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MOBILITY OF PEOPLE AND GOODS IN THE URBAN ENVIRONMENT

MOBILITY OF THE HANDICAPPED AND ELDERLY

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SECOND YEAR FINAL REPORT

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16. Abstract

An evaluation methodology for the analysis of alternative transportation improvements for the handicapped and elderly is proposed. The approach is based on the ability to incorporate the qualitative attributes of transportation systems which are particularly significant to the handicapped and elderly groups. These attributes include comfort and convenience, security and safety, and accessibility. In addition, this study addresses the issues of demonstration projects planning and offers guidelines for the design of demonstration experiments which can produce results that are capable of objective analytical interpretation.

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EXECUTIVE SUMMARY

The purpose of this study has been to develop a methodology for the evaluation of transportation improvements to facilitate the mobility of the handicapped and elderly in an urban environment.

The study concentrated on three aspects of analysis: the first dealt with the identification of the transportation problems of the handicapped and elderly and their levels of travel demands; the second aspect dealt with the need for the development of a technique which allows for the quantification of non-tangible variables such as travel comfort and convenience, security and safety, and accessibility; and the third aspect dealt with the development of an analytical approach to the design of transportation demonstration projects for testing transportation improvements proposed by the planner to correct identified deficiencies in current transportation services.

These three issues have long been in need of attention to improve the state-of-the-art in the study of transportation needs of the handicapped and the elderly, and to develop solutions which are effective in meeting these needs in terms of cost and goal-achievement.

This report is intended to provide technical assistance to local planners involved in the planning, design, and evaluation of transportation improvements for the transportation disadvantaged.

1.1 User Problems and Levels of Travel Demand

The development of transportation improvements for the handicapped and elderly requires a knowledge of the problems experienced by these groups in their use of existing transportation facilities or modes. In addition, estimates of existing and latent travel demands are required for assuring a reasonable level of transportation supply which is capable of satisfying user demands.

This study has identified the physical travel barriers inherent in the existing modes of transportation available to the handicapped and elderly. These barriers were identified and categorized for each of three levels of handicap severity*, and for each transportation mode.

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*WC: those confined on wheelchair
NS : those who cannot climb steps
S : those who can climb steps

In addition, preferences for transportation improvements by the handicapped have been summarized by purpose of trip.

A method for estimating the travel demand of the subject population has been developed for the purpose of estimating the types and size of transportation improvements to meet the needs of each type of handicap. This method differentiates between existing and latent travel demand.

1.2 Evaluation of Transportation Systems

The ability of relating improvements directly to identifiable population subgroups, and to measure the effectiveness (utility) of these improvements in reducing specific travel constraints, is a necessary condition for the development of responsive and financially feasible transportation improvement projects.

The results of the analyses have shown that it is possible to evaluate transportation improvements for the handicapped and elderly in terms of qualitative issues when these can be expressed in terms of utilities which are perceived by the population groups affected by these improvements. Alternative improvement plans may then be evaluated in terms of aggregate or disaggregate utilities which may accrue to the particular population subgroup or the population as a whole.

In this study we have proposed a technique with which it is possible to take objectively into account the qualitative descriptions of transportation systems which are most relevant to the issues confronting the handicapped and elderly population groups. These are convenience and comfort, security and safety, and accessibility.

Based on the distribution of ridership in these various subattributes and the associated perceived utility return for these subattributes, the benefit provided by a proposed or existing service can be effectively quantified. These distributions and utility levels are to be obtained from survey data.

1.3 Planning for Demonstration Projects

The current state of knowledge in the area of cause and effect of transportation systems improvements for the handicapped and elderly is rather limited. A convenient approach commonly used in this analysis is the demonstration project. Although the demonstration project approach has been around for some time in the field of transportation planning*, its design, implementation and monitoring has been left to the localities affected. This practice has resulted in "hit and miss" attempts which in many cases involved expenditures of considerable magnitude and disappointing results.

Research done as part of this study has resulted in the development of guidelines to the planner or analyst involved with the structuring of demonstration projects. The methodology from which the guidelines emanate is fully described by Stephanis** in his doctoral dissertation, and is based on analytical techniques which look promising enough to warrant calibration of the model in an actual urban setting.

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* For example see HUD/UMTA Mass Transit Demonstration Projects implemented since the mid-1960's for the purpose of improving the mobility of the poor. See T. Floyd's "A Progress Report on Experiments Under the Urban Mass Transportation Act" in Conference on Poverty and Transportation, PB 180956.

**Stephanis, B., The Planning Process for Demonstration Projects, Ph. D. Dissertation, Polytechnic Institute of New York, June 1976.

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CHAPTER 1

PREFACE

The transportation resources available to the urban population consist of private automobiles, public transit, taxis and a limited supply of special-purpose vehicles. These resources are not equally distributed among the population:

- Private automobiles - The poor, the elderly, the handicapped and the young are extremely limited in the use of this mode.
- Public transit - Many of the handicapped cannot use transit because of physical barriers; regional coverage of urban opportunities is limited to the size of the system and its configuration. This creates a mobility problem for those who have no access to private autos.
- Taxis - There is a cost-barrier in the use of taxis by the poor, the elderly, the handicapped, and the young.
- Special-Purpose Vehicles - Limited in number and to specific areas, time, and user groups.

In general, it may be stated that those without access to an automobile are severely constrained in their mobility. Public transit, taxis, and special-purpose vehicles are the alternatives to the automobile. But these services tend to serve travel demand in a limited way. The groups most heavily dependent on these alternative modes are the poor, the elderly, the handicapped and the young. Because these four groups rely primarily on the non-automobile mode for access to urban opportunities they are referred to as <u>transportation disadvantaged</u>. When one includes adults living in zero and one-car households (not having first claim on the car) Crain* estimates that about 50 percent of the U. S. population is transit-dependent (or transportation disadvantaged).

The objective of this report is to discuss in detail the mobility problems of two major subgroups of the transportation disadvantaged: the handicapped and the elderly. The ability of using mechanized travel modes becomes a crucial factor for the handicapped and elderly in satisfying their need for human interaction. And the planning for transportation facilities and services to serve the needs for these groups requires specific knowledge of their problems and preferences with and for improved transportation systems.

This study has focused on the accessibility problems experienced by the physically handicapped with the vehicle access and egress features; and with the overall levels of comfort and convenience which should be provided by an improved service to satisfy the mobility needs of the handicapped and elderly. The analysis of these issues has

*<u>Conference on Transportation and Human Needs in the 70's</u>, The American University, August 1972.

produced an evaluation methodology which may be used by the planner to assess needs and to develop improved services which are responsive to the requirements of the handicapped and elderly and the financial constraints of the operating or funding agencies.

CHAPTER 2

INTRODUCTION

2.1 Objectives

This report discusses the issues involved in the planning, evaluation and selection of transportation improvements for the handicapped and elderly population living in our urban environment.

The issues addressed in this report include:

- The types of transportation problems faced by the handicapped and elderly
- The types of physical transportation improvement options which are implementable to meet their transportation needs
- A workable methodology to quantify user benefits
- Analysis techniques for comparing alternative transportation improvement options, and
- A realistic approach in the planning of demonstration projects which are capable of meeting expected goals.

Thus the objectives of this study have been:

- To develop an analytical technique which quantifies the user benefits (tangible and intangible; direct and indirect) of transportation improvements
- To develop a framework for the evaluation of transportation improvements, and
- To develop a methodology for the planning and evaluation of transportation demonstration projects.

2.2 Scope

This study is based on the findings of the First-Year Final Report (1) which consisted of an analysis of transportation problems of 121 orthopedically handicapped adults living in the Borough of Queens, New York City, and an analysis of the transportation problems of the elderly. The results of the First-Year Study provided the basis for the identification of transportation barriers and suggested the need for their removal through transportation improvements. This report proposed a method for evaluating transportation system improvements with respect to their overall cost-effectiveness (measured in terms of cost-utility ratios) as well as to their ability to impact selected user groups. For purposes of discussion three categories of physical handicap were considered and were grouped into functional mobility categories:

(1) Those who are confined to wheelchairs (WC)
(2) Those who cannot climb steps (NS)
(3) Those who can climb steps (S).

The study area used for testing the evaluation methodology was the community of Astoria, New York City. Astoria contains 195, 402 persons (2) living in 6.3 sq. miles. The estimated ambulatory handicapped population (eight years of age and older) in Astoria is 13, 700 persons, of whom 3, 500 persons are elderly (3). The study area is served by 26 miles of bus lines and 18 miles of subway lines, and most of the elderly and handicapped (75%) live within two city blocks from a bus line (1).

In addition to the evaluation methodology, this report also contains suggested guidelines for the planning and monitoring of transportation improvement projects. The proposed method discusses the key issues involved in demonstration projects planning, based on an analytical formulation for the conduct of such projects.

2.3 Organization of Report

This report is organized into eight chapters. Chapters 3 through 7 discuss the relevant work done in the identification of user problems and travel demand, the evaluation methodology and a case study example to illustrate the evaluation methodology.

Chapter 8 presents suggested guidelines for the planning of demonstration projects.

2.4 References

1. "Mobility of People and Goods in the Urban Environment: Mobility of the Handicapped and Elderly," First Year Final Report, Polytechnic Institute of New York, January 1975.

2. U.S. Census, 1970.

3. "Transit Needs of the Elderly and Handicapped," TS No. A122/ Project No. IT-09-0034, Tri State Regional Planning Commission, December 1975.

CHAPTER 3

USER PROBLEMS AND TYPES OF TRANSPORTATION SERVICES

3.1 Introduction

The types of transportation problems affecting the handicapped and the elderly have been discussed in the Final Report of the first year work (1). In that study the transportation problems of the handicapped were identified and categorized into two groups: those related with the presence of physical barriers, and those associated with psychological and economic variables. A brief summary of the major findings of the First-Year Report is given below to provide the reader with an element of continuity between the work reported herein and that which has preceded it.

3.1.1 The Physically Handicapped

The first year study was based on (1) contemporary records of actual trip making and (2) psychological variables extracted from interviews. The sample included 121 persons, 61 men and 60 women in the borough of Queens, New York City.* The degree of disability was assessed; most persons had long-term disability. The average age was 47; half were unemployed. The median income was $750 per month. The sample involved consisted of mostly white, middle-class, middle-aged, apartment dwellers.

Mobility indices were developed; it was found that those who use the bus or the subway lived longer at their current residences. Such travelers most likely lived in walk-up apartment houses rather than elevator buildings. They are older, belong to more organizations, and have had their disabilities a shorter time. Psychologically they have a greater feeling of control over their environments.

Taxi users have higher levels of self-assurance than others of the group. This group uses prosthetic devices and exudes greater confidence than others.

Those who used car services were in the poorest physical and psychological condition of the group, and those who use special car or

*Generalization of these results may not be justifiable until comparative studies are available for other areas.

minibus services have similar characteristics, while including more lower-income women.

Users of private cars have higher incomes, and are generally better-educated males. The private car was, in fact, the most preferred mode, but with greater disability, there is less use of the private car. 42.5% of the group were employed.

Trip-making varied from 3.26* to 1.31* trips per day. The largest proportion was for shopping (33.7%), with most trips within the neighborhood (24%). Trips for medical reasons were low (4.3%).

Public bus and subway was most used by those who could negotiate steps; taxi by those with the least physical handicap; car service (called by telephone) by those with the greatest physical handicap.

Although the private automobile was the most important travel mode for 9 out of 11 trip purposes (the car/minibus is the most important for trips to hospitals and schools), there is a great tendency toward the walk/wheelchair mode for short, neighborhood-oriented trips (for shopping, visiting, religion); high use of car service for shopping outside the neighborhood and doctor/hospital visits; and a lesser demand for car service for work, visiting, and recreation trips.

Major barriers as perceived by members of the sample group include long flights of stairs, high steps, the need to ride while standing, the need for rapid movement, crowds, handling baggage, and long walking distances.

Improvements to available transportation was seen as extremely important by some 44% of the sample; very important by about 30%. The importance of improvements was related to the degree of disability, and was seen as most important by those with two affected limbs, wheelchair users, or those with greater socio-economic, physical, and psychological problems.

The improvement chosen as most important was door-to-door, or van service.

3.1.2 The Elderly

The elderly represent 53% of the handicapped; 35% of the elderly are handicapped. In a related effort, the travel characteristics of the

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*Including walking trips.

elderly were studied, with the purpose of identifying variables useful in characterizing travel behavior, and developing a method to determine latent demand for specific transportation improvements.

The elderly make 4 or 5 trips per week per person, excluding walking trips. About 54% are by automobile, 28% by subway, 15% by bus. Shopping, medical, and personal business trips are the most common.

The significant variables affecting travel characteristics of the elderly are:

- auto availability
- driver license availability
- income
- physical condition
- residential density.

There is a high correlation between health and functional ability and income.

It was found that the demand for transportation changes or innovation among this group is usually overestimated by the members of the group.

3.2 Specific Problems

For the purpose of this report, the transportation problems of the handicapped and elderly are discussed in terms of physical barriers inherent in the public transportation system, with the objective of developing improved systems which reflect the preferences of this population subgroup.

3.2.1 Difficulty in Using Transportation Modes

To assess barriers within transportation modes, the percentage was calculated for those respondents who stated that a specific barrier within a mode was a severe problem for them. These percentages were then rank ordered to obtain a list of barriers within each mode which reflected the degree of severity associated with each obstacle. As seen in Table 3-1, different transportation modes present different barriers to the orthopedically handicapped. In addition, some modes present more numerous barriers and barriers which are more severe in that they affect greater numbers of handicapped.

It is clear that barriers to using public transportation are more numerous and severe. The subway, in particular, presents many difficult obstacles. Long stairs would be a severe problem for 71.9 percent of the handicapped wishing to use the subway. High steps would be a severe barrier to most handicapped wishing to use the public bus (73.9%) as well as the subway (68.9%). Other problems for a majority of handicapped in using the subway and bus include the need to ride standing, the need for rapid movement, the need to move in crowds, and handling baggage. In addition, getting on and off the bus, and long walking distances for both the bus and subway, present great difficulty for most of the respondents.

In contrast with public transportation, other modes present relatively fewer barriers for a majority of handicapped. Personal cost is the barrier affecting the greatest number of handicapped in the use of a taxi or car service. The need to ride standing is the most severe problem associated with use of the specialized car/minibus service. The private car would appear to present the fewest barriers to the handicapped.

3.2.2 Specific Difficulties Across Transportation Modes

As can be seen in Table 3-1, physical barriers constitute a severe problem for a large number of respondents across all transportation modes. High or long stairs, the need to walk long distances, the need to move rapidly, to ride or wait while standing, and to move in crowds, are the most frequently cited barriers across all modes.

