5 -.5 1

MODE 2 PARAMETERS 20 -1.5 -.5 1

MODE 3 PARAMETERS 10 -1.5 -.5 1

MODE 4 PARAMETERS 1.8 -1.0 -.33 1

MODE 5 PARAMETERS 10 -1.0 -.5 1

MODE 6 PARAMETERS 6 -1.5 -.5 1

INCREMENT 100 PERCENT

END

 ******  END OF CURRENT DEFINITION OF PARAMETER PROJ75


ACTION 'PROJ75'

NETWORK 'BASE'

DISTRICT DATA 'PROJ75'

MODE DATA 'PROJ75'

VOLUME/DELAY 'PROJ75'

STOP DEFINITION OF ACTION

 ******  END OF CURRENT DEFINITION OF ACTION PROJ75


GENERAL CONDUCTIVITY DEMAND MODEL CONSEQUENCES 'PROJ75' -
OF ACTION 'PROJ75' PARAMETER 'PROJ75'

STOP

 ******  END OF DEFINITION OF CONSEQUENCE PROJ75


                THE NETWORK IS COMPLETELY ASSIGNED AFTER  5220 ITERATIONS

                    TIME USED SINCE START OF RUN IS   2.47 MINUTES

            DATA HAS BEEN STORED ON DISK IN DATA FILE PROJ75

            FINAL OUTPUT FILE. PROJ75   ALREADY EXISTS.  USE FILE NAME. FINA0001.
```

COST SUMMARIES FOR FLOW PATTERN PROJ75

NETWORK BASE

DAILY USER DATA BY MODE AND ORIGIN

```
                       TOTAL       USER FARES          USER TRAVEL TIME       USER WAIT TIME         WEIGHTED COSTS
                       TRIPS
MODE      ORIGIN                 TOTAL      AVERAGE      TOTAL     AVERAGE     TOTAL     AVERAGE       TOTAL      AVERAGE
          DISTRICT (PASS/DAY)     ($)      ($/TRIP)     (HOURS) (MIN/TRIP)   (HOURS)   (MIN/TRIP)      ($)       ($/TRIP)


AUTODRIV AP1         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV AP2         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV AP3         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D21        65     3.73750E 02    5.75    4.93567E 01   46.     0.0           0.0    3.73750E 02    5.75
AUTODRIV D22         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D23         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D31        60     3.45000E 02    5.75    3.86800E 01   39.     0.0           0.0    3.45000E 02    5.75
AUTODRIV D32         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D33         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D41        29     1.71100E 02    5.90    2.59066E 01   54.     0.0           0.0    1.71100E 02    5.90
AUTODRIV D42         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D43         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D51       105     6.56250E 02    6.25    1.04790E 02   60.     0.0           0.0    6.56250E 02    6.25
AUTODRIV D52         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D53         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D61       106     6.57200E 02    6.20    1.13915E 02   64.     0.0           0.0    6.57200E 02    6.20
AUTODRIV D62         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D63         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D71        86     5.24600E 02    6.10    8.26746E 01   58.     0.0           0.0    5.24600E 02    6.10
AUTODRIV D72         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D73         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D81       219     1.50015E 03    6.85    2.62946E 02   72.     0.0           0.0    1.50015E 03    6.85
AUTODRIV D82         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D83         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D91       537     3.78585E 03    7.05    7.35690E 02   82.     0.0           0.0    3.78585E 03    7.05
AUTODRIV D92         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D93         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D101      150     1.01250E 03    6.75    1.87700E 02   75.     0.0           0.0    1.01250E 03    6.75
AUTODRIV D102        0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTODRIV D103        0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0


AUTOPAX  AP1         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  AP2         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  AP3         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D21        88     9.67999F 01    1.10    5.16266E 01   35.     0.0           0.0    9.67999E 01    1.10
AUTOPAX  D22         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D23         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D31        90     9.44999E 01    1.05    4.24800E 01   28.     0.0           0.0    9.44999E 01    1.05
AUTOPAX  D32         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D33         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D41        33     4.78500F 01    1.45    2.37820E 01   43.     0.0           0.0    4.78500E 01    1.45
AUTOPAX  D42         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D43         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D51        94     2.06800E 02    2.20    7.75813E 01   50.     0.0           0.0    2.06800E 02    2.20
AUTOPAX  D52         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
AUTOPAX  D53         0     0.0            0.0     0.0            0.0    0.0           0.0    0.0            0.0
```

```
AUTOPAX  D61      96  1.96800E 02   2.05  8.65920E 01  54.  0.0       0.0  1.96800E 02  2.05
AUTOPAX  D62       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D63       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D71      83  1.57700E 02   1.90  6.54593E 01  47.  0.0       0.0  1.57700E 02  1.90
AUTOPAX  D72       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D73       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D81     159  5.24700E 02   3.30  1.63452E 02  62.  0.0       0.0  5.24700E 02  3.30
AUTOPAX  D82       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D83       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D91     363  1.34310E 03   3.70  4.34632E 02  72.  0.0       0.0  1.34310E 03  3.70
AUTOPAX  D92       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D93       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D101    111  3.44100E 02   3.10  1.19732E 02  65.  0.0       0.0  3.44100E 02  3.10
AUTOPAX  D102      0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
AUTOPAX  D103      0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0

TAXI     AP1       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     AP2       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     AP3       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D21      31  6.97500E 01   2.25  1.81867E 01  35.  0.0       0.0  6.97500E 01  2.25
TAXI     D22     634  1.42650E 03   2.25  3.71947E 02  35.  0.0       0.0  1.42650E 03  2.25
TAXI     D23       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D31      32  6.72000E 01   2.10  1.51040E 01  28.  0.0       0.0  6.72000E 01  2.10
TAXI     D32     237  4.97700E 02   2.10  1.11864E 02  28.  0.0       0.0  4.97700E 02  2.10
TAXI     D33       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D41      11  3.35500E 01   3.05  7.92733E 00  43.  0.0       0.0  3.35500E 01  3.05
TAXI     D42     200  6.10000E 02   3.05  1.44133E 02  43.  0.0       0.0  6.10000E 02  3.05
TAXI     D43       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D51      31  1.53450E 02   4.95  2.55853E 01  50.  0.0       0.0  1.53450E 02  4.95
TAXI     D52     269  1.33155E 03   4.95  2.22015E 02  50.  0.0       0.0  1.33155E 03  4.95
TAXI     D53       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D61      32  1.47200E 02   4.60  2.88640E 01  54.  0.0       0.0  1.47200E 02  4.60
TAXI     D62     292  1.34320E 03   4.60  2.63384E 02  54.  0.0       0.0  1.34320E 03  4.60
TAXI     D63       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D71      26  1.26100E 02   4.85  2.05053E 01  47.  0.0       0.0  1.26100E 02  4.85
TAXI     D72     272  1.31920E 03   4.85  2.14517E 02  47.  0.0       0.0  1.31920E 03  4.85
TAXI     D73       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D81      52  4.08200E 02   7.85  5.34560E 01  62.  0.0       0.0  4.08200E 02  7.85
TAXI     D82      76  5.96600E 02   7.85  7.81279E 01  62.  0.0       0.0  5.96600E 02  7.85
TAXI     D83       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D91     118  1.03250E 03   8.75  1.41285E 02  72.  0.0       0.0  1.03250E 03  8.75
TAXI     D92     174  1.52250E 03   8.75  2.08336E 02  72.  0.0       0.0  1.52250E 03  8.75
TAXI     D93       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
TAXI     D101     34  2.80500E 02   8.25  3.66747E 01  65.  0.0       0.0  2.80500E 02  8.25
TAXI     D102     12  9.90000E 01   8.25  1.29440E 01  65.  0.0       0.0  9.90000E 01  8.25
TAXI     D103      0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0

SUB/BUS  AP1       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  AP2       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  AP3       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  D21      48  2.16000E 01   0.45  3.73120E 01  47.  0.0       0.0  2.16000E 01  0.45
SUB/BUS  D22       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  D23      21  9.45000E 00   0.45  1.63240E 01  47.  0.0       0.0  9.45000E 00  0.45
SUB/BUS  D31      38  2.28000E 01   0.60  2.47000E 01  39.  0.0       0.0  2.28000E 01  0.60
SUB/BUS  D32       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  D33      65  3.90000E 01   0.60  4.22500E 01  39.  0.0       0.0  3.90000E 01  0.60
SUB/BUS  D41      20  1.00000E 01   0.50  2.08267E 01  62.  0.0       0.0  1.00000E 01  0.50
SUB/BUS  D42       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  D43      10  5.00000E 00   0.50  1.04133E 01  62.  0.0       0.0  5.00000E 00  0.50
SUB/BUS  D51      88  5.28000E 01   0.60  8.58293E 01  59.  0.0       0.0  5.28000E 01  0.60
SUB/BUS  D52       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
SUB/BUS  D53      75  4.50000E 01   0.60  7.31499E 01  59.  0.0       0.0  4.50000E 01  0.60
SUB/BUS  D61      70  4.20000E 01   0.60  9.70199E 01  83.  0.0       0.0  4.20000E 01  0.60
SUB/BUS  D62       0  0.0           0.0   0.0          0.0  0.0       0.0  0.0          0.0
```

```
SUB/BUS  D63          9   5.40000E 00   0.60   1.24740E 01   83.   0.0      0.0   5.40000E 00   0.60
SUB/BUS  D71         57   2.85000E 01   0.50   7.00340E 01   74.   0.0      0.0   2.85000E 01   0.50
SUB/BUS  D72          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D73         43   1.29000E 01   0.30   5.28326E 01   74.   0.0      0.0   1.29000E 01   0.30
SUB/BUS  D81          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D82          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D83          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D91          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D92          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D93          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D101         0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D102         0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUB/BUS  D103         0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0


EMPADRIV AP1          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV AP2          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV AP3          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D21          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D22          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D23        142   7.81000E 01   0.55   9.45719E 01   47.   0.0      0.0   7.81000E 01   0.55
EMPADRIV D31          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D32          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D33        513   2.56500E 02   0.50   2.82634E 02   33.   0.0      0.0   2.56500E 02   0.50
EMPADRIV D41          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D42          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D43         71   4.97000E 01   0.70   5.68000E 01   48.   0.0      0.0   4.97000E 01   0.70
EMPADRIV D51          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D52          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D53        364   4.00400E 02   1.10   3.29299E 02   54.   0.0      0.0   4.00400E 02   1.10
EMPADRIV D61          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D62          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D63         57   5.70000E 01   1.00   5.59360E 01   59.   0.0      0.0   5.70000E 01   1.00
EMPADRIV D71          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D72          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D73        232   2.20400E 02   0.95   2.71376E 02   52.   0.0      0.0   2.20400E 02   0.95
EMPADRIV D81          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D82          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D83        382   6.30300E 02   1.65   4.23001E 02   66.   0.0      0.0   6.30300E 02   1.65
EMPADRIV D91          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D92          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D93        224   4.14400E 02   1.85   2.85973E 02   77.   0.0      0.0   4.14400E 02   1.85
EMPADRIV D101         0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D102         0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
EMPADRIV D103       185   2.86750E 02   1.55   2.14230E 02   69.   0.0      0.0   2.86750E 02   1.55


SUBURBAN AP1          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN AP2          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN AP3          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D21          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D22          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D23          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D31          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D32          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D33          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D41          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D42          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D43          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D51          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D52          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D53          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D61          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D62          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D63          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
SUBURBAN D71          0   0.0           0.0    0.0           0.0   0.0      0.0   0.0           0.0
```

SUBURBAN D72	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D73	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D81	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D82	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D83	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D91	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D92	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D93	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D101	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D102	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBURBAN D103	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
                                            DAILY USER DATA BY MODE

               TOTAL        USER FARES            USER TRAVEL TIME        USER WAIT TIME          WEIGHTED COSTS
               TRIPS
 M O D E                  TOTAL       AVERAGE       TOTAL     AVERAGE      TOTAL    AVERAGE        TOTAL      AVERAGE
            (PASS/DAY)     ($)        ($/TRIP)     (HOURS)  (MIN/TRIP)    (HOURS)  (MIN/TRIP)       ($)       ($/TRIP)

 AUTODRIV       1357   9.02639E 03     6.65    1.60166E 03     71.       0.0          0.0     9.02639E 03     6.65
 AUTOPAX        1117   3.01235E 03     2.70    1.06534E 03     57.       0.0          0.0     3.01235E 03     2.70
 TAXI           2533   1.10647E 04     4.37    1.97485E 03     47.       0.0          0.0     1.10647E 04     4.37
 SUB/BUS         544   2.94450E 02     0.54    5.43166E 02     60.       0.0          0.0     2.94450E 02     0.54
 EMPADRIV       2170   2.39355E 03     1.10    1.94402E 03     54.       0.0          0.0     2.39355E 03     1.10
 SUBURBAN          0   0.0             0.0     0.0              0.0      0.0          0.0     0.0             0.0

T O T A L S     7721   2.57914E 04     3.34    7.12903E 03     55.       0.0          0.0     2.57914E 04     3.34
```

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                                        YEARLY COSTS AND REVENUES BY MODE

 M O D E    TOTAL        USER        TOTAL USER     OPERATOR'S     GOVERNMENT   OPERATOR'S PROFIT  GOVT. REVENUE
            TRIPS        FARES         COSTS          PROFIT        REVENUE       PER PASSENGER    PER PASSENGER

 AUTODRIV   495305    3.29463E 06   3.29463E 06   2.49976E 06      0.0              5.05               0.0
 AUTOPAX    407705    1.09951E 06   1.09951E 06   5.75032E 05      0.0              1.41               0.0
 TAXI       924545    4.03861E 06   4.03861E 06   3.23024E 06      0.0              3.49               0.0
 SUB/BUS    198560    1.07474E 05   1.07474E 05   5.14291E 04      0.0              0.26               0.0
 EMPADRIV   792050    8.73645E 05   8.73645E 05   8.73645E 05      0.0              1.10               0.0
 SUBURBAN        0    0.0           0.0           0.0              0.0              0.0                0.0