In contrast, "psychological" barriers to travel are cited as being a severe problem by few handicapped. Thus, fear for one's physical safety, a fear which is related to the presence of obstacles in the physical environment, is a severe problem in riding the bus or the subway for about 45% of the respondents. In contrast, the fear of inconveniencing other travelers affects less than 10% of the handicapped in any mode. Fear of assault is cited as a severe problem by only 26.3% of the respondents in relation to riding the bus, and by 18.3% in relation to riding the subway.

Many barriers seem to present more difficulty in public transportation than they do in the more individualized modes. Both long

TABLE 3.1

Barriers Within Transportation Modes which Constitute a Severe Problem for Handicapped

Barriers within Modes:	% who find barrier a severe problem
SUBWAY	
Long stairs	71.9
High steps	68.9
Need for rapid movement	67.0
Need to ride standing	66.7
Long walking distances	63.8
Movement in crowds	59.3
Baggage	52.0
Overhead grips	51.2
Fear of physical safety	45.8
Need to wait standing	44.4
Escalators	39.8
Directness	37.1
Sudden vehicle movement	36.7
Traveling alone	35.4
Inability to rise from seat	32.3
Aisle width	25.5
Width of doors	18.4
Fear of assault	18.2
Getting on and off the vehicle	13.9
Handrails on steps	13.7
Fare collection	11.1
Vertical handholds	9.3
Seating comfort	9.0
Inconveniencing others	8.8
Personal cost	6.6
Seating area	3.7
PUBLIC BUS	
High steps	73.9
Need to ride standing	67.9
Need for rapid movement	63.5
Movement in crowds	55.0
Getting on and off the vehicle	54.9
Long Walking distances	54.7
Baggage	53.3
Overhead grips	49.4
Fear of Physical safety	44.6
Need to wait standing	44.4
Directness	39.8
Sudden vehicle movement	38.2
Traveling alone	35.4
Rise from seat	33.0
Fear of assault	26.3
Use of handrails on steps	16.3

Table 3.1 cont.

BUS cont.	% severe problem
Getting on and off	13.9
Vertical handholds	9.6
Seating comfort	8.5
Inconveniencing others	8.0
Aisle width	6.2
Personal cost	5.8
Seating area	2.5
TAXI	
Personal cost	54.1
Need for rapid movement	41.2
Long walking distances	39.6
Need to wait standing	37.2
Baggage	26.7
Traveling alone	19.4
Rise from seat	18.8
Physical safety	13.6
Getting on and off	12.1
Fear of Assault	8.5
Sudden vehicle movement	6.5
Width of doors	5.9
Inconveniencing others	4.8
Fare collection	4.2
Seating area	3.3
Directness	2.9
CAR SERVICE	
Personal cost	55.7
Need for rapid movement	39.2
Baggage	26.1
Long walking distances	25.0
Traveling alone	18.6
Rise from seat	17.7
Getting on and off	12.3
Physical safety	13.3
Fear of assault	8.6
Sudden vehicle movement	6.5
Width of doors	5.9
Fare collection	5.7
Inconveniencing others	4.8
Seating area	4.3
CAR/MINIBUS FOR HANDICAPPED	
Need to ride standing	55.7
Need for rapid movement	39.8
Overhead grips	39.7
Long walking distances	36.1

Table 3.1 cont.

CAR/MINIBUS cont.	% severe problem
Movement in crowds	34.0
Wait standing	27.6
Baggage	26.0
Personal cost	21.1
Physical safety	17.8
Traveling alone	14.1
Use of handrails on steps	12.1
Sudden vehicle movement	7.6
Fear of assault	6.4
Vertical handholds	6.2
Inconveniencing others	5.2
Fare collection	4.3
Getting on and off	4.1
PRIVATE CAR	
Need for rapid movement	37.0
Long walking distances	34.1
Baggage	25.0
Traveling alone	18.2
Rise from seat	16.3
Personal cost	12.5
Physical safety	11.4
Getting on and off	9.3
Fear of assault	6.5
Width of doors	5.9
Sudden vehicle movement	5.5
Inconveniencing others	2.9

walking distances and the need for rapid movement are a severe problem for over 60% of the sample in relation to using a subway or bus, but affect fewer than 40% of the respondents in using the other modes. These data may reflect the fact that the same barrier is not truly comparable across modes. For example, the need to move rapidly in relation to the subway may imply an inability to move fast enough to exit before the doors close, whereas the same need in relation to the use of the private car may imply an ability to coordinate rapid arm and leg movements.

Aside from the barriers which affect large numbers of handicapped across many different modes, and which are probably insurmountable for significant numbers of individuals, numerous other barriers exist which seriously inconvenience handicapped persons. Problems with the handling of baggage are severe for a large number of respondents across all modes. The need to use overhead grips, and difficulty in rising from a seat, also affect many of the respondents. In addition, many handicapped are unable or unwilling to travel alone. The fact that so many barriers affect such large numbers of handicapped suggests that travel via most modes is inconvenient and uncomfortable for these individuals, even where insurmountable barriers do not exist.

3.3 Difficulty in Transportation Modes and the Degree of Handicap

The barriers within transportation modes which were a severe problem for over one-third of the sample were analyzed relative to the degree of handicap. Functional ability was assessed in terms of whether or not the respondent could climb stairs, and if not, in terms of whether or not the respondent used a wheelchair.

As can be seen in Table 3.2, a greater degree of functional handicap tends to be associated with increased susceptibility to barriers within transportation modes. Those who use a wheelchair are generally affected by physical barriers, as are the ambulatory handicapped who cannot climb stairs. This is clearly the case for barriers such as high steps and long stairs, where nine out of ten of the more functionally limited individuals experience severe difficulty. Escalators

TABLE 3.2

PERCENTAGE WITH DIFFERING DEGREE OF FUNCTIONAL DISABILITY WHO FIND BARRIER A SEVERE PROBLEM

Barriers w/in Modes	Functional Disability		
	Can walk no difficulty with steps	Can walk difficulty with steps	Wheel-chair users
SUBWAY			
Long stairs	59.6	85.7	91.7
High steps	55.6	84.6	90.9
Rapid movement	60.0	80.0	73.3
Ride standing	66.0	77.8	64.5
Long walking distance	62.3	88.2	42.8
Movement in crowds	52.6	73.7	61.3
Baggage	51.2	55.6	54.5
Overhead grips	42.0	58.8	66.7
Physical safety	38.5	55.6	52.0
Escalators	27.1	21.4	80.0
Directness	28.8	62.5	39.3
Sudden vehicle movement	42.6	52.9	15.4
Traveling alone	29.1	41.2	42.3
PUBLIC BUS			
High steps	64.3	84.6	90.9
Ride standing	60.8	80.0	78.6
Rapid movement	61.8	77.8	61.3
Movement in crowds	48.3	73.7	54.8
Getting on and off	43.6	64.3	72.0
Baggage	50.0	51.6	57.1
Overhead grips	39.6	58.8	66.7
Physical safety	40.0	55.6	44.4
Wait standing	43.9	66.7	14.3
Directness	30.2	68.8	42.9
Sudden vehicle movement	41.1	58.8	21.4
TAXI			
Personal cost	50.0	47.1	62.9
Need for rapid movement	39.6	47.1	41.9
Long walking distance	34.7	50.0	40.0
Wait standing	65.6	25.0	6.3
CAR SERVICE			
Personal cost	50.0	47.1	62.9
Need for rapid movement	39.6	47.1	41.9
CAR/MINIBUS FOR HANDICAPPED			
Ride standing	47.1	64.3	69.2
Need for rapid movement	37.6	47.1	38.7
Overhead grips	32.4	31.3	66.7
Long walking distance	31.8	50.0	31.8
PRIVATE CAR			
Need for rapid movement	33.3	52.9	35.5
Long walking distance	31.9	43.8	29.2

in the subway are an exception, in that they constitute a severe problem only for a majority of handicapped who are wheelchair users.

In spite of the preceding, less severely handicapped individuals still experience difficulty with numerous barriers within public transportation. A majority of those who can climb stairs have severe problems with seven out of thirteen barriers which constitute a problem for over one-third of the sample in using the subway. Likewise, in using the public bus, a majority of the least severely handicapped experience severe difficulty with five of eleven barriers which affect over one-third of the sample. In short, regardless of the degree of handicap, numerous barriers present severe problems for a majority of handicapped in using public transportation.

3.3.1 Mode Utilization and Degree of Handicap

Another objective of this research was to examine the degree of usage of transportation modes. Table 3.3 shows that some modes of travel are not used equally across the trip purposes.

The relationships between mode utilization and trip purpose give measures of modal choices and may indicate the importance placed on these modes by their users for each trip purpose. Modal choices however, are not only a function of individual preferences but are also conditioned by socio-economic and environmental constraints, and the characteristics of the transportation modes and network configuration. The constraints which are of interest in this research are those related to the degree of impairment of the handicapped. Figure 3.1 which shows the relationships between mode usage and level of handicap, confirms the logical expectation of lower ridership of high-barrier modes by those with more severe handicaps.

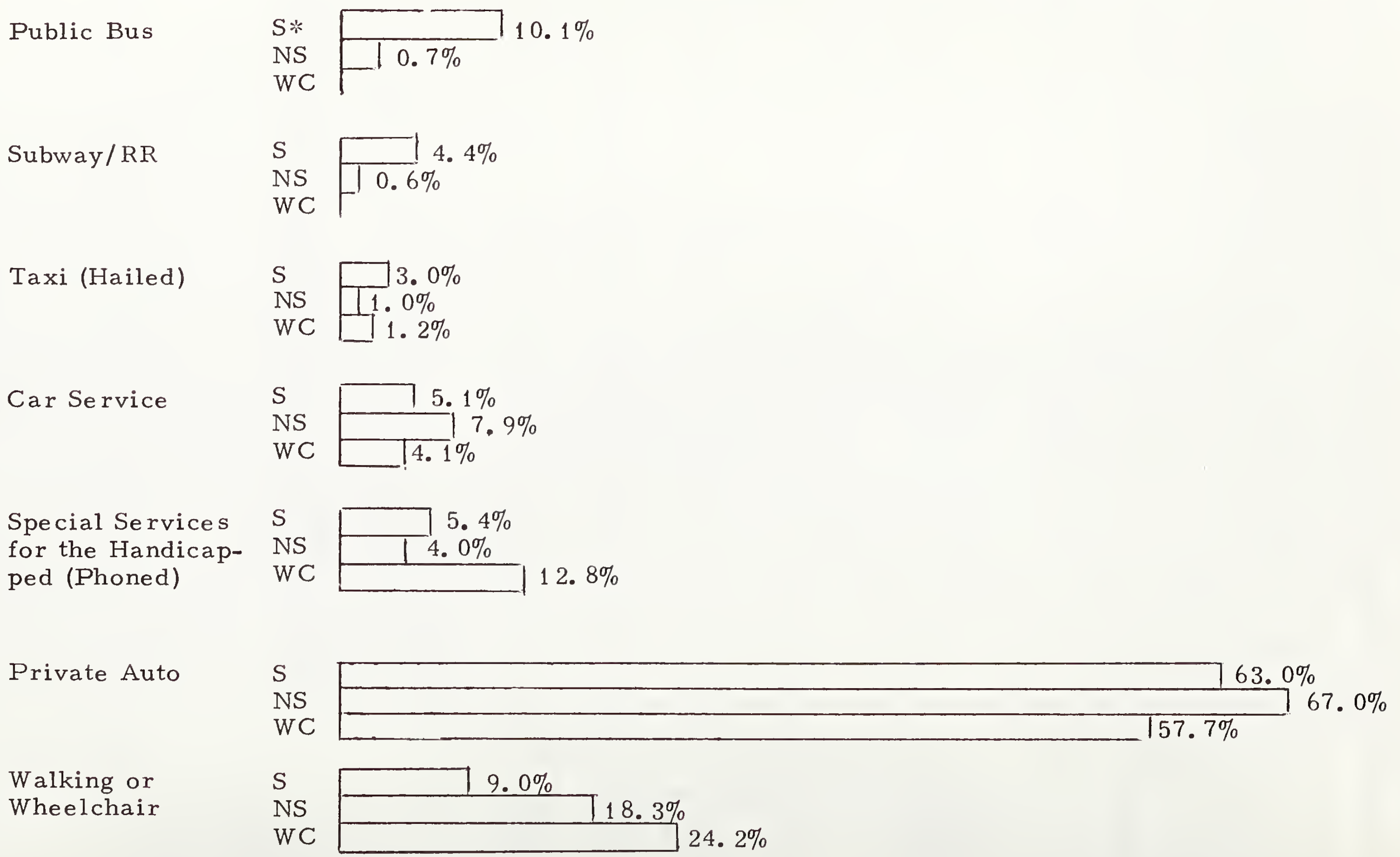
3.3.2 Modal Preferences for Transportation Improvements

In Table 3.4 the percentage of handicapped who select the modes which would best meet their needs for specific purposes, if improvements were made, is reported as a function of disability. In general, the private car is most preferred for all purposes, almost regardless of disability. However, there is a very pronounced trend which indi-

TABLE 3.3: TRIP PURPOSE AND MODE UTILIZATION (PERCENT)

	Public Bus	Subway or Rail-road	Taxi /Hailed on Street	Car Service/ Phoned for/	Car Minibus Service for Han-dicapped Persons/ Phoned for/	Auto-mobile	Walk/ Wheel-Chair	All modes
Shopping/Personal Business in your Neighborhood (gro-cery, haircut, bill-paying, bank)	5.0	0.3	2.2	1.6	0.1	60.8	30.0	100.0%
Shopping/Personal Business Out of your neighborhood (depart-ment store)	5.6	2.4	3.1	8.0	0.3	76.6	4.0	100.0%
Doctor	0.7	1.0	3.8	11.5	19.9	56.5	6.6	100.0%
Dentist	1.6	1.9	3.2	4.1	12.5	65.0	11.7	100.0%
Hospital	2.5	1.0	6.4	21.7	37.7	30.8	----	100.0%
Personal Business (Social Security, Welfare, Veterans Administration)	3.6	6.2	2.9	2.0	4.0	80.6	0.6	100.0%
Work	12.9	5.6	2.0	6.0	7.3	63.9	2.2	100.0%
Visiting Relatives Friends	2.1	3.8	3.1	6.8	0.2	65.0	20.0	100.0%
Attending Religious Services	3.0	----	----	2.2	2.2	66.5	26.1	100.0%
Recreation (Movies Clubs	2.5	1.4	1.3	5.8	12.8	60.3	16.0	100.0%
School	2.5	1.4	1.3	5.8	12.8	60.3	16.0	100.0%
All Purposes	6.1	2.8	2.3	5.4	6.8	62.6	13.8	100.0%

FIGURE 3.1: UTILIZATION OF COMMON TRANSPORTATION MODES BY THE HANDICAPPED BY TYPE OF FUNCTION IMPAIRMENT



*Type of Functional Impairment:

S = Can climb stairs with relative ease
NS = Can climb stairs with extreme discomfort
WC = Regular wheelchair users

TABLE 3.4

PERCENTAGE WHO REPORT WHICH MODE WOULD BEST MEET THEIR NEEDS (FOR EACH TRIP PURPOSE AS A FUNCTION OF DISABILITY)

	Can Walk; No Problem With Steps	Can Walk Difficulty With Steps	Wheel-Chair Users
Shopping-local			
Private Car	60.3%	64.7%	36.8%
Walk/Wheelchair	20.7%	11.8%	15.8%
Bus	10.3%	11.8%	26.3%
Car/Minibus	3.4%	11.8%	10.5%
Shopping-out of Neighborhood			
Private Car	55.4%	66.7%	30.8%
Bus	17.9%	11.1%	30.8%
Bus/Subway	10.7%	11.1%	12.8%
Car/Minibus	8.9%	5.6%	17.9%
Doctor			
Private Car	64.3%	61.1%	38.2%
Car/Minibus	7.1%	11.1%	26.5%
Bus	8.9%	11.1%	14.7%
Dentist			
Private Car	58.5%	58.8%	32.4%
Car/Minibus	7.5%	11.8%	37.8%
Bus	13.2%	5.9%	5.4%
Hospital			
Private Car	51.0%	56.3%	41.9%
Car/Minibus	8.2%	6.3%	16.1%
Car Service	14.3%	12.5%	19.4%
Bus	14.3%	0.0	0.0
Official Business			
Private Car	48.9%	66.7%	
Bus	14.9%	0.0	
Car/Minibus	6.4%	6.7%	
Work			
Private Car	51.0%	81.8%	46.2%
Bus	20.4%	9.1%	15.4%
Bus/Subway	18.4%	0.0	14.2%
Visiting Relatives/Friends			
Private Car	66.1%	64.7%	42.5%
Bus/Subway	12.5%	11.8%	17.5%
Car/Minibus	3.6%	5.9%	17.5%
Bus	10.7%	5.9%	7.5%
Car Service	1.8%	5.9%	12.5%
Attending Religious Services			
Private Car	56.5%	60.0%	47.1%
Bus	21.7%	6.7%	11.8%
Car/Minibus	6.5%	13.3%	17.6%
Car Service	2.2%	13.3%	8.8%
Recreation			
Private Car	47.4%	52.9%	41.0%
Bus/Subway	21.1%	11.8%	12.8%
Car/Minibus	12.3%	5.9%	23.1%
Bus	10.5%	5.9%	7.7%
School			
Private Car	79.2%	90.9%	45.5%
Bus	8.3%	0.0	22.7%
Car/Minibus	8.3%	0.0	9.1%

cates that the greater the disability the less attractive is the private car, regardless of purpose.

3.4 References

1. Mobility of the Handicapped and Elderly, First Year Final Report to the U.S. DOT, Office of University Research, Polytechnic Institute of New York, 1975.

CHAPTER 4

TRAVEL DEMAND ANALYSIS FOR THE HANDICAPPED AND ELDERLY

4.1 Purpose and Scope of the Travel Demand Analysis

The travel demand of the Handicapped and Elderly (H&E) includes trips currently made plus trips that would be made if the constraints to their travel were removed (latent demand). There is a problem, however, in estimating latent demand.

Latent demand may be estimated in several ways: on approaches based on the respondent's projected change in his travel behavior and on approaches based on the interpolation of differentials in existing travel between those who are constrained in their mobility and those who are not.

It has been experienced that when latent demand is estimated by asking the respondents what they would do if travel barriers were reduced or eliminated, the results are not reliable (2). One way to cope with this problem is to scale down the latent demand by a factor (2), which may vary by locality, type of mode considered, and H&E subgroups. Presumably when enough experience is accumulated, reliable calibration curves may be used to factor latent demand estimates by this method. The basic problem with estimating latent demand, however, may not rest with the choice of an analytical technique but with the concept of latent demand per se.

Latent demand may be defined as the difference between an "ideal" travel rate and the actual travel rate. And here is the problem: How does one establish an "ideal" travel demand rate which is visible in the market place? Figure 4.1 illustrates the main point of this discussion: the size of latent travel demand depends on how high or low one sets the goal. The travel constraints of the H&E comprise physical, economic, age, and psychological factors which are endogenous to the population subgroup and cannot be changed through an improvement in the transportation system alone. The approach used to estimate the level of latent demand for a particular subgroup of H&E is to avoid comparisons across subgroups and to retain the subgroup characteristic as given. Thus the elderly are not compared with the non-elderly

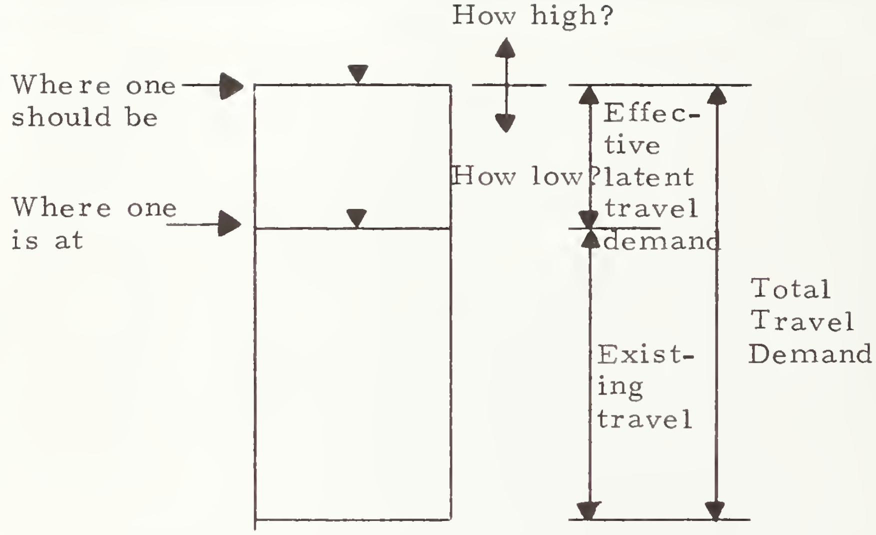


FIGURE 4.1: LEVELS OF TRAVEL DEMAND

to estimate latent travel demand. But they are compared among themselves keeping their various states constant.

The criterion used in estimating the level of latent demand for a particular subgroup is the car-driver status of a person. It is assumed that car-drivers tend to maximize their human interaction potentials because the car provides the highest level of mobility. Thus for a particular subgroup the difference between the trip rate of the car driver and that of the non-car driver represents what is termed maximum potential travel demand of the subgroup; which could conceivably be satisfied by improvements in the public transportation system or by providing a car to the non-car driver (6).

There is a considerable amount of overlap among H&E groups, and the severity of travel constraints increases as one group experiences the states of other groups (3). For example, the poor person who is handicapped and elderly, will be more constrained in his mobility than the poor person who is neither handicapped nor elderly.

The scope of this chapter is to present a methodology for estimating the latent travel demand among the urban disadvantaged in general, and the elderly and handicapped in particular, living in New York City. The data for this analysis was obtained from reports done by the Tri-State Regional Planning Commission (7, 10, 12), the Transportation Systems Center (8), and Polytechnic Institute of New York (3, 4, 5, 9).

4.2 Methodology of the Travel Demand Analysis

The travel demand analysis discussed herein addresses the need for determining the approximate size of latent demand for transportation at the areawide planning level. The purpose is to obtain an overall size of the total latent demand at the regional level in order to assess (1) the quantity of this demand, (2) the types of improvements needed, (3) the capacity required to satisfy this demand, and (4) resourses required to do so.

Figure 4.2 illustrates the steps involved in the overall analysis of travel demand and their relationship with the other steps which deal with plan selection and implementation.

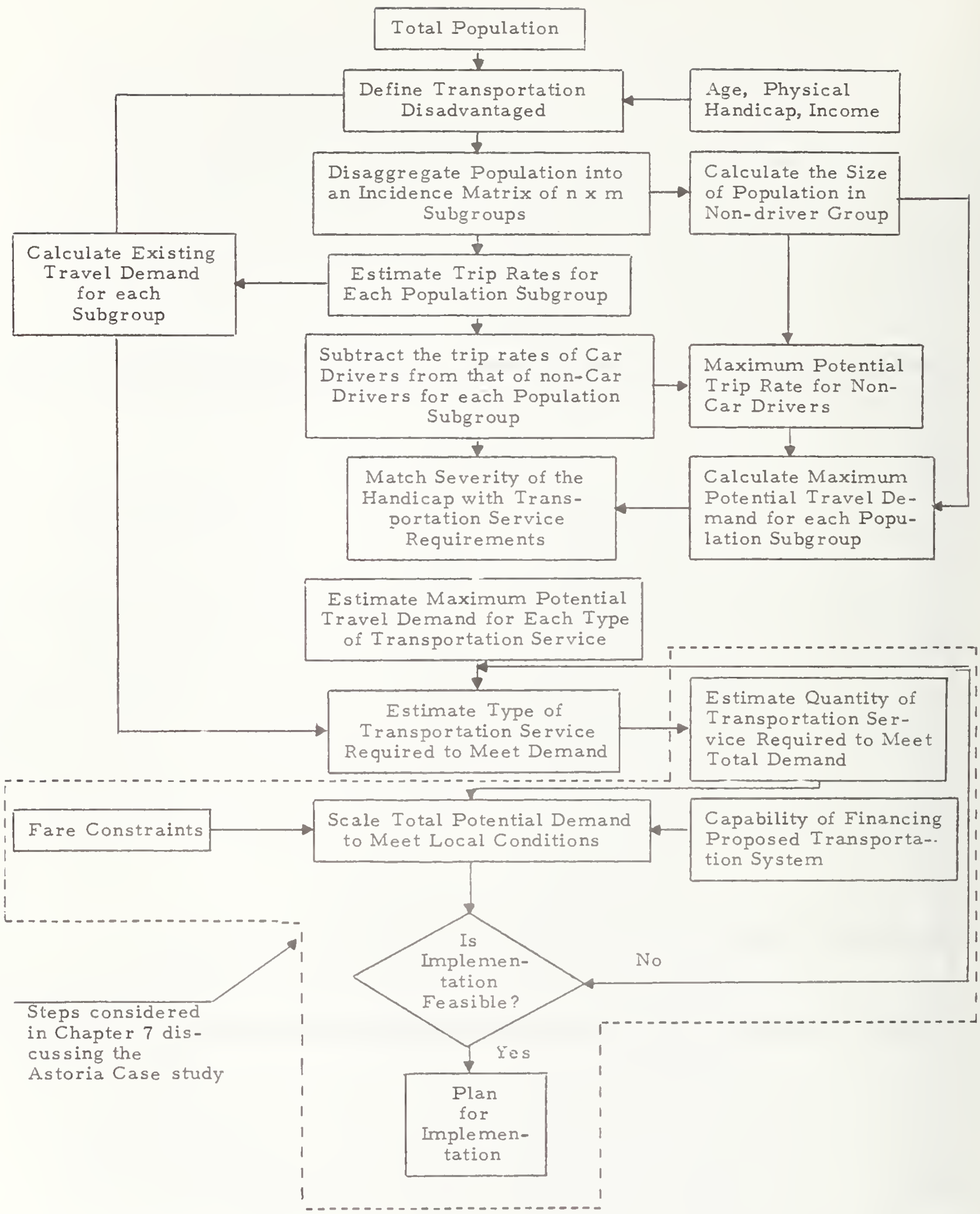


FIGURE 4. 2: METHODOLOGY FOR THE ANALYSIS AND ESTIMATION OF TRAVEL DEMAND FOR THE DISADVANTAGED

4.3 The Handicapped and Elderly as a Subset of the Transportation Disadvantaged

The H&E constitute a group of transportation disadvantaged who experience a high incidence of travel barriers which place severe constraints on their mobility needs. The common experience shared by the handicapped and the elderly is their lack of access to transportation services either by reason of poverty, or inability to use the services due to a personal physical handicap, or because transportation services are not available.

The disadvantaged in urban areas are less affected by their inability to use transportation than those living in the suburbs or rural areas because many opportunities in cities are located within walking distance. For example, approximately 40 percent of the trips made by the elderly living in New York City are walking trips (2, 9, 10). But the population of walking trips declines as the severity of handicap increases (9). Thus for those who are handicapped and elderly a lack of access to transportation services creates a more serious impact on their mobility. The same is true for the non-elderly handicapped, and the severity of "isolation" increases for those who, in addition to being handicapped, are also poor.

Thus an analysis of transportation demand for the disadvantaged needs to recognize the different states that each of the disadvantaged groups may experience. Figure 4.3 shows a proposed structure for the identification of the different states of transportation-disadvantagedness. From Figure 4.3 it is possible to develop a systematic arrangement of all possible combinations of states in which the three population groups are found. Thus the total population (TP) may be divided into three subgroups: the elderly (E), the teenagers (T) and those in-between (M). And each of these subgroups may be handicapped (H) or not handicapped (NH), and so on. All possible mutually exclusive combinations of subgroups and their physical, economic, and car driver states are described in Figure 4.4. Figure 4.4 shows an estimate of probabilities describing the transition from one state to another. These estimates are for New York City and are based on information abstracted from a number of reports (2, 7, 8, 9, 10, 12, 14, 15). These estimates may be subject to change pending more accurate data but they are sufficiently accurate for the purpose of this analysis.