 TOTALS    2818165    9.41387E 06   9.41387E 06   7.23011E 06      0.0              2.57               0.0
```

Question 6.2.1

Discuss the results of hte 1975 projection simulation. Which districts experienced the greatest growth in airport travel? Compare the 1975 airport flow pattern with the 1963 base flow pattern. Are airport trips becoming more or less dispersed in the Boston metropolitan area? Is the auto still the dominant mode for airport trips?

Answer 6.2.1

Boston is typical of several large older U.S. cities, in that it has experienced a rapid suburban growth in population and industry coupled with a general decline in the economic and demographic activity located in the central business district. The results from the projection simulation indicate that there will be a rapid growth in airport trips from suburban areas as compared to the trip generation from the central city. This can be seen by referring to Table 6.2.1. The growth of air passenger trips is most pronounced in districts 8, 9, and 10 representing areas on Route 128, the circumferential highway. Not surprisingly, the smallest growth was exhibited in the districts composed of Charlestown, Somerville and Cambridge (district 4) and the Dorchester, Mattapan, Roxbury area (district 7) where there has been a marked decline in population and employment.

Non-resident air passenger trip origins and airport employee trip origins exhibit a similar growth pattern. The evidence indicates that the origins of airport-destined trips are becoming more dispersed as a result

District	Percentage Increase in Resident Air Passenger Trips	Percentage Increase in Non-Resident Air Passenger Trips	Percentage Increase in Airport Employee Trips
2	139%	140%	176%
3	118%	115%	166%
4	90%	90%	170%
5	143%	143%	200%
6	116%	116%	187%
7	108%	108%	177%
8	234%	234%	254%
9	370%	370%	274%
10	298%	298%	256%

Table 6.2-1

PERCENTAGE INCREASE IN AIRPORT TRIPS ORIGINATING FROM EACH DISTRICT OVER THE PERIOD 1963-1975 of the continuing relative growth of Boston's suburban communities.

The 1975 simulation projects auto usage to continue as the dominant access mode to Logan Airport. The mode split for the base and projection simulations are summarized in Table 6.2.2. There has been a slight increase in the modal share of auto drive, and auto passenger modes at the expense of a slight decline in the patronage of public transit. Taxi's modal share has declined 5.5%, partly as a result of the increased taxi fare over the 12 year planning period.

MODAL SHARE OF EACH MODE IN THE ANALYSIS

MODE	BASE CASE	PROJECTION
1	14.7%	17.6%
2	13.1%	14.4%
3	38.3%	32.8%
4	8.4%	7.0%
5	25.5%	28.2%

Table 6.2-2

7.0 Sensitivity Analysis

Since the determination of the demand parameters employed in this case study was based heavily on judgment, it is important to consider the sensitivity of the results with respect to the particular parameter values chosen. If the equilibrium flow pattern is extremely sensitive to the demand parameters, we cannot place a great deal of confidence in the predicted consequences.

The basic form of the McLynn demand as implemented in our analysis is:

$$V_{ik} = \frac{V_i C_{ik}}{\sum_m C_{im}} = \frac{V_i n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k}}{\sum_m n_m t_{im}^{b_1^m} C_{im}^{b_2^m}}$$

We are interested in determining the percentage change in V_{ik} resulting from a change in the demand parameters. For simplicity, we consider a change only in the exponent of travel time for mode k. Thus, differentiating V_{ik} with respect to b_1^k, we get:

$$\frac{dV_{ik}}{db_1^k} = V_i \frac{d}{db_1^k} \left[\frac{C_{ik}}{\sum_m C_{im}} \right]$$

$$= \frac{V_i \left[n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k} \ln t_{ik} \sum_m C_{im} - n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k} n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k} \ln t_{ik} \right]}{\left[\sum_m C_{im} \right]^2}$$

This expression simplifies to:

$$\frac{dV_{ik}}{db_1^k} = V_i n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k} \ln t_{ik} \frac{\left[\sum_m C_{im} - n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k}\right]}{\left[\sum_m C_{im}\right]^2}$$

$$= \left[\frac{V_i C_{ik}}{\sum_m C_{im}}\right] \cdot \ln t_{ik} \cdot \frac{\left[\sum_m C_{im} - n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k}\right]}{\sum_m C_{im}}$$

We recognize the first bracketed expression as V_{ik}. The second expression in brackets reduces to $\sum_{m \neq k} C_{im}$. Thus, in its simplest form we get:

$$\frac{dV_{ik}}{V_{ik}} = \ln t_{ik} \cdot \frac{\sum_{m \neq k} C_{im}}{\sum_m C_{im}} \cdot db_1^k$$

In words, this equation implies that the percentage change in volume due to a change in the exponent of travel time for mode k is equal to the product of:

i. the absolute change in the exponent - i.e., db_1^k

ii. the natural log of the travel time by mode k

iii. the ratio of the sum of the conductivities of all modes except mode k to the sum of the conductivities of all modes.

From the form of the last equation we can draw three conclusions:

This expression simplifies to:

$$\frac{dV_{ik}}{db_1^k} = V_i n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k} \ln t_{ik} \frac{\left[\sum_m C_{im} - n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k}\right]}{\left[\sum_m C_{im}\right]^2}$$

$$= \left[\frac{V_i C_{ik}}{\sum_m C_{im}}\right] \cdot \ln t_{ik} \cdot \frac{\left[\sum_m C_{im} - n_k t_{ik}^{b_1^k} c_{ik}^{b_2^k}\right]}{\sum_m C_{im}}$$

We recognize the first bracketed expression as V_{ik}. The second expression in brackets reduces to $\sum_{m \neq k} C_{im}$. Thus, in its simplest form we get:

$$\frac{dV_{ik}}{V_{ik}} = \ln t_{ik} \cdot \frac{\sum_{m \neq k} C_{im}}{\sum_m C_{im}} \cdot db_1^k$$

In words, this equation implies that the percentage change in volume due to a change in the exponent of travel time for mode k is equal to the product of:

i. the absolute change in the exponent - i.e., db_1^k

ii. the natural log of the travel time by mode k

iii. the ratio of the sum of the conductivities of all modes except mode k to the sum of the conductivities of all modes.

From the form of the last equation we can draw three conclusions:

1. The greater the change in the initial value of the exponent b_1^k, the greater will be the percentage change in volume.*
2. The larger t_{ik}, the greater is the sensitivity with respect to b_1^k.
3. The smaller the conductivity of mode k, the greater is the sensitivity with respect to b_1^k.

Table 7.0-1 gives an example of the application of the sensitivity analysis to our base case flow pattern. For illustrative purposes, we have shown the results of a change in the travel time exponent of the (air passenger) auto driver mode from -1.5 to -1.4, or 6.7%.

District	% Change in Number of Auto Drivers
2	28%
3	27%
4	29%
5	29%
6	23%
7	24%
8	21%
9	22%
10	22%

Table 7.0-1

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*Notice that the volume changes as a function of the absolute change in b_1^k. Thus, changing the value of b_1^k from -1.5 to -1.4 will have the same effect on volume as change from -150 to -149.9

8.0 Analysis of Alternative Transportation Systems

In section 6.2, the consequences of the 1975 null case projection were described. That simulation serves as a basis with which to compare alternative technology and operating policy options. The analysis of new transportation systems will in general require changes and additions to the network, modal data, and volume/delay data sets describing the airport access system. In the following sections we present an example of an analysis of a new access transportation service - a direct rail link between downtown Boston and Logan Airport.

8.1 DODOTRANS Simulation of a Direct Rail Link Between Downtown Boston and Logan Airport

8.1.1 The Transit System

The existing public transportation service to Logan Airport is provided by the Blue Line of the MBTA. A bus transfer is required to complete the one-mile trip from the airport subway stop to the airline terminal buildings. In the projection simulation, transit accounted for only 7% of the total airport travellers. Of the three traveller groups modelled in the base case and projection simulations, resident air passengers were the most frequent riders. Over ten percent*[10.4%] of the resident air passenger access trips were made on public transit, as compared with 9.3% of employee trips.

Analysis of the available data on airport access to Logan indicates that virtually no non-resident air passengers patronize public transit. Accordingly, in the base case and projection simulations, non-resident air passengers were not assigned any trips on the transit mode.**

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*in the projection simulation

** The transit frequencies between non-resident air passenger districts and the airport were assigned a frequency of zero [see section 5.4]. This is not to imply that transit service is not available to this traveller group. Essentially we have employed an artificial constraint to reflect the fact that the present transit service is not attractive enough [in terms of convenience, perceived time reliability, "image," etc.] The demand model is not complete in representing all the determinants of travel. We are not able to quantify measures of image or time reliability. Thus the use of the zero frequency is a proxy for several variables measuring the "attractiveness" of transit to non-resident air passengers.

Experience with the direct rail service connecting downtown Cleveland with Hopkins Airport* indicates that an attractive public transit system can attract a significant percentage of airport travellers originating from the CBD. The Cleveland service features new air-conditioned cars with special provision for baggage, operating at a peak hour frequency of 6 trains per hour. The 11 1/2 mile trip between Union Terminal in downtown to the airport is covered in 20 minutes for a fare of forty cents.

In a survey [19] conducted ten months after the inauguration of the Cleveland transit service, it was found that:

1. 57.6% of the 3600 daily rapid transit riders to or from the airport are air passengers. Only 1/4 of the air passengers that patronize transit start or end their trip in the CBD.
2. 14.5% of all air passengers originating or terminating their trip at Hopkins Airport ride the rapid transit. 25% of the air passengers with origins or destinations in the rapid transit service area use transit, and 35% of the air passengers going to or from the CBD patronize transit.
3. 11.2% of the airport employees ride the rapid transit.
4. Almost 46% of the total number of air passengers riding the rapid transit are non-residents of northeastern Ohio.

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* Cleveland is the first city in the U.S. to provide direct rail rapid transit service between a CBD and an airport. The service was inaugurated in November, 1968. See reference [9]

5. Approximately 10% of all person trips to Cleveland Hopkins Airport were made on the direct rail service.

In general, the purposes of a direct CBD-to-airport service are two-fold. First, the service is designed to provide fast, moderately-priced airport access from the heavily congested CBD area and other points on the rapid transit system. Second, the system attempts to relieve road congestion in and around the airport by diverting a significant number of airport travellers from autos and taxis.

It is doubtful that a direct rail service can successfully achieve the latter objective.* However the Cleveland experience has shown that an attractive rail access service can attract air passengers [both resident _and_ non-resident] and airport employees whose origins lie in the rapid transit service area. It is with this purpose in mind that we explore in the next section, the consequences of the implementation of a direct rail service to Logan International Airport.

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*There has been no significant decrease in traffic on roads leading to or within Hopkins Airport. This observation is partly attributable to the small fraction of highway travel in the Cleveland area devoted to airport travel, and partly due to the fact that the transit service captured only 10% of the total daily person trips to the airport. See reference[41].

8.2 Modelling the Direct Rail Link

We have chosen to model a direct rail link connecting Boston's Government Center and the airport. Government Center is located about 2 1/2 miles from the main terminal area at Logan, and offers convenient transfers from the Green and Blue lines of the MBTA. A description of the DODOTRANS simulation of the direct rail service is described below.

Network 'Dirail'

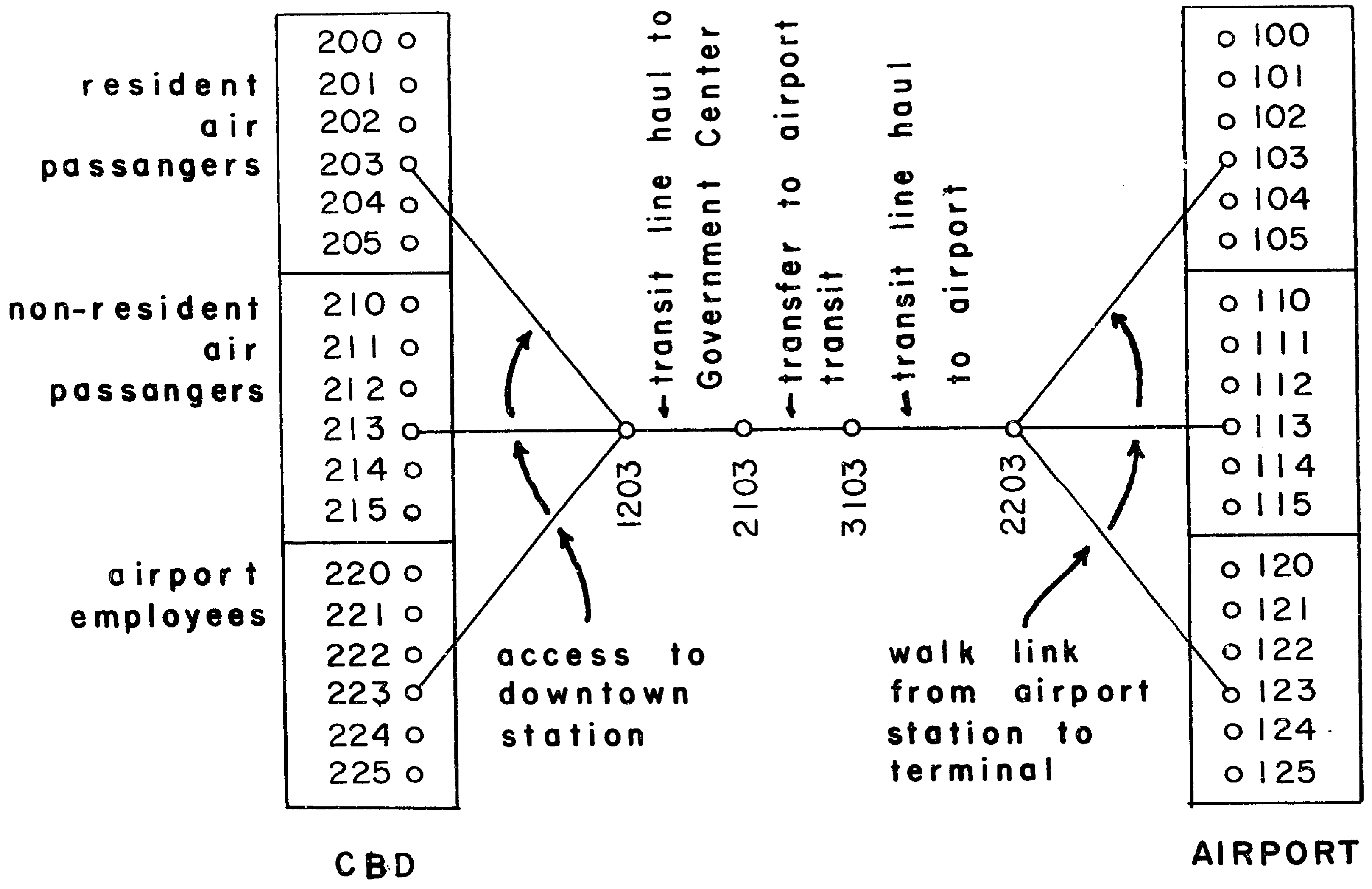
Changes to the base case network include the addition of a new line haul link for the direct rail service, and access links to the downtown station, and from the airport station. Figure 8.2-1 shows the new DODOTRANS link between the CBD district and the airport district.

Volume/Delay 'Dirail'

It is assumed that the new transit service will average 30 miles per hour over the 2 1/2 mile distance between downtown and the airport. A new volume delay function was added to V/D 'PROJ75' to represent this line-haul transit link. Access to the downtown station was not changed from the projection simulation. The distributor walk link from the airport station to the terminal buildings was assigned to a 6 minute travel time using a V/D delay function already coded in the projection run.