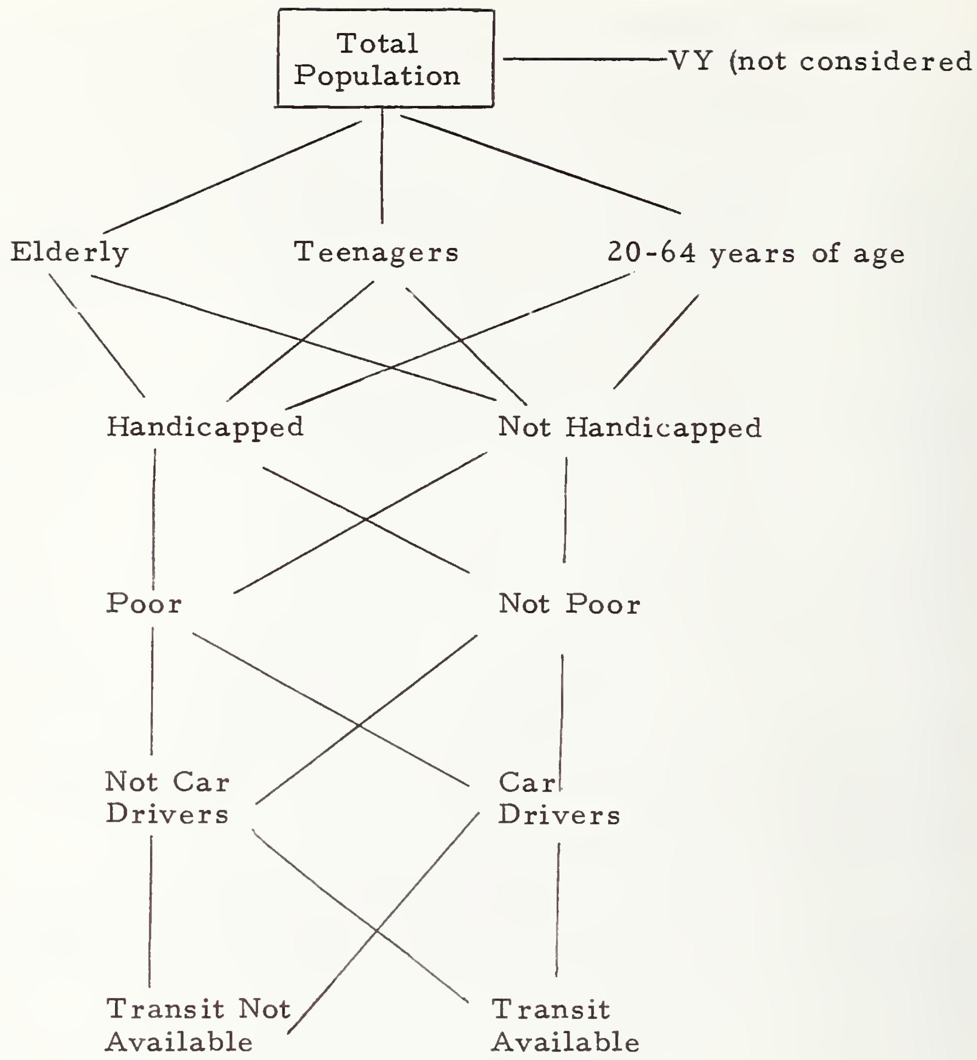


FIGURE 4. 3: STRUCTURE FOR THE ANALYSIS OF TRAVEL DEMAND FOR THE DISADVANTAGED

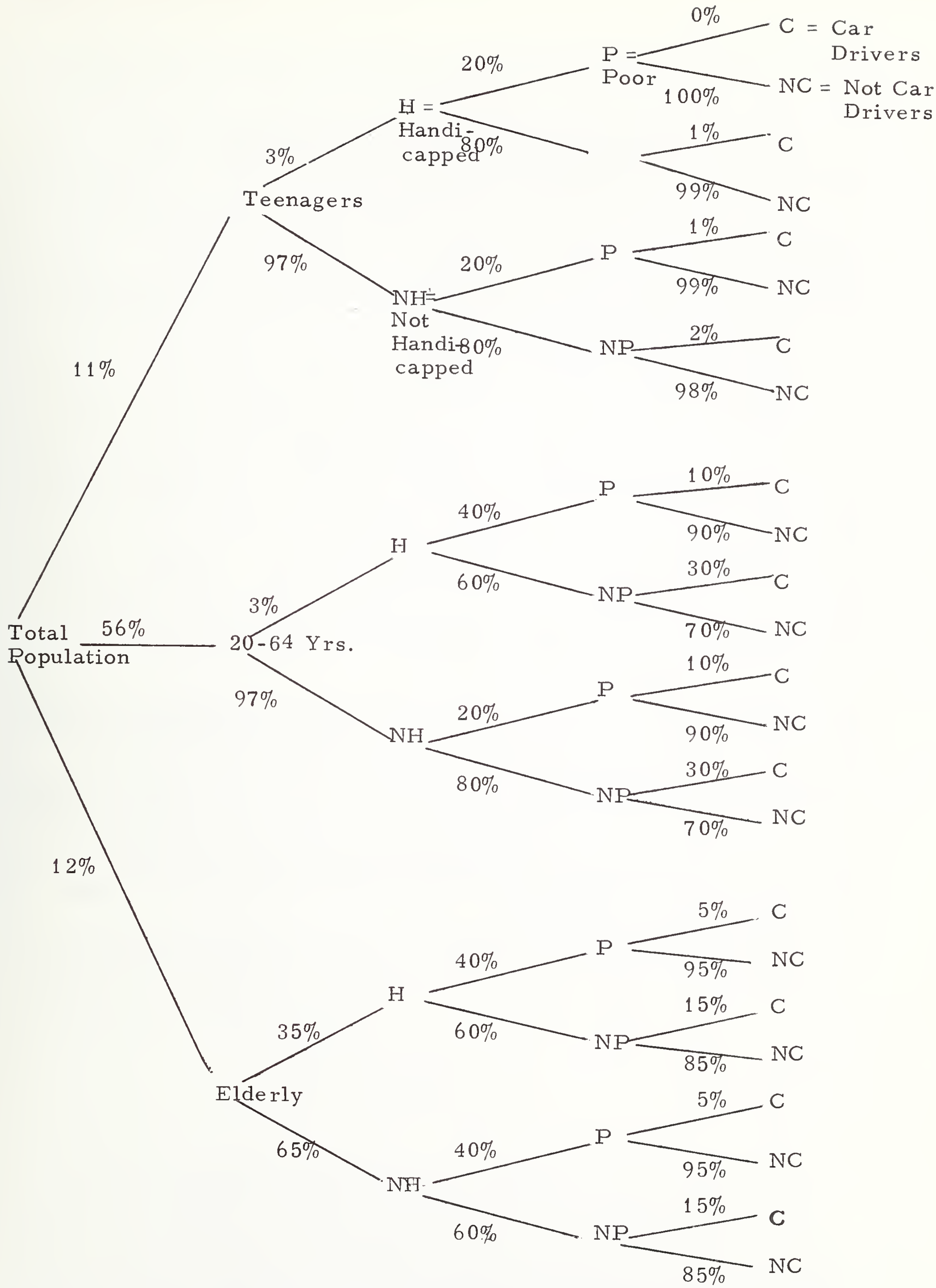


FIGURE 4. 4: COMBINATORIAL ARRANGEMENT OF POPULATION SUBGROUPS AND THEIR CHARACTERISTICS

TABLE 4.1

INCIDENCE MATRIX OF POPULATION SUBGROUPS IN NEW YORK CITY (EXPRESSED AS PERCENT OF TOTAL POPULATION)

Age & Driver Status (i)	Physical and Economic Status (j)				
	(1) H, P	(2) H, NP	(3) NH, P	(4) NH, NP	Total
1. T, CD*	0.000	0.001	0.006	0.047	0.054
2. T, NCD	0.070	0.259	2.124	8.493	10.946
3. E, CD	0.084	0.378	0.156	0.702	1.320
4. E, NCD	1.596	2,142	2.964	3.978	10.680
5. M, CD	0.067	0.302	1.086	13.038	14.493
6. M, NCD	0.605	0.706	9.774	30.422	41.507
TOTAL	2.422	3.788	16.110	56.580	79.000

Handicapped and Elderly Subgroup

*Assumes 3% of teenage population is a potential car driver; Ages 18 and 19 in New York City.

From Figure 4.4 it is possible to develop an incidence matrix of the various states experienced by the transportation disadvantaged persons. Table 4.1 shows that there are 28 mutually exclusive states, of which 16 states include either elderly or handicapped persons. Each matrix entry indicates the proportion of New York City population which belongs in a given state (Pij), identified by the age and car driver status (i) and a physical and economic status (j). Table 4.1 shows that the proportion of New York City population who is transportation disadvantaged because of an incidence of travel barriers due to either handicap, age (65 or over), or both age (65 & over) and handicap, approximates 14 percent of the population; and over 4/5 of this number are elderly. Also, it may be noted that approximately 5 percent (0.702 + 3.978) of the population contains elderly who are neither handicapped nor poor. Thus from this incidence matrix it is possible not only to rate severity of transportation disadvantagedness but also to estimate the size of the problem. This is perhaps better shown in Table 4.2 which contains the estimates of the number of people allocated to each possible state (nij).

4.4 Travel Demand Estimation

The total travel demand for the disadvantaged is defined as the sum of existing travel, Te, and potential travel (latent demand), Tp. Thus we have:

$$T = Te + Tp \qquad (1)$$

Existing travel is estimated from the product of existing trip rates of each population subgroup, (tij), and the number of people in each population subgroup (nij):

$$Te = \sum_{i=1}^{6} \sum_{j=1}^{4} Nij\, Tij \qquad (2)^{*}$$

Latent demand is defined as the maximum potential travel demand of those who are non-car drivers. This is obtained from the product of the trip rate differentials between car drivers and non-car drivers, $(Tij_{CD} - Tij_{NCD})$, and the number of non-car drivers in each

*The indices of summation will vary if different typologies or population breakdowns are used.

TABLE 4. 2

ESTIMATES OF POPULATION SUBGROUPS IN NEW YORK CITY

Age & Driver Status (i)	Physical and Economic Status (j)				
	(1) H, P	(2) H, NP	(3) NH, P	(4) NH, NP	Total
1. T, CD	-0-	80	475	3, 710	4, 265
2. T, NCD	5, 526	20, 448	167, 687	670, 511	864, 172
3. E, CD	6, 632	29, 843	12, 316	55, 422	104, 213
4. E, NCD	126, 002	169, 108	234, 004	314, 058	843, 172
5. M, CD	5, 290	23, 842	85, 738	1, 029, 332	1, 144, 202
6. M, NCD	47, 764	55, 738	771, 644	2, 401, 775	3, 276, 921
TOTAL	191, 214	299, 059	1, 271, 864	4, 474, 808	6, 236, 945

↖Handicapped and Elderly Subgroup

age status, and physical and economic status (Nij_{NCD}):

$$Tp = \sum_{i=1}^{6} \sum_{j=1}^{4} Nij_{NCD}(Tij_{CD} - Tij_{NCD}) \qquad (3)*$$

where

Nij	= number of people in age and driver status (i) and physical and economic status (j) (Nij values are shown in Table 4. 2)
Nij_{NCD}	= number of people in age (i) and non-car driver status [i(NCD)], and physical and economic status (j)
Tij	= trip rate for age and car driver status (i) and physical and economic status (j) (tij values are shown in Table 4. 3).
Tij_{CD}	= trip rate of car drivers in age status (i) and physical and and economic status (j)
Tij_{NCD}	= trip rate of non-car drivers in age status (i) and physical and economic status (j).

Table 4. 3 shows the estimates of trip rates (Tij) for each of the six age and driver states (i), and for each of the four physical and economic states (j). These estimates were derived from various sources (7, 9, 10, 12, 15). Since not all of the Tij's could be estimated directly from those sources, a number of the trip rates in Table 4. 3 were estimated by extrapolation. Thus, although the accuracy of the travel demand estimate for the case study of New York City may not be sufficiently precise for system design purposes, for the purpose of this discussion these estimates may be considered to approximate the values that may be found through a more precise data collection effort.

The results of equation (2) are shown in Table 4. 4. The term (Tij_{CD} - Tij_{NCD}) is shown in Table 4. 5, and equation (3) is tabluated in Table 4. 6, for each age subgroup and physical and economic state. For purposes of comparison, latent demand is expressed as a percentage of existing travel (for each age and physical/economic status) in Table 4. 7.

The results in Table 4. 7 show that those who are handicapped and poor have a latent demand which is 125% of existing travel. This latent demand is lowest for those who are elderly (53%) and highest

*The indices of summation will vary if different typologies or population breakdowns are used.

TABLE 4.3

PERSON TRIP RATE MATRIX OF POPULATION SUBGROUPS IN NEW YORK CITY (EXPRESSED IN TRIPS PER DAY, EXCLUDING WALKING TRIPS)

Age & Driver Status (i)	Physical and Economic Status (j)			
	(1) H, P	(2) H, NP	(3) NH, P	(4) NH, NP
1. T, CD	-	1.1	0.7	1.9
2. T, NCD	0.4	0.6	0.6	1.5
3. E, CD	0.6	2.7	0.5	2.3
4. E, NCD	0.3	0.8	0.3	0.7
5. M, CD	1.4	2.3	1.6	2.4
6. M, NCD	0.4	0.7	0.6	1.7

TABLE 4. 4

EXISTING TRAVEL ESTIMATE FOR POPULATION SUBGROUPS IN NEW YORK CITY (EXPRESSED IN PERSON TRIPS PER DAY, EXCLUDING WALKING TRIPS)

Age & Driver Status (i)	Physical and Economic Status (j)				
	(1) H, P	(2) H, NP	(3) NH, P	(4) NH, HP	Total
1. T, CD	-0-	87	332	7, 050	7, 469
2. T, NCD	2, 211	12, 267	100, 612	1, 005, 766	1, 120, 856
3. E, CD	3, 979	80, 267	6, 158	127, 470	218, 182
4. E. NCD	37, 801	135, 286	70, 201	219, 840	463, 128
5. M, CD	7, 406	54, 837	137, 181	2, 470, 397	2, 669, 821
6. M, NCD	19, 106	39, 017	462, 986	4, 083, 018	4, 604, 127
TOTAL	70, 503	322, 069	777, 470	7, 913, 541	0, 083, 583

↖Handicapped and Elderly Subgroup

TABLE 4.5

MAXIMUM POTENTIAL TRAVEL DEMAND RATES (EXPRESSED IN PERSON TRIPS PER DAY, EXCLUDING WALKING TRIPS)

Population Subgroup	Car Trip Rate	No-Car Trip Rate	Maximum Potential Travel Demand Rate
1. Teenagers Handicapped, Poor	-	0.3	*
2. Teenagers Handicapped, Not Poor	1.1	0.6	0.5
3. Teenagers Not Handicapped, Poor	0.7	0.6	0.1
4. Teenagers Not Handicapped, Not Poor	1.9	1.5	0.4
5. Elderly Handicapped, Poor	0.6	0.3	0.3
6. Elderly Handicapped, Not Poor	2.7	0.8	1.9
7. Elderly Not Handicapped, Poor	0.5	0.3	0.2
8. Elderly Not Handicapped, Not Poor	2.3	0.7	1.6
9. Middle Handicapped, Poor	1.4	0.4	1.0
10. Middle Handicapped, Not Poor	2.3	0.7	1.6
11. Middle Not Handicapped, Poor	1.6	0.6	1.0
12. Middle Not Handicapped, Not Poor	2.4	1.7	0.7

*Assumes some demand rate as the Teenagers Handicapped and Not Poor

TABLE 4.6

MAXIMUM POTENTIAL TRAVEL DEMAND (LATENT DEMAND)

Maximum Potential Travel Demand Estimate of Population Subgroup = (Demand Rate for Subgroup) • (Population Subgroup of No-car Drivers)

Teenagers (13-19 years)	HP	= 0.5(5526)	= 2,763
	HNP	≐ 0.5(20448)	= 10,224
	NHP	= 0.1(167,687)	= 1,677
	NHNP	= 0.4(670,511)	= 268,204
	TOTAL		282,868
Elderly (65 years & over)	HP	= 0.3(126,002)	= 37,800
	HNP	= 1.9(169,108)	= 321,305
	NHP	= 0.2(234,004)	= 46,801
	NHNP	= 1.6(314,058)	= 502,493
	TOTAL		= 908,399
Middle (20-64 years)	HP	= 1.0(47,764)	= 47,764
	HNP	= 1.6(55,738)	= 89,181
	NHP	= 1.0*771,644)	= 777,644
	NHNP*	= 0.7(2,401,775)	= 1,681,243
	TOTAL		= 2,589,832
T + E + M			3,781,099

* This population subgroup is not considered to be transportation disadvantaged. However, improvements in transportation services to meet the needs of those who are disadvantaged will increase the travel demand of this group.

TABLE 4.7

LATENT DEMAND EXPRESSED AS PERCENT OF EXISTING TRAVEL

Age Status	Physical-Economic Status (j)				
	(1) H, P	(2) H, NP	(3) NH, P	(4) NH, NP	Total
Teenagers	125%	82%	2%	26%	25%
Elderly	53%	149%	61%	145%	133%
Middle (20-64 yrs)	180%	95%	129%	26%	36%
TOTAL	125%	131%	105%	31%	42%

for those between 20 and 64 years of age. For the non-poor handicapped, however, the elderly have the highest percentage increase potential of trip making (149%). For both the handicapped and non-handicapped elderly the latent demand changes are lower for the poor than the non-poor. As a group, the elderly's latent travel demand expressed as a percentage of existing travel is higher (133%) than that of the rest of the population.

4.5 The Non-Handicapped Elderly

From Table 4.8 it may be estimated that those elderly who are non-handicapped and poor and those elderly who are not handicapped, and not poor, are expected to generate a total potential demand of (46,801 + 502,493), 549,294 daily trips which could be served by conventional transit service, and paratransit service. This is an upper limit which requires considerable expansion of geographic and system accessibility of public transportation services in the area. The extent of this expansion depends on the conditions which prevail in each subarea relative to automobile levels of service, and requires local level analyses to estimate the extent of the capabilities of New York City in meeting the maximum potential demand. Or, conversely, one could estimate the proportion of latent demand that could be served by a given level of improvement, based on the resources available.

4.6 The Handicapped (Elderly and Non-Elderly)

In addition to the transportation improvements in the conventional transit services required for the non-handicapped, the handicapped require vehicles which are accessible. For most of the handicapped, transit vehicles may be made accessible simply by the installation of special features such as lower steps and slanted bars at the entrance and exit doors of buses. For others, demand-responsive service with lift for wheelchair is needed. Table 4.9 shows the national estimates of transportation service requirements for the handicapped (8).

From the information in Table 4.9 it is possible to estimate the number of potential trips by New York City residents which must be served by a particular service requirement such as a lift for wheelchair. Table 4.10 shows a summary of transportation requirements

TABLE 4.8

SUMMARY OF MAXIMUM POTENTIAL TRAVEL DEMAND

Physical/Economic Status	AGE STATUS		
	Under 65 yrs.	65 yrs. & Over	Total Total
1. H, P	50,527	37,800	88,327
2. H, NP	99,405	321,305	420,710
3. Total Handicapped	149,932	359,105	509,037
4. NH, P	773,321	46,801	820,122
5. NH, NP	1,949,447	502,493	2,451,940
6. Total Non-Handicapped	2,722,768	549,294	3,272,062

TABLE 4.9

1970 NATIONAL ESTIMATES OF TRANSPORTATION SERVICE REQUIREMENTS FOR THE HANDICAPPED*

Category	H. under 65 No.	H. under 65 %	H. 65 & Over No.	H. 65 & Over %	TOTAL No.	TOTAL %
A. Non-Ambulatory						
1. Cannot leave home	878,000	12.5%	878,000	13.8%	1,756,000	13.1%
2. Acute Condition	185,000	2.6	50,000	0.8	235,000	1.8
3. Institutional	30,000	0.4	930,000	14.7	960,000	7.1
B. Ambulatory						
1. Demand Responsive Service with lift for Wheelchairs	230,000	3.3	200,000	3.2	430,000	3.3
2. Demand Responsive Service without lift.	923,000	13.1	953,000	15.0	1,876,000	14.0
3. Conventional Transit Vehicles with Special Features	4,784,000	68.1	3,329,000	52.5	8,113,000	60.7
C. TOTAL	7,030,000	100.0%	6,340,000	100.0%	13,370,000	100.0%

*Adapted from The Handicapped and Elderly Market for Urban Mass Transit, UMTA and Transportation Systems Center, Oct. 1973

TABLE 4.10

ESTIMATE OF TRANSPORTATION SERVICE REQUIREMENTS FOR THE HANDICAPPED IN NEW YORK CITY

Type of Service	Under 65 yrs.	65 yrs. & Over	Total
1. Demand Responsive with Lift for Wheelchair	5,855 (*)	16,254	22,109
2. Demand Responsive without Lift	23,244	76,189	99,433
3. Total Demand Responsive	29,099	92,443	121,542
4. Conventional* Transit with Special Features	120,833	266,662	486,928

*This does not simply imply the installation of special features on existing transit vehicles and infrastructure. To meet this latent demand fully, or nearly so, it is also implied that the regional and subregional accessibility of the transit system must be increased to approximate that of the automobile

(*) $5855 = \underbrace{[3.3 \div (3.3 + 13.1 + 68.1)]}_{\text{Table 4.9}} \times \underbrace{[149,932]}_{\text{Table 4.8}}$

for the handicapped in New York City. Approximately 120,000 daily trips would require the use of Demand Responsive Transportation (DRT), and about one half million trips would require special features on the transit vehicles which serve the general public.

These requirements represent the amount of latent demand which would be generated by transportation system improvements -- if these improvements would raise the level of transit service to that provided by the automobile. These generated trips, therefore, require two types of improvements on the transit system: (1) those related to vehicle accessibility and those related to regional accessibility. It is realistic to assume that total latent demand is not likely to be satisfied because the level of regional accessibility provided by the automobile cannot be expected to be approximated by the transit system. This being the case, latent travel demand calculated by the above method would have to be reduced to account for the lower accessibility provided by the transit system. A second observation requires the consideration of the existing trips (by automobile and walking trips) made by the H&E which would be shifted to an improved public transportation system (standard and paratransit services). This added travel would, in turn, increase the travel demand for the improved system.

4.7 Conclusions

This chapter has shown an approach for estimating the latent demand of the disadvantaged living in a large urban area. The results it produces are useful to determine orders-of-magnitude requirements and permit an assessment of the kinds of commitments which must be made at the local level to satisfy the special requirements of the handicapped and elderly. This type of information may help in the formulation of policy which is responsive to the magnitude of the need, the financial resources required, and which does not encourage unrealistic expectations from the policy maker and the affected public.

The limitation of data accuracy in this example needs to be recognized and the results should not be used without further verification. The methodology for estimating travel demand, however, is useful when viewed in the context of the demand analysis process outlined in Figure 4.2, and may serve as a recommended approach for use by others.

4.8 References

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CHAPTER 5

CRITERIA FOR THE EVALUATION OF TRANSPORTATION SYSTEM IMPROVEMENTS FOR THE ELDERLY AND HANDICAPPED

5.1 Introduction

The travel demand estimates for the H&E population which were discussed previously must be allocated to the transportation system (both existing and proposed), in order to estimate system requirements in terms of modal allocation of supply and its operational features. As was discussed in Chapter 3, the H&E transportation market is considerably varied in terms of its functional physical states (ability to climb steps, no ability to climb steps, and wheelchair groups), in terms of mode usage (which varies by trip purpose), and in terms of preferences for mode improvements.

In order to plan, test and evaluate alternative system improvements for the purpose of selecting those which are not only responsive to the needs of the H&E but are also responsive to cost-effectiveness requirements, it is necessary to develop an analysis technique which accounts for both costable (quantitative) and non-costable (qualitative) variables. This chapter outlines a proposed methodology which can comprehensively address the plan evaluation issues.

Those system variables which are considered in the evaluation methodology include: travel time, comfort, convenience, security and safety, accessibility, and cost. The approach consists in using utility theory to account for any combination of these variables in the methodology, and is based on estimated utility and weighting values. For an actual application of this method, utility and weighting scales should be obtained through a field survey.

Each of the criteria contained in the evaluation methodology is discussed below. The evaluation methodology is described in Chapter 6.

5.2 The Valuation of Travel Time

The valuation of travel time cannot always be easily determined. However, in the conventional transportation systems evaluation, monetary measures of time value returns to investment must be used in any cost-benefit, or rate of return analysis, because returns must be measured in the same terms as costs. In this study we introduce an analytical technique which will use the Utility-Cost-Effectiveness analysis. In such analysis, degrees of achievement of various benefits (that are not measured directly in terms of money) are compared with costs, but no monetary returns are explicitly measured. Thus the need for a given time value in terms of money is theoretically eliminated. Therefore, most of the benefits (both tangible and intangible) which occur from transportation improvements, including travel time, will be evaluated in terms of Utility.

The utility of time saving is a function of the following factors:

- Trip purpose (in this study we will divide trip purpose into work trip and non-work trip)
- Characteristic of Tripmaker (the Elderly & Handicapped)
- Amount of time saved.

To avoid mathematical problems, and to be more practically oriented, we will consider the utility of time saving separately, for different purposes of trip, and for different groups of tripmakers. Since we know that time has a value only because people value it, a possible way to find the utility of time saving is to set up a questionnaire, to ask respondents to value it in terms of Utilities. The questionnaire would be sent to random elderly and handicapped respondents. For the purpose of illustrating the proposed methodology, we will set up hypothetical values of time saving for the improved transportation system (in this case, a Demand-Responsive-Transportation System), and assume that other factors such as cost, comfort, convenience, safety, etc., are constant. If a tripmaker can reduce travel time more he will have more satisfaction than if he reduces travel time less. The utility scale to be used is from 0 to 1. We expect that travel time for the Demand-Responsive-Transportation System will be less than travel time by the existing public transportation. However, if the travel time by the Demand-Responsive-Transportation System is greater than travel time by existing public transportation, the utility of travel time by the DRTS, where the tripmaker has to travel more than with the existing, will be negative. If we separate the groups of tripmakers into average people and elderly & handicapped, and in each group we divide trip purpose into work trip and non-work trip, then, the utility of travel time saved will depend solely on the amount of time saved. Table 5.1 illustrates a form of questionnaire for respondents to give the Utility in each level of time saved. From each level of time saved we expect to have a different value of Utility, because each individual tripmaker may have a different preference. Then the aggregate utility for each level will represent the utility of time saved.

Figure 5.1 illustrates the utility of travel time saved expected to be received by the respondents to the questionnaire.

TABLE 5.1

THE UTILITY OF TRAVEL TIME SAVED FOR HANDICAPPED PEOPLE -- WORK TRIP

Travel Time Saved (minutes)	Utility of Travel Time Saved
0 - 5	--------
6 - 11	--------
12 - 17	--------
18 - 23	--------
24 - 29	--------
30 - 35	--------
36 - 41	--------
42 - 47	--------

5.3 Defining Comfort and Convenience

It is apparent that every individual must have a different idea of what he thinks is comfortable or convenient. However, there are certain points concerning each variable that tripmakers mention more often than others when defining comfort and convenience. The problem of definition of comfort and convenience, according to Stopher, et al (33) states that "there are at least two reasons for the general lack of success, so far, in quantifying comfort and convenience attributes of travel modes." The first problem is that the techniques which have been used are rather inappropriate or not responsive to the needs of quantifi-

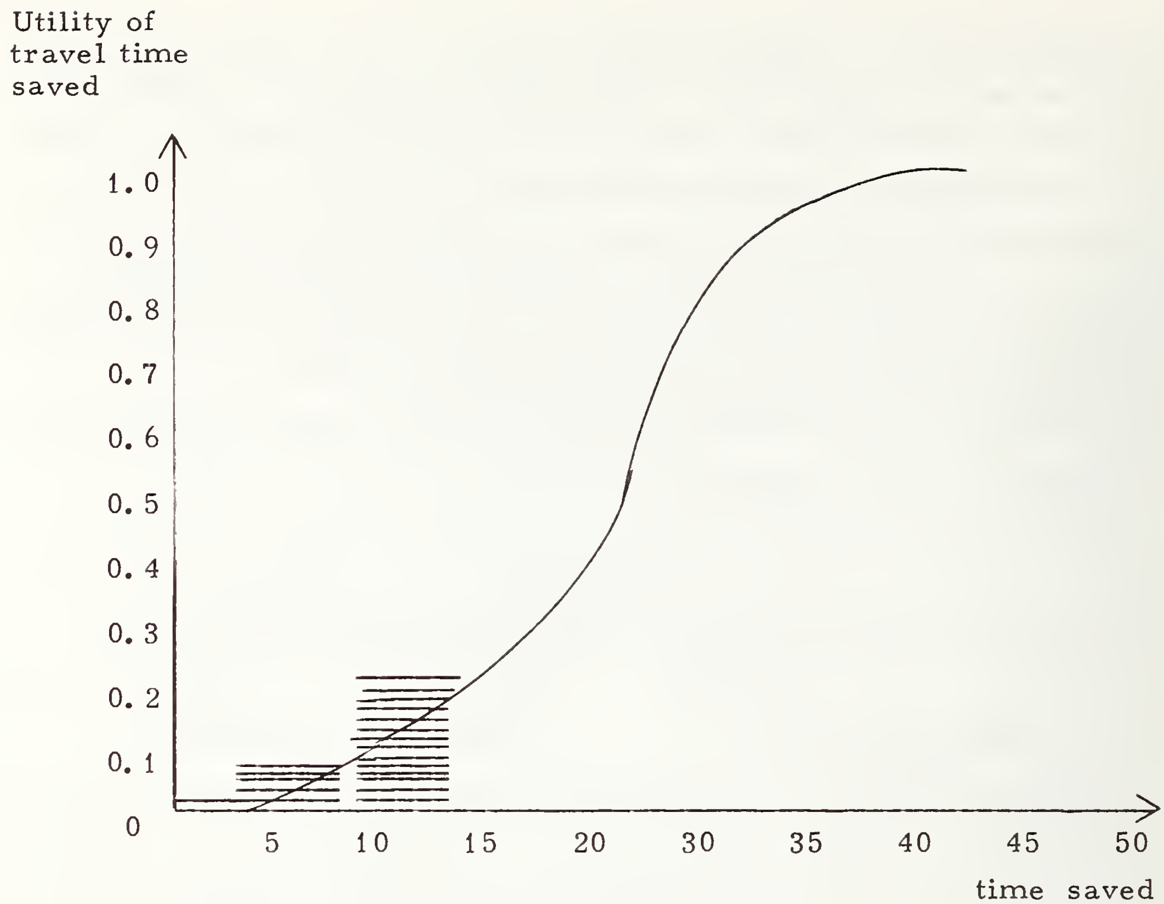


FIGURE 5.1: HYPOTHETICAL UTILITY OF TRAVEL TIME SAVED

cation. The second problem is that an all-inclusive definition of either comfort or convenience does not exist. What probably happens is that each individual responding to a transportation survey has his own definition of comfort and convenience. Therefore, any studies which use the words "comfort" or "convenience" without defining those words have been gathering data on transportation in ambiguous terms.