Modal Data 'Dirail'

The peak period frequency for the direct rail service is taken to be 6 trains per hour. Assuming three cars per train, and 50 seats per car, the rail service provides seating capacity of 1800 over the two


resident
air
passangers
non-resident
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employees
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222
223
224
225
CBD
←transit line haul to
Government Center
←transfer to airport
transit
←transit line haul
to airport
1203
2103
3103
2203
access to
downtown
station
walk link
from airport
station to
terminal
100
101
102
103
104
105
110
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125
AIRPORT

Figure 8.2.1

hour peak. Changes to the projection modal data set include the addition of a 25¢ fare for the new rail service, and the coding of a non-zero frequency for non-resident air passenger districts [see footnote, page 156].

Costs

Cost data for the new transit service is presented in appendix 1. Assuming a twenty minute round trip time between Government Center and the airport terminal [including a 5 minute station dwell time at each end], two 3-car trains are needed to provide the 10 minute headway service. Vehicle acquisition costs are thus 6 x \$100,000 = \$600,000. Total track and tunnelling costs are computed as 2 1/2 miles x \$15.3 x10^6/mile = \$38.25 x 10^6. Operating costs are assumed to be 3¢/passenger-mile. Only one-fourth of the total fixed cost was assigned to the morning peak since it is assumed that approximately one-fourth of the revenue will be generated during this period.

8.3 Consequences

In this section, the consequences of the direct rail simulation are summarized in user and operator impact matrices. An impact matrix is a tabular description of the consequences [impacts] resulting from an action on each actor in the analysis. The user impact matrix includes the following impact types: volume, average travel time, average fare, and change in consumer surplus. Included in the operator impact matrix are: total revenue, total cost, and net revenue. The actors in the user impact matrix include resident air passengers by mode, non-resident air passengers by mode and airport employees by mode. Three operator groups, MASSPORT [airport garage operator], MBTA, and taxi owners were included in the operator impact matrix.

All of the impacts, with the exception of consumer surplus, are self explanatory. Consumer surplus measures the excess of the price consumers are willing to pay over the selling price of a product. A brief dexcription of the consumer surplus concept was given in section 7.1 of the Southeast Corridor Case Study [3].

Three measures of the change in consumer surplus comparing action 'DIRAIL' and 'PROJ75' are given in table 8.3-1. We have defined the change in weighted consumer surplus [ΔWCS] as:

$$\Delta \text{WCS} = \text{CONSUMER FARE SURPLUS} + [\text{Value of Time}] \times \text{CONSUMER TIME SURPLUS.}$$

ΔWCS gives an aggregate indication of whether a user group is better or worse off after the implementation of an action. The weighted consumer surplus was computed using values of time of 7$/hour, 5$/hour and 3$/hour for non-resident air passengers, resident air passengers and airport employees respectively.

All the data in the impact matrices are taken directly from the DODOTRANS output with one exception. The airport garage operator's total fare revenue given in the DODOTRANS output includes the user's perceived operating cost. Accordingly, MASSPORT's garage revenues were computed manually by multiplying the yearly auto driver trips by the $5 parking charge [see table 8.3-2].

USERS' IMPACT MATRIX

ACTIONS:DIRAIL,(PROJ75)*

Group	Volume (Pass./a.m.peak)		Average Travel Time (minutes)		Average Fare ($)	
Resident Air Pass.						
- auto drive	1333	(1357)	71	(71)	6.66	(6.65)
- auto passenger	1088	(1117)	58	(57)	2.73	(2.70)
- taxi	357	(367)	57	(56.8)	6.40	(6.36)
- subway/bus	384	(321)	57.5	(62.5)	.59	(.54)
Non-Resident Air Passenger						
- taxi	1567	(2208)	48	(44.2)	4.66	(3.96)
- subway/bus	641	(0)	29	(-)	.51	(-)
Ariport Employee						
- auto drive	2133	(2170)	54	(54)	1.11	(1.10)
- subway/bus	260	(223)	53.8	(55.7)	.58	(.56)

Table 8.3-1

*Values in parentheses indicate user impacts for projection simulation.

Group	Consumer Travel Time Surplus* (hours/day)	Consumer Fare Surplus* ($/day)	Weighted Consumer Surplus** ($/day)
Resident Air Pass.			
- auto drive	0	-13.45	-13.45
- auto passenger	-18.4	-33.07	-125.07
- taxi	-1.2	-14.34	-21.34
- subway/bus	+29.4	-17.42	+129.58
Non-Resident Air Passenger			
- taxi	-119.2	-1291.25	-2125.65
- subway/bus	+154.9	+163.50	+1247.80
Airport Employee			
- auto drive	0	-21.51	-21.51
- subway/bus	+7.65	-48.3	-25.35

Table 8.3-1 (Continued)

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*Values are changes in consumer surplus with respect to projection simulation.

**Computed using values of time of $5/hour, $7/hour and $3/hour for resident air passengers, non-resident air passengers and airport employees respectively.

OPERATORS' IMPACT MATRIX

ACTIONS: DIRAIL (PROJ75)*

Operator	Total Revenue (10^3\$/year)	Total Costs (10^3\$/year)	Net Revenue (10^3\$/year)
MASSPORT (garage)	2432.72 (2476.52)	75.00 (75.00)	2357.72 (2471.52)
Taxi	3492.86 (4038.61)	695.26 (808.37)	2797.60 (3230.24)
Subway/bus	226.70 (107.47)	694.80 (56.04)	-468.10 (51.43)

Table 8.3-2

*Values shown in parentheses pertain to projection simulation.

Question 8.3

Study the impact matrices given in tables 8.3-1 and 8.3-2. Which groups have benefited from the direct CBD-airport rail service? Which have not? What can you conclude about this alternative as a "solution" to Boston's airport access problem?

9.0 Final Assignment

You are now on your own to formulate and test alternative solutions to Boston's airport access problem.

i. Develop one or more desirable alternatives.

ii. Discuss the reasons for choosing these alternatives and hypothesize the expected consequences.

iii. Prepare and run one or more DODOTRANS simulations to test your hypotheses.

iv. Review your results and repeat steps i-iii, if desirable. Do not exceed your computer budget!

v. Prepare a short, final report on the results:

  a. Summarize the key choice issues. Which groups benefited from your alternative; which did not? How successful was your alternative in improving airport access? Make final recommendations based on your analysis.

  b. Document your analysis process, including an explanation of the major assumptions in your analysis, and a description of the values and criteria used to evaluate your alternatives.

APPENDIX 1

Summary of Cost Data for Urban Transportation Systems

As an aid to the formulation of alternatives for the airport access case study, a short summary of cost data for several intraurban transportation systems is presented below. The cost data was collected from references [18], [39], [28], and [31].

Urban Rail Transit

tunnelling and track costs	$\$15.3 \times 10^6$ / double track mile
transit vehicle acquisition	\$100,000 / car
service and maintenance of passenger facilities	\$8.60 / passenger / year
yards, garages, and shop operations	\$4650 / year / vehicle
conductance (power) costs	\$0.08 / vehicle-mile
direct labor cost (train crew)	\$10 / vehicle hour

Urban Bus

(assume no right of way or terminal costs)

storage, maintenance shop operation	\$600 / vehicle
bus acquisition	\$3100 / vehicle
fuel and oil costs	\$0.30 / vehicle-mile
driver costs	\$5 / vehicle-hour

Exclusive Bus Lane

highway construction cost* = 1.7×10^6 / mile**

ROW acquisition* $600,000 / mile**

other costs same as for Urban Bus

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* based on roadway construction and right of way acquisition cost relationships given in [28], pages 204 and 210

$$Y_k = W_c(311000 + 70{,}800X) + 86{,}000k$$

where k = number of lanes (in both directions)
Y_k = construction cost for k lanes in dollars per mile
x = net residential density in thousands of persons per square mile
W_c = right of way (ROW) as fraction of ROW required for 8 lanes
= .65 for 2 lanes
= .77 for 4 lanes
= .88 for 6 lanes

$$S_{row,k} = (0.005X)Y_k$$

where S_{row} = right of way acquisition costs for a k-lane facility in dollars per mile

** these figures represent the costs for 2 lanes of a 6-lane freeway in an area with an average net residential density of 70,000 persons/square mile

VTOL (Vertical Takeoff and Landing) Feeder Systems

The data presented here are derived from reference [39] and are representative of costs for a currently available 28 passenger helicopter.

terminal costs	$3.26 x 10^6 / terminal
direct operating costs	
total flying expenses (fuel, oil, other expenses)	$0.74 / vehicle mile
maintenance (airframe and engine)	$1.14 / vehicle mile
depreciation (airframe, engine, flight equipment)	$0.39 / vehicle mile
indirect operating costs	
passenger handling	$2.04 / passenger
vehicle handling	$1.78 / departure
overhead costs	$0.095 / revenue passenger mile

In order to compute the total costs of transportation facilities, capital expenditures (e.g. terminal contruction, vehicle acquisition) must be converted to equivalent annual costs. By assigning an assumed amortization period (length of time that a facility is used) and interest rate on capital, we can compute the relevant capital recovery factor (CRF). Annual cost, $C_A = C \cdot CRF$, is defined as the product of the capital cost, C, and the relevant CRF. The capital recovery factor is defined as

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where i = interest rate on capital

n = amortization period in years

In table A1-1, the capital recovery factors for several transportation facilities are presented.

Capital Item	Service Life (years)	CRF at 69% interest
Rail		
rolling equipment	30	.07265
yards and shops	50	.06344
rail stations	50	.06344
railbed and track	50	.06344
right of way (land acquisition)	infinite	.06000
Bus		
right of way (land acquisition)	infinite	.06000
roadway	35	.06897
yards and shops	40	.06646
stations, terminals	50	.06344
vehicles	12	.1193
VTOL		
terminal structures	50	.06344
garage and maintenance facilities	50	.06344
vehicles	12	.1193

Table A1-1*

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*source [28], [41]

APPENDIX 2

Modelling the Demand for Airport Access Trips

A2.1 Introduction*

A great deal of effort has been expended in the research and development of a wide variety of advanced technology modes designed to improve the quality of access to metropolitan airports.** A prerequisite for the systematic evaluation of these alternatives is the development of reliable models for predicting the modal split of airport-destined trips. Very little work has been done in this area for a variety of reasons.

Widespread recognition of an "airport access problem" has been comparatively recent. Traditionally, the federal role in commercial aviation has been limited to supporting non-terminal airport facilities, airways, and air traffic control equipment. In the 1946 Airport Act, Congress authorized the administrator of the Civil Aeronautics Authority, (CAA; later to become the Federal Aviation Agency (FAA) in 1958) to provide federal aid to publicly owned airports on a 50/50 matching basis. The CAA was also required to prepare a National Airport Plan each year specifying "in terms of general location and type of development, the projects considered by the Administrator to be necessary to provide a system of public

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* The purpose of this appendix is to discuss in greater detail than presented in the case study, some fundamental issues underlying the demand for airport access trips. The appendix was not part of the original case study distributed to the Urban Transportation class. However, the issues described herein were presented in lectures complementing the case study exercises.

** See for example [37] and [29], page 46 airports adequate to anticipate the needs of civil aeronautics."* The National Airport Plan does not include a description of access characteristics of major metropolitan airports. Moreover, it was not the intent of Congress to provide financial assistance for the improvement of airport access facilities. Subsequent Congressional debate and amendments to the 1946 Airport Act have not significantly broadened the federal role in supporting commercial aviation.

Thus, despite the growing awareness that provision of an adequate access system is a necessary complement to the maintenance of an adequate system of public airports, the federal government has provided little incentive for truly comprehensive airport planning. The airport access problem has been considered as a local problem. With the limited resources and technical expertise available to municipal governments, research in the area of airport access has been lacking.

The federal policy of dealing with the "urban transportation problem" has been markedly different. The need for a continuing comprehensive transportation process became a matter of national policy with the passage of the 1962 Highway Act. In accordance with the statutory requirements under Title 23, Section 134 of the U.S. Code, an elaborate set of transportation forecasting models have been developed and applied in over 220 urban areas with a population greater than 50,000. These models range in