A review of the various definitions of convenience are given by the researchers appearing in Stopher, et al (33). Some of the definitions of comfort and convenience should be noted:

Beigelmacher and Zusman [1972] (40), defined convenience as relating to overall time savings. It is the convenience factors, that is, waiting, accessibility, transferring and parking, which in many instances affect mode choice. They also defined comfort as relating to seating space, ride quality, air quality, air conditioning and noise.

Stopher, et al. (33), defined convenience as referring to the efficiency and effectiveness with which a person can be transported from origin to destination; and comfort as referring to the environment in which the trip is made, the extent to which a trip may be enjoyed or not.

Nicholaidis (36), gives the same definition as Stopher, et al (33), in his questionnaire survey.

Kobayashi, et al (39) defined comfort and convenience by using a hierarchical structure of comfort and convenience, developing it into secondary and tertiary attributes as far as they are able to be quantified by means of physical measures, or classified into categories for which a situation can be conceived concretely by a person. They classified comfort and convenience as follows:

Primary Attributes	Secondary Attributes	Tertiary Attributes
Convenience →	→ Reliability of Schedule	
	→ Walking	
	→ Waiting	
	→ Transfer	
Comfort →	→ Congestion	
	→ Privacy	
	→ Ride quality →	→ Vibration
		→ Comfort of seat
	→ In vehicle condition →	→ Air Conditioning
		→ Feeling of unsafety
		→ Noise

After reviewing the literature on comfort and convenience, Table 5.2 has been prepared to consolidate all of the attributes most often used to represent Comfort and Convenience in attribute surveys.

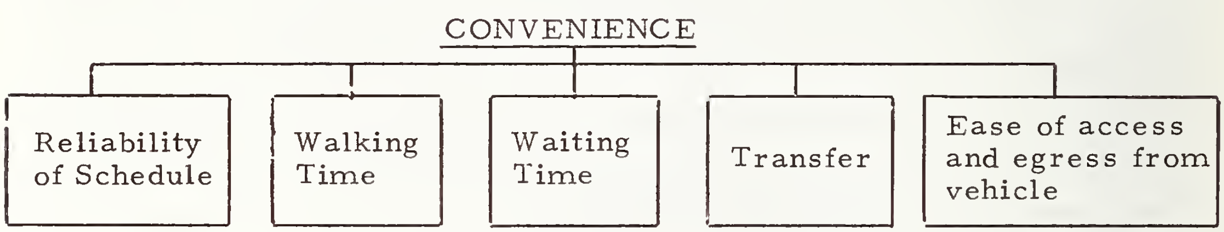
After careful review of the literature on definitions and attributes of comfort and convenience variables, we define convenience as the level of expenditure of time and effort during which a person travels from origin to destination; and comfort as the level of satisfaction associated with the vehicle and terminal environment during which a person travels from origin to destination. The level of comfort on public transportation systems is usually affected by temperature, odor, ventilation, noise, vibration, acceleration, deceleration, position change (or jerks), and density or crowdedness. Each of these effects can be divided into three tolerance levels [Solomon, et al, 1968 (41)]:

"1. an upper physiological limit, beyond which the condition is physically intolerable;

2. a limit, beyond which the body will survive, but will be uncomfortable or unsatisfied, and

3. a psychological condition in which one's body is 'comfortable' but the situation is not pleasant."

The following attributes will be used to represent convenience and comfort variables.



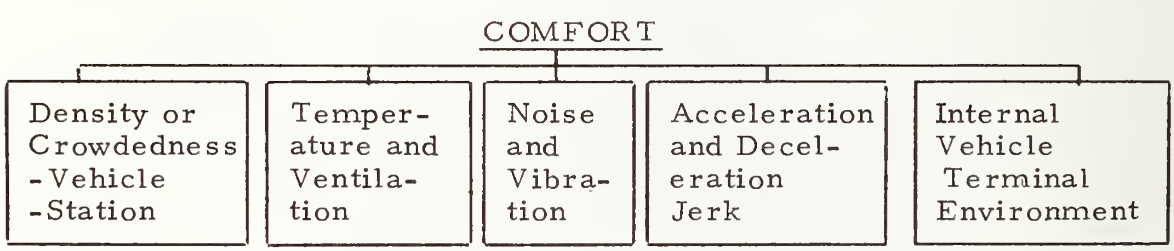


TABLE 5. 2

ATTRIBUTES OFTEN USED REPRESENTING COMFORT AND CONVENIENCE IN ATTITUDE SURVEYS

Convenience	Comfort
- Arrive at the intended time	- Means of travel is well-protected from weather conditions.
- Avoid stopping for repairs	- Possibility of adjusting the temperature
- Arrive in the shortest time	- Plenty of storage space for parcels, shopping bags, etc.
- Avoid changing vehicles	- Few stops due to pick-up stops, traffic lights, etc.
- Avoid a long wait for the vehicle	- Immediate environment is clean
- Avoid a long walk	- Good visibility of the surroundings
- Ride in a safe vehicle	- No fatigue felt when using the means of travel, (constant attention, glare, uncertainty), etc.
- Ride in a vehicle that is unaffected by weather	- There is a feeling of privacy
- Pay as little as possible for the trip	- Ease of entrance and exit from means of travel.
- Have station easily accessible to home	
- Avoid having to leave early to be on time for work	
- Avoid traveling in undesirable areas.	
- Avoid paying daily for the trip	
- Have easy-to-understand schedules and routes	
- Have a choice of departure times	
- More frequent service	
- Having a seat	
- Longer hours of service	
- Coming without delay	
- Adjustable seats	
- Availability to meet friends on vehicle	

5.4 Methodology of Measurement

The literature shows that earlier methods of measuring comfort and convenience can be classified into three general approaches:

The first approach is a means of determining whether comfort and convenience are important variables in mode-choice.

The second approach is a ranking procedure, in which the survey respondent is asked to rank order a number of travel mode attributes of a specific mode.

The third approach is uses of psychological scaling techniques, of which many are available; many are in their infancy, both in general and specifically in applications to transportation, Stopher, et al (33).

In the latest approach two methods of data collection techniques are most often used for scaling models:

- Semantic differential, and
- Paired comparisons.

Semantic differential involves questioning respondents about a quality, and asking for an answer on a numerical scale which represents the range between two extreme phases. The scale is generally divided into five or seven intervals where the central interval shows a lack of preference, or indifference.

The following are examples of a question usually used for five-/ and seven-scale intervals.

				neither agree nor disagree			
five interval	: Strongly agree	5	4	3	2	1	Strongly Disagree

Seven interval:	Excellent	7	6	5	4	3	2	1	Poor

Paired comparisons involve questioning respondents to make a series of trade-offs between pairs of specified qualities of the same entity, such as trip or travel mode. For example, in Bauer's study the pair comparison used involved choices regarding the amount of light, air, heat and sound present in the interior of the vehicle; the exit and entry ways, and several others. In this case the choice would be selected by circling the appropriate letter of the following:

1\. A. Ability to adjust the amount of light, air, heat and sound existing in the vehicle,

OR

B. Easier entry and exit from the vehicle.

2\. A. Easier entry and exit from the vehicle

OR

B. Lower fare for passengers,

etc.

Basically, there are two types of scaling which include: unidimensional scaling (U-D-S) and multidimensional scaling (M-D-S) techniques. Unidimensional scaling (U-D-S) is based on the assumption that the stimulus may be represented as a point value on a line, where each mode or submode has one value. Multidimensional scaling (M-D-S) is just an extension of the notion of Unidimensional scaling (U-D-S). Instead of a stimulus to be represented by a point on a line, a stimulus is represented as a point in a space of several dimensions. For a more detailed discussion of Unidimensional and Multidimensional scaling see Torgerson [1958] (40), Pfanjalg [1968] (41), Green and Carmone [1970] (42), Dobson, et al [1974] (34), Stopher, et al (33), and Nicholaidis (39).

5.4.1 Methodology Steps

The following is a description of the steps in the method to set up a standard of measurement of comfort and convenience variables.

First: definition, identification, hierarchical structuring of convenience and comfort attributes.

Second: defining and classifying level-of-service and level-of-satisfaction of subattributes of convenience and comfort attributes.

Third: methodology of measurement -- the application of utility theory.

Fourth: attitude survey; to determine people's opinion about utility of level-of-service and level-of-satisfaction for each subattribute of the convenience and comfort attributes. Stratified random sampling will be used, by classifying trip purposes into work trip and non-work trip, and by classifying tripmakers into "average" elderly and handicapped people.

Fifth: ranking and rating subattributes of convenience and comfort for each trip purpose and for each group of tripmakers.

Sixth: set up Utility Trip Matrix

A. Convenience Attributes
   for Average people work trip
   for Average people non-work trip
   for Elderly and Handicapped work trip
   for Elderly and Handicapped non-work trip

B. Comfort Attributes
   for Average people work trip
   for Average people non-work trip
   for Elderly and Handicapped work trip
   for Elderly and Handicapped non-work trip

Seventh: methodology for classifying overall level-of-service and level-of-satisfaction of convenience and comfort attributes.

5.5 Defining and Classifying Level-of-Service and Level-of-Satisfaction for Subattributes of Convenience and Comfort Attributes

This section will discuss the various subattributes of the convenience and comfort attributes as they relate to the attitude survey. Tables 5.3 through 5.12 will illustrate the corresponding levels-of-service and levels-of-satisfaction, based on approximate values derived from the literature, and subject to field validation for the elderly and handicapped population.

5.5.1 Convenience Attributes

5.5.1.1 Reliability -- The user perceives reliability not in the sense of "is the system reliable enough to get me to my destination?" but in the sense of does the transportation mode operate according to schedule, or is the service predictable? Perhaps the primary component of reliability is whether the user perceives the system or link as likely to perform the same daily task on the same schedule. The schedule for the automobile user may be self-made (within the constraints of the traffic system), but the public transit rider must gear himself to company schedule. There are many studies, such as Gustafson, et al [1971] (43), Bauer [1972] (44), Wallin and Wright [1974] (16), Paine, et al [1967] (7), and Stopher [1974] (33), which indicate that reliability (to arrive at the intended time or arriving when planned) is the most important of the public transit attributes. This subattribute is ranked high for both average people and the elderly, and for both work trips and non-work trips.

Reliability refers to "not more than one minute early, nor one minute late" and means that the trip is made "on time."

A higher percentage of "on time" is more preferable than a lower percentage of "on time" level-of-service for work trips and non-work trips, as classified in Table 5.3.

TABLE 5.3

LEVEL-OF-SERVICE OF RELIABILITY SUBATTRIBUTES

Work Trip	L-O-S	Non-Work Trip
% on time		% on time
90 - 100	A	85 - 100
80 - 89	B	75 - 84
70 - 79	C	65 - 74
60 - 69	D	55 - 64
50 - 59	E	45 - 54
< 50	F	< 45

5.5.1.2 Walking Time -- Walking time is defined as the time necessary to get to public transit from a trip origin, then from public transit to the trip destination. Walking is a major problem for the elderly and handicapped in using public transit. A typical travel barrier of the handicapped, as stated by U.S. DOT [1970] (45) is considered as having to walk more than one block. Less walking time is more preferable than more walking time. The assumed levels-of-service of walking time for work trips and non-work trips are classified in Table 5.4.

TABLE 5.4

LEVEL-OF-SERVICE OF WALKING TIME

Work Trip	L-O-S	Non-Work Trip
Walking time (minutes)		Walking time (minutes)
0 - 2	A	0 - 3
3 - 5	B	4 - 8
6 - 8	C	9 - 13
9 - 11	D	14 - 18
12 - 15	E	19 - 23
> 15	F	> 24

5.5.1.3 Waiting time -- Waiting time as a convenience factor is associated with time savings on the entire trip, and with the uncertainty of schedules. Psychological studies have shown that waiting passengers perceive their waiting time to be considerably longer than it actually is.

Long waiting times present a considerable inconvenience and a strong disincentive to the use of public transit, according to Solomon, et al [1968] (46).

Less waiting time is more preferable than more waiting time. Assumed levels-of-service of waiting time for work trips and non-work trips are classified in Table 5.5.

TABLE 5.5

LEVELS-OF-SERVICE OF WAITING TIME

Work Trip	L-O-S	Non-Work Trip
Waiting time (minutes)		Waiting time (minutes
0 - 2	A	0 - 4
3 - 5	B	5 - 9
6 - 8	C	10 - 14
9 - 11	D	15 - 19
12 - 14	E	20 - 24
> 14	F	> 24

5.5.1.4 Transfer -- In Lansing's study (4), he found that "having to change or transfer seems to have a depressing effect on the use of public transit." National Analysts, Inc.'s study (1) revealed that most public transit users and potential users consider uncertainty about the arrival of the second vehicle to be a major disadvantage in transferring. Although 84% of the people questioned disliked transfers, 88% said they would accept an "ideal transfer" if it were included as part of the trip, with only one fare paid at the beginning of the trip, including parking; the longest wait while transferring should be 5 minutes in a covered shelter; transfers where trains or buses at different levels are involved should be by escalator; and schedules should be 100% reliable.

Transfer time includes both walking time and waiting time, and fewer transfers is preferable to more transfers. Table 5.6 is a classification of assumed Levels-of-Service for Transfers.

TABLE 5.6 LEVEL-OF-SERVICE FOR TRANSFERS		
Work trip	L-O-S	Non-Work trip
Transfer		Transfer
No transfer	A	No transfer
1 with less than 3 min. wait time	B	1 with less than 5 min. wait time
1 with 3-5 min. wait time	C	1 with 5-12 min. wait time
1 with more than 5 min. wait time or 2 with less than 5 min. total time	D	1 with more than 12 min. wait time or 2 with less than 10 min. wait time
2 with more than 5 min. wait	E	2 with more than 10 min. wait
3 or more transfers	F	3 or more transfers

5.5.1.5 Ease of Access and Egress from Vehicle -- This subattribute of the convenience factor includes:

- Walk from entrance of boarding platform
- Entrance or exit station
- Boarding bus via steps
- Buying token, operating turnstile, holding overhead grip, using exit turnstile
- Signal bus, deposit fare, grasping overhead grip, pulling signal cord.

Since transportation facilities are designed to accommodate a mythical "average" person, almost any atypical body configuration exceeds the tolerances of the equipment. A man in a wheelchair is barred from passing through a turnstile simply because his chair makes him too wide. Someone using crutches encounters similar problems with narrow passageways compounded by his inability to make free use of his arms. Victims of muscle and joint diseases are frequently unable to flex their knees well enough to climb stairs. These are just a few of the ways in which transportation systems present barriers to people with unusual sizes and shapes on limited articulation.

Much of the delay which encourages passengers to rush is caused by bottlenecks around fare collection and ticket-selling areas. Delays due to payment for trips could be greatly reduced by reconsidering the whole process of fare collection. To improve the entry/exit bottleneck for the handicapped the following is recommended:

- Redesign fare turnstiles to eliminate push-bars; widen channel; pressure mates to open fare gates when coin is deposited; automate doors at exits.
- Improve coin receiver to eliminate precision movements.
- Modify bus to lower entrance; mechanize steps; add ramp or lift.
- Provide raised platforms at bus stops.

Table 5.7 shows a classified level-of-service of ease of access and egress from vehicle. The best design should be preferable to the less design.

TABLE 5.7

ASSUMED LEVELS-OF-SERVICE OF EASE OF ACCESS AND EGRESS FROM VEHICLES

Condition	L-O-S
No steps + Wheelchair lift; no pressure needed at turnstile	A
3 steps +	B
5 steps no lift	C
7 steps	D
10 steps	E
10 + steps	F

5.5.2 Comfort Attributes

5.5.2.1 Density or Crowdedness -- The public transit passenger's definition of comfort has often been, simply, getting a seat. National Analysts, Inc. [1963] (1) showed that 60.2% of respondents in Washington, D.C., criticized public transit because it is overcrowded;

54.3% specifically mentioned "no seat." Lansing [1964] (4) finds a similar reaction in his survey of modal choice for journeys to work: "The most important factor in determining comfort seems to be the availability of seats. 57% of positive comments about comfort relate to getting a seat." Usually, density, or crowdedness, can occur both in terminals and vehicles. Higher area per passenger should represent a higher satisfaction level than lower area per passenger. The classification for levels-of-satisfaction* is shown in Table 5.8.

TABLE 5.8

ASSUMED LEVEL-OF-SATISFACTION OF DENSITY OR CROWDEDNESS

Semantic Difference	L-O-Sat	Description
Very high satisfaction	I	- each passenger has invidüal, separate seat
High satisfaction	II	- each passenger has a seat as regular public transit seat
Neither satisfaction nor unsatisfaction	III	- 100-110% of seated load
High unsatisfaction	IV	- 111-125% of seated load
Very high unsatisfaction	V	- more than 125% of seated load or two square feet or less per person

5.5.2.2 Temperature and Ventilation -- Temperature comfort criteria, especially air conditioning, rank high in passenger perceptions of comfort factors. National Analysts, Inc. [1963] (1) found that 76% of Washington, D.C., commuters stated that subway cars should be air conditioned and/or heated properly when questioned on which factors they considered important in assuring that the proposed Washington rapid transit system be comfortable. Temperature ranked higher than "getting a seat" in this case.

Generally, 72°F is considered a desirable temperature for transportation vehicles when they are being heated, and 76°F is an acceptable temperature for air-conditioning such vehicles. The actual

*The term Level of Satisfaction is synonymous with the term Level of Service. Level-of-Satisfaction refers to the level of service perceived by different population subgroups.

temperature will obviously vary with the amount of clothing people are wearing in the vehicle. In winter, thermostats should be set lower (about 60°F) on subways and local buses, so that passengers are not too warm while wearing a topcoat.

Outside air needed for heating and air-conditioning can be controlled so that ventilation needs are met at the same time.

To determine Level-of-Satisfaction we will consider temperature and ventilation at the same time. Table 5.9 illustrates levels-of-satisfaction for temperature and ventilation.

TABLE 5.9

LEVEL-OF-SATISFACTION FOR TEMPERATURE AND VENTILATION

Temperature		L-O-Sat	Ventilation
Low(deg)F	High(deg)F		(ft^3/min/passenger)
72	76	I	>35
68	78	II	30-35
64 - 58	80 - 84	III	20-30
50	90	IV	15-20
<50	>90	V	<15

5.5.2.3 Noise and Vibration -- Noise is defined as the noise perceived by passengers while they are inside the public transit vehicle. Loud noise is universally recognized as an undesirable feature of transportation systems.

Vibration is defined as repetitive oscillatory movements in any direction. Severe vibrations, as described by the Institute for Rapid Transit, should be eliminated during equipment testing [Botzow 1974](47).

Lower noise and vibration levels are preferable to higher levels. Many criteria have been outlined in an attempt to establish a "riding comfort index," but none have been universally accepted. Therefore, vibration criteria will not be included in the level-of-satisfaction of noise and vibration. Table 5.10 illustrates levels-of-satisfaction of noise.

TABLE 5.10 LEVEL-OF-SATISFACTION OF NOISE		
Semantic Difference	L-O-Sat	Description of Noise (dB)
Very high satisfaction	I	< 60
High satisfaction	II	60 - 75
Neither satisfaction nor unsatisfaction	III	75 - 90
High unsatisfaction	IV	90 - 95
Very high unsatisfaction	V	> 95

5.5.2.4 Acceleration, Deceleration and Jerk -- Rapid acceleration and deceleration increase system speed, but only at the expense of passenger comfort. Fast acceleration is easier on seated passengers than on standing passengers -- especially for the elderly and handicapped passengers. Therefore, the levels-of-satisfaction are selected with the comfort of standing passengers in mind.

There are other kinds of acceleration in public transit, including linear and torsional (rotational) acceleration. The most common varieties on public transit systems are "sway" and "jouncing." Acceleration standards have been adopted for both horizontal (longitudinal, lateral, and other horizontal) and vertical movements.

Jerk is defined "as the rate of change in acceleration," and is measured in feet per second^3 [Botzow, 1974] (47). The effect of jerk is most noticeable to passengers on side seats during deceleration and stopping.

The classification of levels-of-satisfaction of acceleration, deceleration and jerk will be considered at the same time.

5.5.2.5 Interior Vehicle Environment -- The elderly often have poorer vision, need for walking aids, and a higher incidence of overweight -- among other impairments. The "comfort" aspects of which interiors are, therefore, more critical to their being able to negotiate a vehicle and to be seated and transported safely than they are to the general public. Recommended interior design requirements for

TABLE 5.11

LEVEL-OF-SATISFACTION OF ACCELERATION, DECELERATION AND JERK

Acceleration & Deceleration			
Horizontal ft/sec^2	Vertical ft/sec^2	L-O-Sat	Jerk (ft/sec^3)
<1.0	<1.5	I	<1.0
1.0 - 2.0	1.5 - 3.0	II	1.0 - 2.0
2.0 - 3.5	3.0 - 5.2	III	2.0 - 4.5
3.5 - 4.0	5.2 - 6.0	IV	4.5 - 6.0
>4.0	>6.0	V	>6.0

vehicles in service to the elderly include [Bell, 1975]*:

- adequate aisle widths;
- a high level of illumination;
- well-padded seats;
- frequent handholds (at entrance and exit, seat back and overhead);
- good color contrast between seats and surrounding areas.

For the wheelchair and no-steps group, seat spacing and seating arrangements will be required. From Brooks, et al. (undated)** we have the following guidelines:

Seat Access -- A 68 cm (26.8") seat spacing was considered better by elderly and handicapped both for getting in and out.

The doubled subjects had the most difficulty with the 60.9 cm (24") spacing.

Seat Spacing -- 91% of the subjects considered the 68 cm (26.8") seat spacing as "just right" compared with 57% on the 60.9 cm (24") spacing.. 43% considered 60.9 cm (24") spacing gave the seat in front as "too near" compared with 7% with the 68 cm (26.8") spacing.

*Bell, William G., Editor, "Proceedings of a National Transportation Conference; Fifth in a Series: Improving the Quality and Quantity of Transportation for Elderly and Handicapped," Florida State University, 1975.

**"An Investigation of Factors Affecting the Use of Buses by Both Elderly and Ambulant Disabled Persons," Transport and Road Research Laboratory Contractor Report, British Leyland U.K. Ltd.

Seat Spacing Preference -- All subjects show a strong preference for the 68 cm (26.8") seat spacing.

Seat Position Preference -- Of the total sample 91% prefer forward-facing seats as a first choice.

TABLE 5.12

LEVEL-OF-SATISFACTION OF INTERIOR VEHICLE ENVIRONMENTS

Semantic Difference	L-O-Sat	Seat Spacing
Very high satisfaction	I	68 cm
High satisfaction	II	66 cm
Neither satisfaction nor unsatisfaction	III	64 cm
High unsatisfaction	IV	62 cm
Very high unsatisfaction	V	60.9 cm

5.6 Methodology of Measurement -- the Application of Utility Theory

The term "utility" appeared quite early in the economic literature, but its meaning has shifted continuously. Initially it had the same meaning as the common synonym "usefulness" [International Encyclopedia of Social Sciences] (42). Utility may also be defined [the McGraw-Hill Dictionary of Modern Economics/1973/] (43) as a "service to satisfy human wants." It expresses the relationship between goods and man's pleasures or pains. It is the property possessed by a particular "good", or service, which gives an individual pleasure; or prevents pain during its consumption on the period of anticipation of its consumption.

Early economists, such as W. Stanley Jevons [1891], Leon Wallas [1874], and Alfred Marshall [1890], considered utility as a measurable quantity, just as weight is measurable. The consumer was assumed to be able to assign a number to every commodity which would represent the amount or degree of utility associated with it. Utility was thought of as the measurable quality of a given commodity. It was further assumed that utility is an additive quality. These economists assumed that utility is measurable and that the utility of one good is not affected by the rate of consumption of another.

In the past three decades, Van Neumann and Morgenstern [1944] (50) defined utility as just an indicator of preferences which could be measured.

In measuring comfort and convenience we assume that convenience or comfort is a commodity which users consume when they make a trip. This commodity (convenience or comfort) is a collection of characteristics, such as reliability of schedule, walking time, waiting time, transfer, and ease of access or egress from vehicle. Therefore, utility of convenience is the additive of utility of these characteristics. Different levels of these characteristics will possess different utilities of convenience.

We assume that there exist some preference relations among the levels-of-service or the levels-of-satisfaction. Each user has exact and full knowledge of all information about the level-of-service or the level-of-satisfaction provided by the planner. We also assume that higher levels-of-service or levels-of-satisfaction are always preferred to lower levels-of-service or levels-of- satisfaction.

In this example we have assumed six levels-of-service and five levels-of-satisfaction, from the "best" level-of-service A (or level-of-satisfaction I) to the "worst" level-of-service F (or level-of-satisfaction V). If the user cannot perceive the other four levels-of-service (or the other three levels-of-satisfaction), we assume that we must have at least one level-of-service (or level-of-satisfaction) between the "best" level-of-service A (level-of-satisfaction I) and the "worst" level-of-service F (level-of-satisfaction V). Then we have the following axiom.

AXIOM I. If level-of-service A is preferred to level-of-service B; level-of-service B is preferred to level-of-service C; level-of-service C is preferred to level-of-service D; level-of-service D is preferred to level-of-service E; and level-of-service E is preferred to level-of-service F; then level-of-service A is preferred to level-of-service F.

If $>$ means "preferred to" and $\sim$ means "indifferent to," we can write in the following notation:

$$A > B,\ B > C,\ C > D,\ D > E, \text{ and } E > F.$$

Then $A > F$.

When $A > B > C > D > E > F$

Therefore $U(A) > U(B) > U(C) > U(D) > U(E) > U(F)$

AXIOM 2. If level-of-service A is defined as the "best" and level-of-service F is defined as the "worst"; there must exist at least one level-of-service between the "best" and the "worst". The possible levels-of-service will be:

$A \sim B,\ B > C,\ C > D,\ D > E,\ E > F$

$A \sim B > C > D > E > F$

Therefore, $U(A) \sim U(B) > U(C) > U(D) > U(E) > U(F)$ --------(1)

$A > B,\ B \sim C,\ C > D,\ D > E,\ E > F$

$A > B \sim C > D > E > F$

Therefore, $U(A) > U(B) \sim U(C) > U(D) > U(E) > U(F)$-------- (2)

$A > B,\ B > C,\ C \sim D,\ D > E,\ E > F$

$A > B > C \sim D > E > F$

Therefore, $U(A) > U(B) > U(C) \sim U(D) > U(E) > U(F)$ --------(3)

$A > B.\ B > C,\ C > D,\ D \sim E,\ E > F$

$A > B > C > D \sim E > F$

Therefore, $U(A) > U(B) > U(C) > U(D) \sim U(E) > U(F)$ --------(4)

$A > B,\ B > C,\ C > D,\ D > E,\ E \sim F$

$A > B > C > D > E \sim F$

Therefore, $U(A) > U(B) > U(C) > U(D) > U(E) \sim U(F)$ --------(5)

$A \sim B \sim C > D > E > F$

Therefore, $U(A) \sim U(B) \sim U(C) > U(D) > U(E) > U(F)$ --------(6)

$A > B \sim C \sim D > E > F$

Therefore, $U(A) > U(B) \sim U(C) \sim U(D) > U(E) > U(F)$ --------(7)

$A > B > C \sim D \sim E > F$

Therefore, $U(A) > U(B) > U(C) \sim U(D) \sim U(E) > U(F)$ --------(8)

$A > B > C > D \sim E \sim F$

Therefore, $U(A) > U(B) > U(C) > U(D) \sim U(E) \sim U(F)$ --------(9)

$A \sim B \sim C \sim D > E > F$

Therefore, $U(A) \sim U(B) \sim U(C) \sim U(D) > U(E) > U(F)$ --------(10)

$A > B \sim C \sim D \sim E > F$

Therefore, $U(A) > U(B) \sim U(C) \sim U(D) \sim U(E) > U(F)$ --------(11)

$A > B > C \sim D \sim E \sim F$

Therefore, $U(A) > U(B) > U(C) > U(D) \sim U(E) \sim U(F)$ --------(12)

Assume that U(con) = Utility of Convenience

U(com) = Utility of Comfort

X_1 = Reliability

X_2 = Walking time

X_3 = Waiting time

X_4 = Transfer time

X_5 = ease of access and egress from vehicle

Y_1 = Density of crowdedness

Y_2 = Temperature and ventilation

Y_3 = Noise and vibration

Y_4 = Acceleration, deceleration, and jerk

Y_5 = Interior vehicle environment.