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* See reference [34], page 26

complexity from the growth factor approaches* used in the early urban planning studies over a decade ago, to the recently developed disaggregate, stochastic travel behavior models [34].

Is there a need to develop demand models specifically designed to predict airport access flow patterns? With all the research that has been devoted to developing sophisticated urban transportation demand models, it is tempting to simply apply an "off-the-shelf" technique to airport access analyses. Unfortunately, as discussed in section 5.6, applying state-of-the-art demand models to the task of forecasting airport access trips raises several difficulties. Thus it is strongly believed that a continuing research effort into modelling airport access is needed. The science of transportation demand forecasting is still in its infancy. Although it is a rapidly evolving field, economists are still struggling to gain a better understanding of the complex phenomena underlying travel behavior.

Some of the problems encountered in predicting airport access demand are illustrated by a modal split analysis conducted by Alan M. Voorhees and Associates for the U.S. Department of Transportation [44]. Using date collected before and after the inauguration of the Cleveland Transit System's airport service, the researchers attempted to calibrate a series of diversion curves as a tool for predicting the modal split between transit and auto trips to Hopkins Airport.** The attempt to calibrate the modal

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* For a cogent description of these techniques, see [25], section c-4

** A diversion curve is a modal split technique that relates transit usage to the transit level of service (LOS) relative to auto LOS. See [25] page 118 split proved unsuccessful for the following reasons:*

1. in attempting to obtain travel time and cost data for small areas, the number of trips when stratified by group was too small to be able to compute meaningful percentages.
2. when all groups were combined, groups with different characteristics were being aggregated.
3. inaccuracies in coding the data from the survey forms were encountered.

In another, unrelated research effort, Rassam, Ellis and Bennett [33] applied an n-dimensional logit model** to airport access data collected for National Airport in Washington, D.C. The authors met with only limited success, citing a lack of data stratifying air passengers according to their residence as the cause for their difficulties.

The results from the two research efforts mentioned above make it clear that further research is needed towards the development of reliable airport access models. Some of the issues that should merit special attention are discussed briefly below:

1. The Analysis Framework

Most air trip generation models and airport access modal split models assume that the demand for intercity air travel is completely inelastic with respect to the level of service on the access portion of

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* See reference [44], page 48

** The n-dimensional logit model is a recently developed modal split technique. See reference [34] the trip. This is a somewhat paradoxical assumption in view of the fact that it is widely recognized that the demand for transportation services is dependent on total door-to-door travel time and costs. The issue here is whether we can structure our analyses by focusing our attention only on the access system, and not on the characteristics of intercity air travel. This question is discussed in greater detail in the following sections of this appendix.

2. Diversity of Trip Purposes / Stratification

Airport travellers are characterized by a wide range of trip purposes and socio-economic status. It is commonly accepted that there are differences in the travel behavior of air passengers and airport employees, resident air passengers and non-resident air passengers and other classification types.* It is essential that we gain a better understanding of the inherent travel behavior of the various groups of airport travellers, so that demand models can reflect the significant stratifications.

3. Data Requirements / Explanatory Variables

There is evidence to indicate that access trip time and cost are not the only, and perhaps not even the most significant, criteria by which airport travellers make modal choices. This is particularly true for

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* For example, in the Cleveland-Hopkins Airport Access Study [44], air passengers were stratified into twelve groups according to trip purpose, residence, and local origin. Significant variations in the modal choices of these twelve groups were observed.

air passenger access trips. The survey results of the Cleveland Rapid Transit System's airport service [10] show that to a significant degree, an air passenger's access modal choice is influenced by his baggage burden, and the number of visitors accompanying him to the airport. The implication of this finding is clear. Reliable airport access modal split models must incorporate all the significant explanatory variables. The traditional use of just access time and cost is one reason why airport access split models have not yielded satisfactory results.

A2.2 Accessibility and Air Trip Generation

A2.2.1 Overview

The remainder of this appendix explores in detail* the effect of airport accessibility on air trip generation. The rapid growth in air passenger volumes has tended to hide the effect of an airport's inaccessibility on the realization of the air passenger market potential. It is tempting to consider what air trip generation would be if the quality of service on the access portion of air trips were improved. This consideration is especially important in assessing the impacts of proposed transportation alternatives that seem to promise radical improvements in airport accessibility (e.g. implementation of satelite V/STOL terminals to serve as both a feeder service to regional airports, and as departure points for short-haul trips).

Few studies have considered the impact of airport accessibility on air trip generation. Two problems plague such a study. The analyst must:

1) define a suitable measure of "the potential market";** and
2) isolate the effects of accessibility from the set of other factors which influence air trip generation.

Preliminary studies have dealt with these problems with moderate success,

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* The student is not required to understand the econometric analysis included in this section. The emphasis should be on understanding the assumptions and conclusions.

** i.e., we need to develop an understanding of to what extent (if at all) we can tap a potential air trip market which would develop with improvements in airport access.

and the evidence indicates that accessibility does have a strong influence on air trip generation. One approach, taken by the Port of New York Authority (PONYA), was based on their 1960 in-flight survey at the three New York metropolitan airports. In this study [32], PONYA computed the relative share of traffic originating from each zone in the study area for each of the three airports. As an example of their method, consider air trip generation from Nassau county. In terms of average driving time, Newark is the least accessible airport to Nassau. For all flights for which Newark provided exclusive New York air service, 10.4% of the total passenger volume originated in Nassau. At LaGuardia and Kennedy Airports, Nassau generated 14% of the total passenger volume. Thus, they hypothesize that the relative inaccessibility of Newark caused a loss of potential trip generation of $\frac{14-10.4}{14} = 26\%$. Similar analysis for all zones in the study area indicated an average 19% loss of potential trip generation for cases where counties are served exclusively by the least accessible airport in the metropolitan area.

In a 1965 paper [5], John F. Brown concluded that a more accessible airport will, ceteris paribus, serve relatively more passengers than a less accessible airport. The evidence supporting Brown's conclusion was based on an examination of the growth rates from 1946 to 1947 of air trips originating in Detroit, compared with the growth rates of a control group or origin/destination pairs. In 1947, all commercial flights from Detroit City Airport (6 miles from the CBD) were switched to Willow Run Airport (31 miles from the CBD). Brown focused attention on the growth rates between Detroit, and 9 cities within a 300 mile radius of Detroit. His control group consisted of the pairings of these 9 cities amongst themselves. He noted that the year-to-year percentage increase was smaller for the sum of Detroit pairs than for non-Detroit pairs between 1946 and 1949. Thus, he concluded that the effect of Detroit's airport relocation extended over a three year period, causing a loss in potential air trip generation ranging from 33.5% in 1947 to 46.3% in 1949. Brown tacitly assumed that, since no radical changes were experienced in accessibility to airports in the control group, the growth rates of Detroit pairs would equal the growth rates of non-Detroit pairs (in a given year) _if_ Detroit's airport was not moved.

In a 1966 critique [30] of Brown's paper, Rolla Park performed an analysis of variance on the Detroit, non-Detroit O-D data. Park claimed that Brown's use of _average_ Detroit, non-Detroit growth rates does not take account of the irregular variation of individual city pair growth rates. Thus he argues that Brown's study does not "justify any quantitative statements about the accessibility effect on passenger totals."* Park's analysis concludes that the relocation of Detroit's airport caused a significant loss of potential air trip generation only in the year immediately following the move (i.e. 1947). His estimate of the potential volume lost during that year was 28%--as compared to Brown's estimate of 33%

The following sections extend the analysis on the Detroit air passenger data. A description of the methodology employed is given in

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* reference [30], page 67

Section A2.2.4.

A2.2.2 Analysis Data

This appendix tests the following hypothesis: the relocation of Detroit City Airport in 1946 caused a significant decrease in air passenger trip generation. This loss of market potential was most pronounced for shorthaul air trips (less than 300 miles).

In order to investigate the effects of accessibility on trip generation for different stage length air trips, 3 classifications were established.

1. short-haul air trips--cities within a 300 mile radius of Detroit.
2. medium haul air trips--cities between 300 and 1000 miles from Detroit.
3. long-haul air trips--cities greater than 1000 miles from Detroit.

Data for short-haul air trips were taken from Park's 1966 study [30]. Data for the other two stage-length classifications were obtained from the Civil Aeronautics Board's (CAB) origin/destination studies for the years 1946 to 1958 [45]. The CAB data was compiled from ticket counts in the following manner:

a. in 1946, a one-month September ticket count was tabulated

b. from 1947 to 1950 inclusive, 2 one-month ticket counts were tabulated--one in March, and the other in September

c. no O-D data was collected in 1951

d. in 1952 a 2-week ticket count was taken in March

e. from 1953 to 1957 inclusive, 2-week ticket counts were taken in March and September.

f. in 1958, a 2-week ticket count was taken in March only.

The data revealed marked seasonal variation between March and September passenger totals. Since no O-D data were collected in March of 1946, it was decided to use only September data in this study. Thus, the data for medium and long-haul trip analyses consists of the September O-D passenger totals for the years 1946-1950*, and 1953-1957. For the short-haul market analysis, Park's O-D data for the years 1946-1958 (excluding 1951) is used.

The O-D trip data was used to generate a series of growth rates for each city pair and year in the analysis. The growth rate measure used here is the year-to-year change in passengers divided by the average number of passengers over the two-year period.

$$(1) \quad Y_{i,n} = \frac{V_{i,n} - V_{i,n-1}}{1/2\ (V_{i,n} + V_{i,n-1})}$$

where: $Y_{i,n}$ = growth rate for the i^{th} city pair in year n

$V_{i,k}$ = number of air passengers in the i^{th} city pair market in year k (k=n or n-1)

The use of an average passenger volume in the denominator of equation 1 was employed in order to avoid overemphasizing increases in growth rates compared to corresponding decreases.

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* the one month sample passenger totals for these years were halved to be consistent with the two week ticket counts for the years 1953-1957.

In a later section of the analysis, it is hypothesized that city pairs with a high index of initial year (1946) market penetration experience slower year to year growth rates. The index of initial year market penetration for a particular city pair is defined as the 1946 passenger count* divided by the average populations of the two cities.

$$X_{p,i} = \frac{V_{i,n}}{\overline{P}_i} \tag{2}$$

where X_{pi} = index of initial year market penetration

n = 1946

$\overline{P}_i$ = average population of the i^{th} city pair

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* the data summarized in the CAB origin/destination sample survey did not identify the number of intra-airport transfers. Ideally, we would like to count only those air trips which began from local origins in the metropolitan areas.

A2.2.3 Assumptions in the Analysis

The ultimate goal of this study is to justify or reject the general hypothesis stated on page 186. The appendix is structured in terms of a series of smaller, testable hypotheses which, taken together, build up inferences about accessibility effects on air trip generation.

It should be stated at the outset that in trying to isolate the effects of airport accessibility on the realization of air passenger market potential, we are neglecting a whole range of other factors which influence trip making behavior. Among these "other factors" are

1) changes in the level of service offered by competing modes
2) differences* in aircraft type serving Detroit; non-Detroit city pairs
3) changes in the frequency of air service over the years
4) changes in non-stop/intermediate air service
5) changes in passenger preferences; market acceptance of air travel
6) changes in the level of economic activity over the years.

Neglecting the first factor is not considered an onerous omission. On short-haul trips where the auto strongly competes with air service, it is noted that no major interstate highway construction was completed during the time period studied in this analysis. On long-haul trips, the cross elasticities of service characteristics of modes competing with air service

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* as well as the changes in aircraft type introduced during the analysis time period 1946-1958

are very small.

In neglecting factors 2 through 5, we assume that no drastic changes in the quality of intercity air service occurred between 1946 and 1958. Since jet service on domestic routes was introduced in 1959, our assumption isn't totally unreasonable. The last factor--the effect of year-to-year fluctuations in economic activity--is explicitly modeled in a later section where the yearly growths are pooled.

A2.2.4 Hypotheses Concerning the Accessibility Effect on Short-haul Air Trips

Consider the initial question-

> did the growth rate of Detroit passengers differ significantly from the growth rate of non-Detroit passengers in the year immediately following the relocation of Detroit City Airport?

Or, in other words, is it possible to explain a significant (in the statistical sense) amount of the total variation in growth rates by splitting the growth rates into two classifications--Detroit and non-Detroit. In this context, we consider the non-Detroit data as a control group--whose growth rates are drawn from a common population--against which we compare the Detroit growth rates. The control group consists of the pairings of non-Detroit cities that are within 300 miles of each other.* To test for the homogeneity of the growth rates in the control group, estimates of β_1 and β_2 were derived from the following model

$$(3) \quad Y_{i,n} = \beta_1 + \beta_2 X_k + U_{i,n}$$

where: Y_{in} = growth rates for the i^{th} (control-group) city pair in year n

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* With the following exceptions-
the Cincinnati-Youngstown, Columbus-Youngstown, Indianapolis-Youngstown, and Buffalo-Youngstown pairings were discarded from the control group because of their small passenger volumes and widely fluctuating growth rates

X_k = dummy variable = 1 if the i^{th} observation is a growth rate for city k, 0 otherwise

$U_{i,n}$ = error term

For a particular city k in year n, β_1 estimates the mean growth rate of all city pairs excluding k. β_2 estimates the difference between the mean growth rates of k and non-k city pairs. Accordingly, using the t-statistic of β_2, we can test the null hypothesis that the mean growth rate of k-city pairs is <u>not</u> significantly different from the growth rates of other city pairs in the control growth.* A summary of the results from these regressions is given in table A2.2.4-1. As a whole, it is concluded that the control group forms a homogeneous sample.**

Thus we can now proceed to test the hypothesis posed at the beginning of this section. The model is similar to equation (3)

$$(4) \quad Y_i = \beta_1 + \beta_2 X_{DET} + U_i$$

where: Y_i = growth rate for the i^{th} city pair in 1946-47

X_{DET} = dummy variable = 1 if the observation is of a Detroit pair and) if it is of a non-Detroit pair.

In this formulation, β_2 estimates the difference between the mean growth of

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* throughout this paper, we will reject a null hypothesis if our computed valve of a test-statistic exceeds the .05 level table value of the test-statistic

** although it is recognized that the extremely small sample size does not permit precise inferences.

	1946-47	1947-48	1948-49	1949-50	1952-53	1953-54	1954-55	1955-56	1956-57
Buffalo non/ Buffalo									
Chicago non/ Chicago		X							
Cincinatti non/ Cincinatti									
Cleveland non/ Cleveland							X		
Columbus non/ Columbus	X								
Indianapolis non/ Indianapolis									

HOMOGENEITY OF THE CONTROL GROUP-X INDICATES SIGNIFICANCE OF THE ESTIMATE OF β_a AT 5% LEVEL

Table A2.2.4-1

Detroit and non-Detroit city pairs. Our null hypothesis states:

- in the year immediately following the relocation of Detroit City Airport, the growth rate of Detroit's air passenger trip generation was not significantly different from the air passenger growth rates of a control group of nine cities within a 300 mile radius of Detroit.

The results of regression equation 4 are summarized below.

coefficient	estimate	t-statistic
β_1	15.3	1.58
β_2	-31.1	-1.79

F-stat (1,27) = 3.23

Detroit/non-Detroit classification 1946-47

At the 5% confidence level, the regression as a whole is not significant (computed F-statistic = 3.23; $F_{1,27,.05} = 4.21$), and we must accept the null hypothesis. Because of the inherent variability of the growth rate data, we are not able to discern any significant difference between Detroit and non-Detroit growth rates. The residuals from this regression proved to be both normal and homoscedastic--thus justifying the use of the t and F test statistics.

Regressions on the significance of the Detroit, non-Detroit classification were run for all other years in the analysis period, and the results are summarized in table A2.2.4-2

year	estimate of β_1	estimate of β_2	t(β_1)	t(β_2)	F
1947-48	14.0	-10.2	1.53	- .62	.39
1948-49	12.2	3.8	3.21	1.96	3.84
1949-50	- 5.9	13.9	-1.04	1.3	1.89
1952-53	11.1	- 0.94	4.12	- .19	.04
1953-54	22.1	-11.2	7.98	-2.22	4.95
1954-55	- 1.78	14.94	- .57	2.69	7.25
1955-56	30.75	31.52	4.96	-2.83	8.02
1956-57	- 8.02	12.50	-1.23	1.07	1.18
1957-58	- 3.47	-15.70	-1.3	-3.28	10.73

Table A2.2.4-2

The computed F-statistics of the regressions for the years 1953-54, 1954-55, 1955-56, and 1957-58 are significant. And in all of these years except 1954-55, the estimate of β_2 (as measured by $t(\beta_2)$) is significant at the 5% level. These rather surprising results contradict our intuitive feeling that the change in accessibility should effect air trip generation in the year immediately following the relocation of Detroit's airport rather than several years later.

The probable explanation of these results is that the sample size (29 observations in each year) was too small to accurately test our current hypothesis. In order to increase the precision of inference from the data base, it was decided to pool the air passenger growth rates for all years.

It was strongly expected that the pooled growth rate data would be significantly effected by fluctuations in the year-to-year "economic climate," and by the initial year air passenger market penetration (see equation 2). To verify these hypotheses, an analysis of variance (ANOVA) was performed to test the significance of:

1) a year-to-year classification of growth rates and 2) addition of an index of initial year market penetration.

To test the first classification, we pose the model:

$$(5)\quad Y_i = \beta_1 + \beta_2 X_{47} + \beta_3 X_{48} + \beta_4 X_{49} + \beta_5 X_{50} + \beta_6 X_{53} + \beta_7 X_{54} + \beta_8 X_{55} + \beta_9 X_{56} + \beta_{10} X_{57} + U_i$$

where: Y_i = growth rate for the i^{th} city-pair

X_{47} = 1 for 46-47 growth rates; 0 otherwise

•

•

•

X_{57} = 1 for 56-57 growth rates; 0 otherwise

U_i = error term

After obtaining estimates of $\beta_1, \ldots, \beta_{10}$ the explained sum of squares was computed as:

$$SSQ_{EXP} = \sum_{i=1}^{290} (\hat{Y}_i - \overline{Y})^2 = 23434$$

The full ANOVA table for this regression is shown below in table A2.2.4-3. The F-statistic, computed as the ratio of the explained mean square to the error mean square, is found to be 3.63. This exceeds the 5% critical value of F ($F_{9,279,105}$ = 1.91). Thus we can reject the null hypothesis that there is no significant variation in yearly growth rates.

source of variation	SSQ	DOF	MS	F
variation explained by time period classification	23434	9	2603.8	
unexplained	200585	280	717.3	3.63
total	224292	289		

Table A2.2.4-3: ANOVA for time period classification

To test the second classification--the index of initial year market penetration--we add the variable X_{pi} to equation 5:

$$(6) \quad Y_i = \beta_1 + \beta_2 X_{47} + \ldots + \beta_{10} X_{57} + \beta_{11} X_{pi} + U_i$$

where: X_{pi} = initial year market penetration index for the i^{th} city pair.

The explained SSQ for this regression is equal to 37959. Thus by adding variable X_{pi}, we have increased the explained sum of square (from our last regression) by 4522.

The f-statistic for the additional explanation* is computed as:

$$F = \frac{\dfrac{\text{addition to explained SSQ}}{1}}{\dfrac{\text{error SSQ}}{\text{error degree of freedom}}} = \frac{\dfrac{4522}{1}}{\dfrac{224292}{289}} = 6.42$$

(see ANOVA table A2.2.4-4 below). Since this value exceeds the table of $F_{1,289,.05}$ (=3.87), the variable X_{pi} has increased significantly the explanatory power of our model.

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* Note that the F-statistic as computed above is equal to $t^2(\beta_{11})$

source of variation	SSQ	DoF	MS	F	
variation explained by time-period classification	23434	9	2603.8		
addition to explained variance by the addition of variable X_{pi}	4522	1	4522.0		6.42
unexplained	196336	279	703.7		
total	224292	289			

Table A2.2.4-4 ANOVA for addition of variable X_{pi}

The least squares estimate of β_{11}, $\hat{\beta}_{11}$ was found to be -1.65...implying that a unit increase in the initial year market penetration index is apparently associated with a 1.65% decrease in air passenger growth rates.

We are now ready to use the pooled data to answer our primordial question --expressed below as a null hypothesis

-the relocation of Detroit City Airport caused no significant decrease in Detroit city pair growth rates.

To test this hypothesis, a dummy variable X_{D47} is added to equation 6:

$$(7) \qquad Y_i = \beta_1 + \beta_2 X_{47} + \ldots + \beta_{10} X_{57} + \beta_{11} X_{pi} + \beta_{12} X_{D47} + U_i$$

where: X_{D47} = 1 if the i^{th} observation is of a Detroit city pair in 1946-47.

The ANOVA table for this regression is presented below in table A2.2.4-5. As shown, the computed F for the additional variation explained by the addition of the 1946-47 Detroit/non-Detroit classification exceeds the critical value of $F_{1,278,.01}$ (=6.72). Thus we can emphatically reject the null hypothesis.

source of variation	SSQ	DoF	MS	F
variation explained by time-period classification and initial year market penetration index	27956	10	2795.6	
additional variation explained by addition of 1946-47 Detroit, non-Detroit classification	4737	1	4737	6.97
unexplained	191555	278	690	
total	224292	289		

Table A2.2.4-5: ANOVA for addition of variable X_{D47}

The least squares estimate of β_{12}, $\hat{\beta}_{12}$ was found to be -28.0...implying that the relocation of Detroit's airport caused a 28% decrease in air passenger trip generation in the year 1946-47.

Placing a 95% confidence interval on β_{12} (as a measure of the accessibility effect on air trip generation) we compute:

$$\hat{\beta}_{12} - t_{278,.025}\, s(\hat{\beta}_{12}) \leq \beta_{12} \leq \hat{\beta}_{12} + t_{278,.025}\, s(\hat{\beta}_{12})$$

$$-28 - 1.97(10.6) \leq \beta_{12} \leq -28 + 1.97(10.6)$$

$$-48.9 \leq \beta_{12} \leq -7.1$$

Thus with 95% confidence, we can conclude that the relocation of Detroit's airport caused at least a 7.1% loss, and as much as a 48.9% loss of potential air passenger volume.

Similar analyses of the Detroit/non-Detroit classification were performed for the years 1947-48, 1948-49, and 1949-50. The ANOVA tables for these regressions are shown in tables A2.2.4-6-8. In all these cases, we can conclude that there is <u>no</u> significant difference between Detroit and non-Detroit growth rates at the significance level of 5 %.

source of variation	SSQ	DoF	MS	F
variation explained by time period classification and initial year market penetration index	27956	10	2795.6	
additional variation explained by addition of 1947-48 Detroit/non-Detroit classification	281	1	281	.399
unexplained	196055	278	705	
total	224292	289		

Table A2.2.4-6: ANOVA - significance of a 1947-48 Detroit/non-Detroit classification

source of variation	SSQ	DoF	MS	F
variation explained by time period classification and initial year market penetration	27956	10	2795.6	
additional variation explained by addition of 1948-49 Detroit/non-Detroit classification	611	1	611	.865
unexplained	195725	278	706	
total	224292	289		

Table A2.2.4-7: ANOVA - significance of a 1948-49 Detroit/non-Detroit classification

source of variation	SSQ	DoF	MS	F
variation explained by time period classification and initial year market penetration index	27956	10	2795.6	
additional variation explained by a-dition of 1949-50 Detroit/non-Detroit classification	1936	1	1936	2.77
unexplained	194,400	278	700	
total	224,292	289		

Table A2.2.4-8: ANOVA - significance of a 1949-50 Detroit/non-Detroit classification

Summary of Major Conclusions of the Analysis Investigating the Accessibility Effect on Detroit Air Passenger Trip Generation in the Short Haul Market

1. Using unpooled data, no significant difference could be discerned between Detroit and non-Detroit growth rates in the year immediately following the relocation of Detroit City Airport.
2. The pooled data exhibited a significant year-to-year variation
3. The initial year market penetration index significantly added to the explanatory power of the model
4. The addition of a 1946-47 Detroit/non-Detroit classification proved to be significant at the 1% level
5. A 95% confidence interval on the loss of potential Detroit passenger growth in 1946-47 was determined to be

$$-48.9\% \leq \beta_{12} \leq -7.1\%$$

6. The data does <u>not</u> support a conclusion that the accessibility effect on growth rates extended over more than one year.

A2.2.5 Analysis of the Medium-Haul Air Trip Market

The analysis of the medium haul air trip market parallels the previously presented short-haul analysis. Thus the results here will be described cursorily. Using equation 3, regressions were run to test for the homogeneity of the control group sample. The results are summarized in table A2.2.5-2. As with the previous analysis, the regressions on the unpooled yearly data supports, on the whole, the assumption that the growth rates of the control group city pairs are drawn from a common population.

Using the unpooled data to test for the significance of a Detroit/non-Detroit classification (see equation 2) failed to indicate a significant accessibility effect for <u>any</u> of the years in the analysis time period. (see table A2.2.5-3) Again, it was decided that pooling the growth-rate data would increase the precision of inference. However, surprisingly, it was found that there was no significant year-to-year variation in city pair growth rates. This can be seen by examination of table A2.2.5-1, which gives the ANOVA table based on regression equation 3.

source of variation	SSQ	DoF	MS	F
variation explained by time period classification	2587	7	369.5	.97
unexplained	43514	112	388.3	
Total	46101	119		

<u>Table A2.2.5.1:</u> ANOVA significance of the year-to-year growth rate classification

	1946-47	1947-48	1948-49	1949-50	1953-54	1954-55	1955-56	1956-57
Atlanta non/ Atlanta					X			
Boston non/ Boston							X	
Charlotte non/ Charlotte								
Kansas City non/ Kansas City								
Minneapolis non/ Minneapolis								

HOMOGENEITY OF THE CONTROL GROUP-X INDICATES SIGNIFICANCE OF THE ESTIMATE OF β_2 AT 5% LEVEL

Table A2.2.5-2

Year	Estimate of β_1	Estimate of β_2	t(β_1)	t(β_2)	F
1946-1947	19.24	- 3.62	2.80	- .38	.15
1947-1948	5.17	- 6.09	.65	- .56	.31
1948-1949	15.78	- 3.06	1.62	- .23	.05
1949-1950	2.64	13.23	.30	1.10	1.21
1953-1954	26.23	-17.69	3.73	-1.84	3.39
1954-1955	5.30	6.87	1.05	.99	.98
1955-1956	15.36	- 2.44	2.32	- .27	.07
1956-1957	9.54	4.13	1.32	.42	.17

Table A2.2.5-3

UNPOOLED DATA

YEAR BY YEAR SIGNIFICANCE

OF THE DETROIT/NON-DETROIT CLASSIFICATION

MEDIUM-HAUL MARKET

The medium haul air market exhibited a remarkable stability in year to year growth rates. This fact is manifested by figure A2.2.5-1, which compares the mean yearly growth rates of the medium haul to the long haul air markets. The coefficient of variation, V, of the mean yearly growth rates for city pairs in the medium haul market is equal to 2.18. This is compared to a V = 9.34 for the long-haul market growth rates.

The pooled data was next used to test the significance of the initial year market penetration index. Since the year-to-year classificatory variables are dropped from further consideration, the model used here is simply:

$$Y_i = \beta_1 + \beta_2 X_{pi} + U_i \tag{8}$$

where: Y_i = growth rate for the i^{th} city pair

X_{pi} = initial year market penetration index for the i^{th} city pair

The ANOVA table resulting from this regression is given in table A2.2.5-4. As shown, the computed F is less than the critical value of $F_{1,118,.05}$ = 3.93. Thus, the index of initial year market penetration is also dropped from further consideration in the analysis of variance.

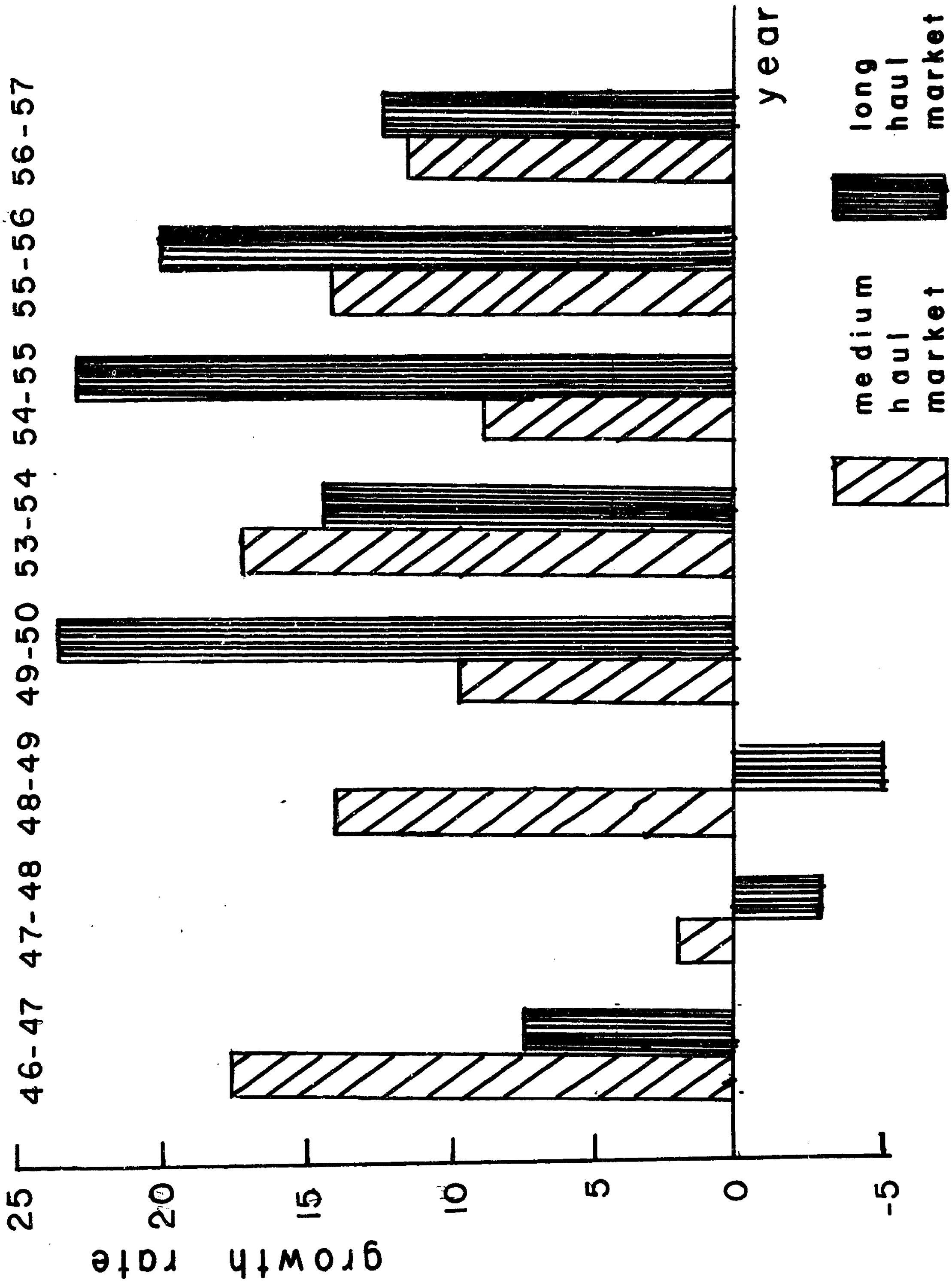

Figure A2.2.5-1

source of variation	SSQ	DoF	MS	F
variation explained by initial year market penetration index	1033	1	1033	2.70
unexplained	45120	118	383	
total	46153	119		

Table A2.2.5-4: ANOVA - significance of the index of initial year market penetration

Finally, the pooled data is used to test the significance of the Detroit/non-Detroit classification in the years 1946-47, 1947-48, 1948-49, and 1949-50. The ANOVA tables summarizing the results of these regressions are presented in tables A2.2.5-5-8. As shown, all the F values are less than the critical table value of $F_{1,\ 118,.05}$(=3.93). Thus it can be concluded that there was no significant loss of air trip generation from Detroit in the medium haul market as a result of the 1946 relocation of Detroit City Airport.

source of variation	SSQ	DoF	MS	F
variation explained by 1946-47 Detroit/non-Detroit classification	142	1	142	.36
unexplained	46011	118	390	
total	46153	119		

Table A2.2.5-5

source of variation	SSQ	DoF	MS	F
variation explained by 1947-48 Detroit/ non-Detroit classification	1331	1	1331	3.50
unexplained	44822	118	380	
total	46153	119		

Table A2.2.5-6

source of variation	SSQ	DoF	MS	F
variation explained by 1948-49 Detroit/ non-Detroit classification	11	1	11	.029
unexplained	46142	118	392	
total	46153	119		

Table A2.2.5-7

source of variation	SSQ	DoF	MS	F
variation explained by 1949-50 Detroit/ non-Detroit classification	659	1	659	1.70
unexplained	45494	118	387	
total	46153	119		

Table A2.2.5-8

Summary of Major Conclusions of the Analysis Investigating the Accessibility Effect on Detroit Air Passenger Trip Generation in the Medium Haul Market

1. Using pooled or unpooled data, no significant difference could be discerned between Detroit and non-Detroit growth rates in the years following the relocation of Detroit City Airport.
2. The pooled data did not exhibit a significant year-to-year variation.
3. The initial year market penetration index was not a significant variable in explaining variation in the pooled growth rates.

A2.2.6 Analysis of the Long-Haul Air Trip Market

In this section results are presented in tabular form without further discussion. Table A2.2.6-1 shows the results of regressions of the form given by equation 2 using unpooled long-haul growth rate data. Table A2.2.6-2 presents an ANOVA for regression equation 3 using pooled data. Table A2.2.6-3 shows the ANOVA for the addition of the initial year market penetration index. As indicated, the estimated coefficient of this variable is not significant at the 5% level. Thus the initial year market penetration index is dropped from further analysis. Tables A2.2.6-4-7 present ANOVA's testing the significance of the addition of a Detroit/non-Detroit classificatory variable in the years 1946-47, 1947-48, 1948-49, and 1949-50.

Year	Estimate of β_1	Estimate of β_2	$t(\beta_1)$	$t(\beta_2)$	F
1946-1947	9.07	- 4.16	1.03	- .25	0.067
1947-1948	- 2.18	- 3.27	- .37	- .30	0.09
1948-1949	-18.76	43.75	-2.88	3.66	13.41
1949-1950	25.80	- 6.60	4.64	- .64	.41
1953-1954	15.12	- 2.31	2.80	- .23	.054
1954-1955	26.21	- 9.61	5.99	-1.19	1.43
1955-1956	22.01	- 6.94	3.83	- .65	.43
1956-1957	8.62	12.32	1.72	1.34	1.81

Table A2.2.6-1

UNPOOLED DATA

YEAR BY YEAR SIGNIFICANCE

OF THE DETROIT/NON-DETROIT CLASSIFICATION

LONG-HAUL MARKET

source of variation	SSQ	DoF	MS	F
variation explained by time-period classification	24325	7	3475.	4.79
unexplained	150984	208	725.4	
total	175309	215		

Table A2.2.6-2: ANOVA significance of the year-to-year growth rate classification

source of variation	SSQ	DoF	MS	F
variation explained by time period classification	24325	7	3475	
additional variation explained by addition of index of initial year market penetration	733	1	733	.976
unexplained	150251	207	751	
total	175309	215		

Table A2.2.6-3: ANOVA significance of the index of initial year market penetration

source of variation	SSQ	DoF	MS	F
variation explained by time period classification	24325	7	3475	
additional variation explained by addition of 1946-47 Detroit/non-Detroit classification	98	1	98	.14
unexplained	150886	207	730	
total	175309	215		

Table A2.2.6-4

source of variation	SSQ	DoF	MS	F
variation explained by time period classification	24325	7	3475	
additional variation explained by addition of 1947-48 Detroit/non-Detroit classification	60	1	60	.077
unexplained	150924	207	730	
total	175309	215		

Table A2.2.6-5

source of variation	SSQ	DoF	MS	F
variation explained by time-period classification	24325	7	3475	
additional variation explained by addition of 1948-49 Detroit/ non-Detroit classification	10775	1	10775	15.9
unexplained	140209	207	678	
total	175309	215		

Table A2.2.6-6

source of variation	SSQ	DoF	MS	F
variation explained by time-period classification	24325	7	2475	
additional variation explained by addition of 1949-50 Detroit/ non-Detroit classification	245	1	245	.36
unexplained	150739	207	729	
total	175309	215		

Table A2.2.6-7

Summary of Major Conclusions of the Analysis Investigating the Accessibility Effect on Detroit Air Passenger Trip Generation in the Long-Haul Market

1. Using pooled or unpooled data, no significant difference could be discerned between Detroit and non-Detroit growth rates in the year immediately following the relocation of Detroit City Airport.
2. The 1948-49 Detroit/non-Detroit classification was significant at the .01 level for both pooled and unpooled data sets (it is not probable that the accessibility effect is the cause of the significant classification. In fact, the Detroit city pairs had a higher mean growth rate than the non-Detroit city pairs in this year).
3. The year-to-year classificatory variables were significant at the .05 level, while the initial year market penetration index was not.

A2.2.7 The Need for Future Research

The preceding sections have demonstrated that, based on the Detroit experience, accessibility does have a significant effect on short-haul air trip generation. Moreover, studies done in Dallas/Fort Worth, New York, Buffalo/Niagra Falls, and Green Bay [5] suggest that our conclusion is not an isolated case. One immediate implication of these analyses is apparant. Failure to take the effect of inaccessibility into account can lead to the development of airports to serve markets which, in fact, can only be partly served from the sites selected, thus destroying the initial economic justification for such airports.*

Traditionally, air trip generation models have ignored explicit consideration of airport accessibility. The methodology described in the literature [6], [14], [31] is characterized by two basic approaches:

1) regression analysis on aggregate socio-economic descriptors
2) market analysis method

The first approach employs a correlative multivariate regression model which predicts air patronage as a function of population, employment, national income, and other socio-economic variables. The model is correlative in the sense that it is not based on a causal hypothesis of travel behavior. As such, the model is wholely insensitive to changes in the level of service on the access portion of an air trip, the price of air travel, or the level of service on competing modes.

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* reference [5], page 58

The market analysis method takes a slightly different approach. First, a national or regional population is stratified by socio-economic class (e.g. income, education, age, occupation) into a set of sub-population "cells." For each cell, past in-flight survey data is used to compute an air travel participation rate (i.e. the number of air passengers per thousand members of a particular cell). The population of each cell is projected for a future year, and air patronage is estimated by applying the calculated participation rates and expanding the cell totals in accordance with the sampling rate of the survey.*

As with the correlative multivariate regression technique, the market analysis method is not sensitive to changes in the level of service of air travel or competing modes. Both approaches make a rather heroic ceteris paribus assumption concerning the characteristics of future intercity transportation services. This is a particularly onerous omission in the analysis of trip generation and modal split in short-haul corridors. In the Northeast Corridor, for example, air fares have risen dramatically over the past few years.** Coincidentally, rail service in the corridor has improved markedly with the introduction of Turbotrain and Metroliner services.

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* Since the majority of air travelers are in high income/education cells, sampling rates for other cells are quite small. See reference [31].

** In January, 1969, the CAB fare formula for short haul air trips was changed from $6.44 + 5.7 cents/mile to $9.00 + 6 cents/mile. A special congestion route surcharge of $4.00 was added to the Boston-New York and Washington-New York fares as of February 1, 1971. Moreover, the CAB is currently considering an application from the airlines for a fare increase of more than 10 percent.

Decreased time savings, and rising fares have made it increasingly evident that air transportation's competative advantage over ground transport is dwindling in short haul corridors. Recent developments in Europe and Japan show that improved rail services make a significant penetration into air market shares. One striking example is the London-Manchester/Liverpool corridor where British Rail introduced an improved (faster, more frequent), electric rail service in April, 1966. In a traffic survey conducted in October, 1966 it was found that [12]:

-Before electrification, 59 percent of the journeys from the North-West to London were made by rail, 23 percent by air, 4 percent by coach, and 14 percent by private car.

-After electrification, the figures were 70 percent by train, 11 percent by air, 5 percent by coach, and 14 percent by car. The total number of journeys made from the North-West to London in the second survey was about 17 percent above the number in the first survey.

What can be learned from the British Rail experience? It seems clear that intercity trip generation <u>and</u> modal choice decisions are related to the quality of the available transportation services. Research in the areas of V/STOL technology and high speed ground transport holds the promise of drastically altering the present characteristics of intercity transportation services. It is, therefore, particularly important that we develop techniques to analyze intercity travel behavior for short haul corridors in the proper context--that of a multimodal network in which travel decisions are based on perceptions of the relative merits of mode-specific levels of service. We should not continue to follow the myopic approach of projecting market shares by extrapolating past trends.

Ideally, models should be developed to represent intercity travel as shown schematically in figure A2.2.7-1 [2]. Each trip is considered to originate in a subzone of the origin city, and terminate in a subzone of the destination city. In both the origin and destination cities, a local access network characterizes the level of service between the subzones and the intercity terminals. Thus the model explicitly recognizes that access characteristics affect trip generation and modal choice. The line haul portion of the trip is represented by links from the intercity terminal in the origin city, and the intercity terminal in the destination city.

The demand model to be used in accordance with this network representation should be structured to relate trip-making with characteristics of the travelers, and the levels of service on available modes. Direct demand models of this form have been used in the Northeast Corridor Transportation Project [27], and efforts should be directed towards improving our understanding of intercity passenger demand.

The analysis taks suggested above is formidable. It is proposed in order to stimulate discussion on possible avenues for future research. Ultimately,lack of data* will limit our ability to calibrate and implement

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* intercity data is generally not available on a subzone level.

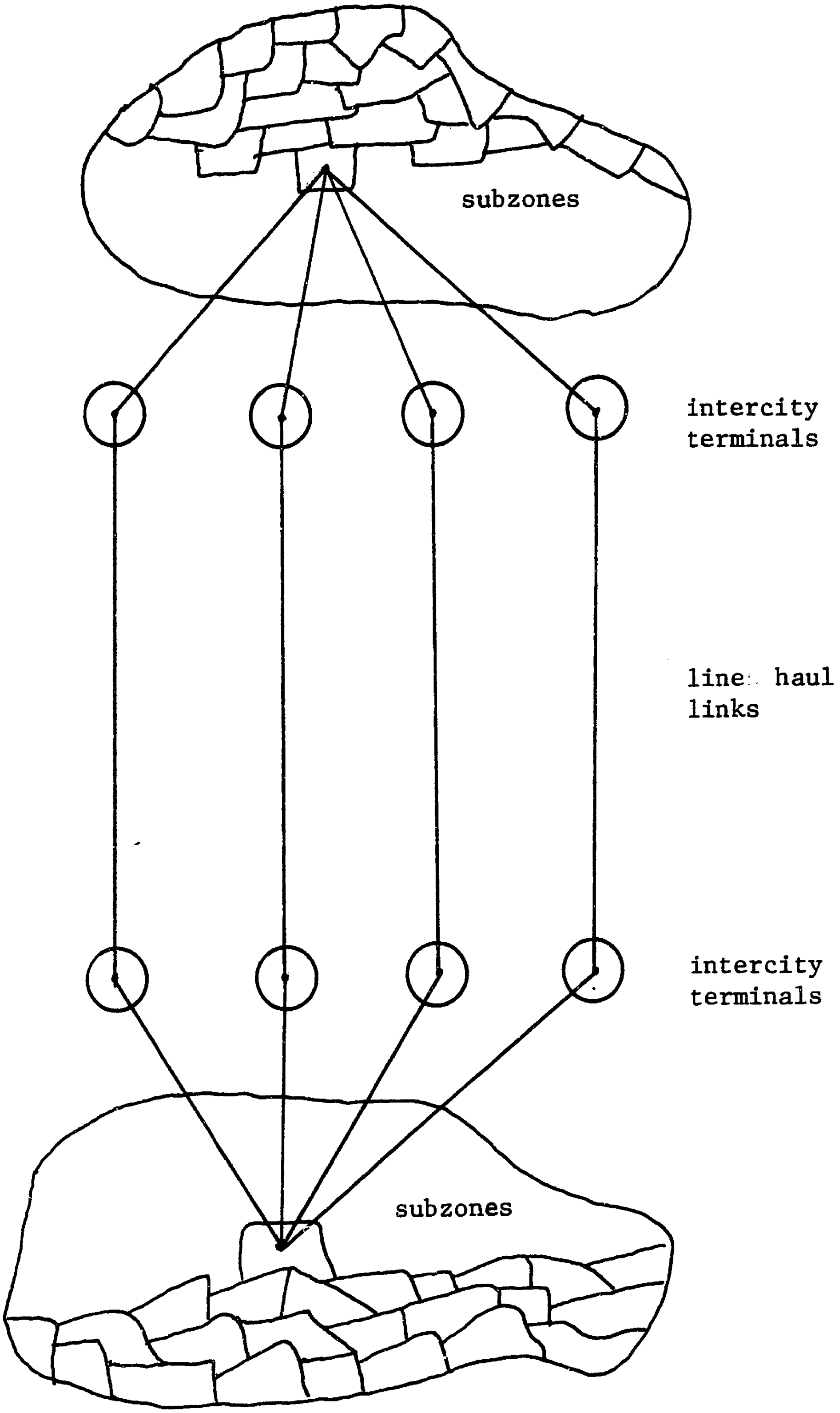

Figure A2.2.7-1

intercity demand models. However, it is strongly believed that the extent to which we can rationally plan for improvements in short-haul intercity transportation services, is contingent on the development of a more realistic framework for analysis.

APPENDIX 3

Revised Final Case Study Assignment

Final Assignment

The purpose of this assignment is to test your understanding of some of the significant issues involved in modelling the airport access problem. The percentages in paretheses indicate the relative weights assigned to each question.

(25%) 1. Several simplifying assumptions were incorporated into the base case analysis. Itemize the most crucial assumptions and discuss their significance in the base case simulation

(15%) 2. Suppose we had adopted the explicit approach (as discussed in lecture and section 5.1) to modelling the interaction between urban work commuter flows and airport access flows. Indicate the necessary changes in the DODOTRANS simulation.

- What additions would have to be made to the network?
- How would the volume/delay set change?
- What types of data would be required for the analysis?
- Try to estimate the number of DODOTRANS zones required for this simulation

(10%) 3. As described in section 5.6, the simplified form of the McLynn demand model can be expressed as:

$$V_{ik} = \frac{V_i C_{ik}}{\sum_m C_{im}}$$

a. According to this model, will the total number of trips (by all modes) from district i change if the level of service on mode k is improved? if the level of service offered by all modes is improved? Is this behavior realistic? Does this bias the results?

b. Show that the cross elasticity of demand for mode k with respect to a change in the travel time of mode 1 is given by:

$$E_{k,t_1} = - b_1^1 \Omega_1$$

Discuss this result. What does it imply about the change of volume on all modes k ($k \neq 1$) in response to a change in the travel time on mode 1?

(10%) 4. The McLynn demand model incorporated in this analysis considered access travel time and cost as the only components of airport access level of service. Are there other variables which you feel are particularly important in determining travellers' modal choices?

- If so, describe how these variables could be quantified.
- Would it be possible to collect data on these variables?

(10%) 5. One alternative that has been suggested to alleviate growing ground access and airport congestion is the use of helicopters both as a feeder to major metropolitan airports, and as a short-haul intercity (e.g. Boston-New York) service. Could this alternative be tested within the framework adopted in this case study? Why or why not?

(30%) 6. What improvements can you suggest to the structure of the airport access analysis? Be specific!

a. Assume that you have been hired as a consultant by the city of Boston to make recommendations for improving airport access to Logan. You have been given a computer budget substantially larger than the 1.20 class budget. However, you are aware of the severe lack of data (see section 5.1.2) on Logan's access. Since your study is to run for only 9 months, you will not have time to conduct extensive data collection procedures. The types of alternatives you will be testing range in scope from the do-nothing case to the use of helicopters in an intercity/feeder capacity (see question 5).

How would you structure a DODOTRANS analysis? Discuss in terms of the network, volume/delay functions and demand model. What would be the major assumptions in you analysis?

b. Suppose now that your time constraints were removed, and your budget allowed extensive data collection. Would your analysis change? Discuss briefly.

III. Conclusions and Recommendations

The Airport Access Case Study is currently being presented for the second time in the Urban Transportation Laboratory. The comments and suggestions received from the students have indicated that in general they accept the case study approach as an effective format for gaining an understanding of complex, real-world transportation systems. Several students suggested that it might be useful to present a series of shorter case studies so that the course could cover a wider range of transportation problems. Others however were a bit frustrated by some of the limiting assumptions that had to be adopted even within the scope of the major case studies. It is extremely encouraging to note that this sense of frustration reflects the students' understanding of the tremendous complexity of urban transportation problems, and our relatively limited ability to simulate these systems on the computer.

The differences between the Southeast Corridor Case Study [3] and the Airport Access Case Study illuminated the versatility of DODOTRANS as a planning tool. The students appreciated the usefulness of DODOTRANS in providing a framework to structure a wide range of transportation systems problems. However, the shortcomings of DODOTRANS were also made apparent. Like any modelling system, DODOTRANS forces the analyst to make a series of assumptions--in the structure of the network, volume/delay set, modal data, and activity system characteristics, especially. Teaching the students how to structure a transportation systems analysis has been an extremely important aspect of the course. Throughout the case studies and lectures, the class was encouraged to recognize the nature of possible biases resulting from the various assumptions incorporated into the case studies.

The Airport Access Case Study was characterized by a particularly long list of simplifying assumptions. There was a high degree of aggregation in the choice of areal units (i.e. DODOTRANS districts), and in the definition of actors in the analysis. The implicit analysis (see section 5.1), and use of horizontal volume/delay functions limited the precision with which we could predict consequences. Moreover, the adoption of an analysis framework encompassing only the access network limited the types of alternatives that could be evaluated. For example, within the structure of the case study simulations, the students were unable to test alternatives specifying the use of V/STOL technology both as a feeder to Logan Airport, and as a short-hual intercity service.

As indicated by their reponses to a course evaluation questionnaire after the first semester of use of the case study, the students recognized the limitations of the Airport Access Case Study. This has been gratifying in that it shows that the students have thought through the various steps in the airport access analysis. Therefore, in the second semester (spring 1971), the case study was handled differently from the preceding term. The students were not required to formulate and test alternatives according to the final assignment given in section 9.0. Rather, the aim of the case study was to stimulate the class' understanding of how to structure a transportation systems analysis. The lectures covered a variety of topics concerning approaches to modelling airport access demand. (see appendix 2). Following the lectures, the students were given the airport access case study as an example of one approach to modelling the airport access problem.

The students were asked to critique this approach. Special attention was given to ensure that the class understood the nature of inherent biases of the assumptions in the analysis. The final assignment* further required the student to structure alternative approaches to modelling the airport access problem. The intent here was to have the students use the theory covered in the introductory lectures together with their experience with the capabilities of DODOTRANS to grapple with the problems of structuring an analysis.

As a research project, the preparation of the Airport Access Case Study has been useful in defining the nature of the airport access problem, the difficulties encountered in modelling the system, and the critical areas where further research is required.

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* See appendix 3.

The econometric analysis in appendix 2 has shown that the growth of short-haul air travel is significantly related to the quality of access service. This has a particularly important implication for Boston where 36% of Logan's passengers are destined for New York.

Whereas the case study focused attention primarily on the access network to Logan, it is a conclusion of this research project that further work is required in analyzing the airport access problem in its proper context--as a component of the multimodal intercity transportation system.

In terms of the specific content of the case study, the conclusions were generally as expected. Boston's airport access is characterized by a highly dispersed, auto-dominated flow pattern. The dispersed origin pattern tends to discourage alternatives proposing fixed-route transit services linking the airport and the CBD. Furthermore, unlike the Southeast Corridor Case Study [3], we are not dealing with high density corridor movements. Thus the financial viability of public transportation alternatives is questionable.

Although the limitations imposed on the scope of the analysis were formidable, the intent was to illustrate the structure of the overall analysis process. Further research is required in the area of modelling airport access analyses as outlined in the conclusions to appendix 2.

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