$U(con) = U(X_1) + U(X_2) + U(X_3) + U(X_4) + U(X_5)$ .... *

$U(com) = U(Y_1) + U(Y_2) + U(Y_3) + U(Y_4) + U(Y_5)$ .... **

In each level-of-service of X_1, X_2, X_3, X_4, and X_5 and level-of-satisfaction Y_1, Y_2, Y_3, Y_4, and Y_5, there are different utility values. These utility values are different for each individual. Therefore, to determine the utility function of convenience and comfort representing the utility function of a group of people, we must determine the utility function for the individual and then aggregate this utility function.

5.7 Attitude Survey

Sampling techniques should be used in the attitude survey. We know that each group of people has a different utility function, and that there is a different utility function for different trip purposes. In the survey method one should use the stratified sample, in which the population is divided into groups. In this case one divides the population into two groups: the elderly and the handicapped. Each group is then sampled randomly to represent the population in each group. The percentage of sampling depends on the number of persons in each group and the purpose of the study.

In the questionnaire to be sent to random respondents in each group, the levels-of-service and levels-of-satisfaction of the subattributes of convenience and comfort should be clearly shown. Respondents are asked to provide a utility rating for each level-of-service and level-of-satisfaction. The utility scale to be used is $0 \rightarrow 1$. For the "best", or highest level-of-service or level-of-satisfaction, the respondent would indicate a 1 rating, and for the "worst", or lowest level-of-service or level-of-satisfaction, the respondent would indicate a 0 rating. Between the "Best" and the "Worst" the respondent will also show ratings between 1 and 0 that are considered appropriate. Based on the axioms given in the previous section, the expected utility function should be sloped downward from the left to the right (the X-axis moves from the highest level-of-service or level-of-satisfaction to the lowest level-of-service or level-of-satisfaction).

The hypothetical utility function that is expected from the survey is shown in Figure 5.2.

For illustration of the concept of marginal disutility see Table 5.13.

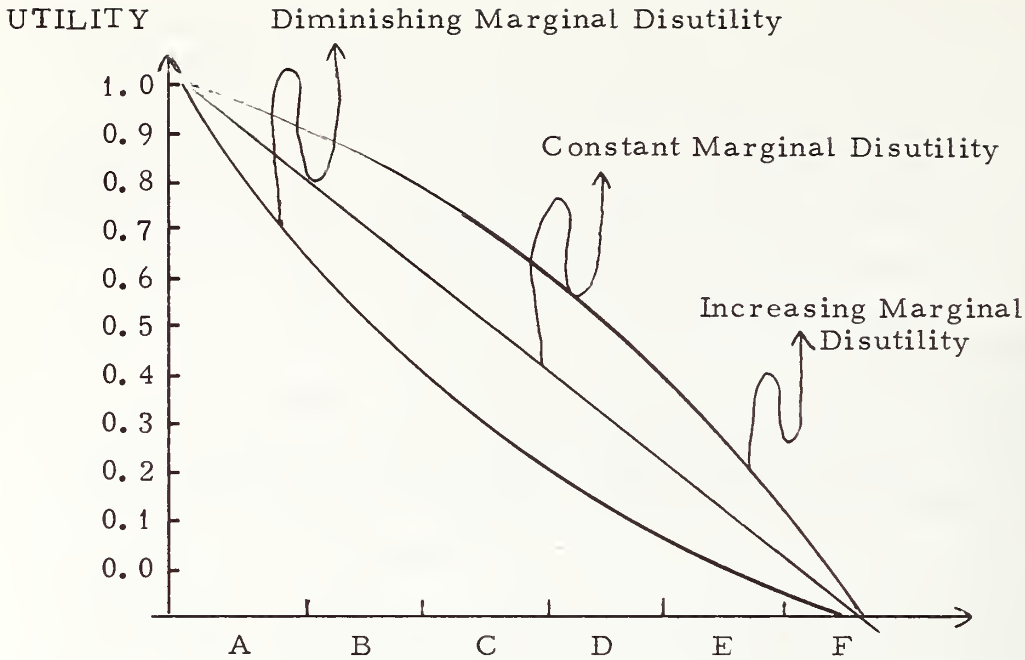


FIGURE 5.2: HYPOTHETICAL UTILITY FUNCTION OF LEVEL-OF-SERVICE OF CONVENIENCE SUBATTRIBUTES

TABLE 5.13

ILLUSTRATION OF DIFFERENT TYPES OF MARGINAL DISUTILITY OF LEVEL-OF-SERVICE

	Constant Marg. Disutility		Increasing Marg. Disutility		Diminishing Marg. Disutility	
L-O-S	Utility	Marg. Disutil.	Utility	Marg. Disutil.	Utility	Marg. Disutil.
A	1.0		1.00		1.00	
		0.2		0.05		0.35
B	0.8		0.95		0.65	
		0.2		0.08		0.25
C	0.6		0.87		0.40	
		0.2		0.18		0.20
D	0.4		0.69		0.20	
		0.2		0.29		0.15
E	0.2		0.40		0.05	
		0.2		0.40		0.05
F	0.0		0.0		0.0	

From the survey data we can find the average utility of each level-of-service or level-of-satisfaction for each subattribute of convenience or comfort, for each group of persons, and for each purpose of trip.

Let $\overline{Z}$ = estimated mean S = standard deviation

Z_i = sampling data

$$\overline{Z} = \frac{1}{n} \sum_{i=1}^{n} \overline{Z}_i \; \ldots\ldots *$$

$$S = \left(\frac{1}{n} \sum_{i=1}^{n} (Z_i - \overline{Z})^2\right)^{1/2} \; ------ **$$

For example, when a survey would be made concerning the utility of walking time for the work trip (from the handicapped group), the result of the survey would be shown as in Table 5.14 below.

TABLE 5.14

HYPOTHETICAL UTILITY OF WALKING TIME FOR WORK TRIP (HANDICAPPED)

L-O-S	Respondents										Z	S
	1	2	3	4	5	6	7	8	9	10		
A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0
B	1.00	1.00	0.90	0.70	0.60	0.50	0.70	0.80	0.75	0.65	0.76	0.17
C	1.00	0.90	0.85	0.55	0.30	0.50	0.60	0.80	0.55	0.65	0.67	0.21
D	0.90	0.80	0.75	0.45	0.20	0.20	0.55	0.60	0.35	0.30	0.53	0.23
E	0.50	0.70	0.50	0.35	0.20	0.10	0.25	0.40	0.35	0.30	0.36	0.16
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0

5.8 Ranking and Rating Subattributes of the Convenience and Comfort Variables

Since the people who make a trip perceive the subattributes of convenience and comfort in different level of importance, these subattributes of convenience and comfort have different importance for different groups of people, and for different purposes of trip. Before setting up the Utility Trip Matrix for utility measurement of the convenience and comfort variables, we have to weight these subattribute variables according to the group of people involved(in this case, the elderly and the handicapped), and by purpose of trip (work trip and non-work trip).

Simple ranking and rating will be used. The questionnaire on ranking and rating these subattributes would be mailed to the respondents at the same time as the questionnaire on utility rating. The respondents will be asked to rank the importance of these subattributes when they make a trip. The weight for level of importance will be assigned as: The 1st rank of importance will be equal to 5, the 2nd rank = 4, 3rd rank = 3, 4th rank = 2, and 5th rank = 1 respectively.

An example of ranking and rating is illustrated in Table 5.15.

The rating or weighting of these subattributes is expected to be extracted from the questionnaire, as in the following:

A. 1 Average people work trip

$X_1^{\bullet w} = x_1^{\bullet w}$ $\quad$ $Y_1^{\bullet w} = y_1^{\bullet w}$

$X_2^{\bullet w} = x_2^{\bullet w}$ $\quad$ $Y_2^{\bullet w} = y_2^{\bullet w}$

$X_3^{\bullet w} = x_3^{\bullet w}$ $\quad$ $Y_3^{\bullet w} = y_3^{\bullet w}$

$X_4^{\bullet w} = x_4^{\bullet w}$ $\quad$ $Y_4^{\bullet w} = y_4^{\bullet w}$

$X_5^{\bullet w} = x_5^{\bullet w}$ $\quad$ $Y_5^{\bullet w} = y_5^{\bullet w}$

A. 2 Average people non-work trip

$X_1^{\bullet nw} = x_1^{\bullet nw}$ $\quad$ $Y_1^{\bullet nw} = y_1^{\bullet nw}$

$X_2^{\bullet nw} = x_2^{\bullet nw}$ $\quad$ $Y_2^{\bullet nw} = y_2^{\bullet nw}$

$X_3^{\bullet nw} \doteq x_3^{\bullet nw}$ $\quad$ $Y_3^{\bullet nw} = y_3^{\bullet nw}$

$X_4^{\bullet nw} = x_4^{\bullet nw}$ $\quad$ $Y_4^{\bullet nw} = y_4^{\bullet nw}$

$X_5^{\bullet nw} \doteq x_5^{\bullet nw}$ $\quad$ $Y_5^{\bullet nw} = Y_5^{\bullet nw}$

Notations

X_1 = relability subattribute
X_2 = walking time subattribute
X_3 = waiting time subattribute
X_4 = transfer time subattribute
X_5 = Ease of access or egress to and from vehicle

Y_1 = crowding
Y_2 = temperature and ventilation
Y_3 = noise and vibration
Y_4 = acceleration, deceleration, jerk
Y_5 = interior vehicle environment

w = work trip
nw = non-work trip
ϕ = elderly and handicapped subgroups

TABLE 5.15

RANKING AND RATING SUBATTRIBUTES OF CONVENIENCE FOR HANDICAPPED PEOPLE'S WORK TRIP

Respondents	Convenience Subattributes									
	Reliability		Walking		Waiting		Transfer		Ease of acc/egress	
	Rank	Rate	Rank	Rate	Rank	Rate	Rank	Rate	Rank	Rate
1	1	5	2	4	3	3	4	2	5	1
2	1	5	3	3	2	4	4	2	5	1
3	1	5	3	4	4	2	3	3	5	1
4	2	4	1	5	3	3	4	2	5	1
5	3	3	2	4	1	5	3	2	5	1
6	1	5	5	1	2	4	3	3	4	2
7	3	3	2	4	1	5	4	2	5	1
8	4	2	5	1	2	4	1	5	3	3
9	2	4	5	1	3	3	1	5	4	2
10	1	5	5	1	3	3	2	4	4	2
11	1	5	3	3	2	4	4	2	5	1
12	3	3	4	2	2	4	1	5	5	1
13	4	2	5	1	2	4	1	5	3	3
14	1	5	4	2	3	3	2	4	5	1
15	1	5	5	1	3	3	2	4	4	2
16	1	5	4	2	2	4	3	3	5	1
17	5	1	1	5	2	4	3	3	4	2
18	1	5	5	1	2	4	4	2	3	3
19	2	4	4	2	3	3	1	5	5	1
20	1	5	5	1	2	4	3	3	4	2
Total Weight		86		48		77		66		32

GRANT TOTAL WEIGHT = 309

Assume that 309 = 1

Reliability = 0.28
Walking = 0.16
Waiting = 0.25
Transfer = 0.21

B. 1 Elderly and handicapped work trip

$X_1^{\phi w} = x_1^{\phi w}$ $Y_1^{\phi w} = y_1^{\phi w}$

$X_2^{\phi w} = x_2^{\phi w}$ $Y_2^{\phi w} = y_2^{\phi w}$

$X_3^{\phi w} = x_3^{\phi w}$ $Y_3^{\phi w} = y_3^{\phi w}$

$X_4^{\phi w} = x_4^{\phi w}$ $Y_4^{\phi w} = y_4^{\phi w}$

$X_5^{\phi w} = x_5^{\phi w}$ $Y_5^{\phi w} = y_5^{\phi w}$

B. 2 Elderly and handicapped non-work trip

$X_1^{\phi nw} = x_1^{\phi nw}$ $Y_1^{\phi nw} = y_1^{\phi nw}$

$X_2^{\phi nw} = x_2^{\phi nw}$ $Y_2^{\phi nw} = y_2^{\phi nw}$

$X_3^{\phi nw} = x_3^{\phi nw}$ $Y_3^{\phi nw} = y_3^{\phi nw}$

$X_4^{\phi nw} = x_4^{\phi nw}$ $Y_4^{\phi nw} = y_4^{\phi nw}$

$X_5^{\phi nw} = x_5^{\phi nw}$ $Y_5^{\phi nw} = y_5^{\phi nw}$

5.9 The Utility Trip Matrix

After we know the utility function of each level-of-service of the subattributes of convenience, and each level-of-satisfaction of the subattributes of comfort, for each group of persons and for different purposes of trip, we also have the relative weights of each subattribute of convenience and comfort.

Now we can set up the utility trip matrix to use as the standard of measurement for the comfort and convenience variables.

The following utility trip matrix we can set up.

A. 1 The Utility Trip Matrix of convenience for the average people's work trip.

A. 2 The Utility Trip Matrix of convenience for the average people's non-work trip.

A. 3 The Utility Trip Matrix of convenience for the Elderly and Handicapped's work trip.

A. 4 The Utility Trip Matrix of convenience for the Elderly and Handicapped's non-work trip.

B. 1 The Utility Trip Matrix of comfort for the average people's work trip.

B. 2 The Utility Trip Matrix of comfort for the average people's non-work trip.

B. 3 The Utility Trip Matrix of comfort for the Elderly and Handicapped's work trip.

B. 4 The Utility Trip Matrix of comfort for the Elderly and Handicapped's non-work trip.

Table 5. 16 will illustrate the Utility Trip Matrix of convenience for the handicapped people's work trip.

Since we have six levels-of-service of the convenience subattributes, and five subattribute variables, then the possibility of how trips can occur = $6^5 = 7776$ ways.

5. 10 Overall Level-of-Service and Level-of-Satisfaction of Convenience and Comfort Attributes.

From the Utility Trip Matrix we have many different utilities for convenience or comfort, ranging from zero to one. It is not convenient to use this Utility Trip Matrix in practice; therefore, we have to aggregate these utilities into six levels as overall levels-of-service.

The range for each level $= \frac{1.00}{6} \sim 0.17$

The Utility of level-of-service A will start from 0. 84 - 1. 00.
The Utility of level-of-service B will start from 0. 67 - 0. 83.
The Utility of level-of-service C will start from 0. 50 - 0. 66.
The Utility of level-of-service D will start from 0. 33 - 0. 49.
The Utility of level-of-service E will start from 0. 16 - 0. 32.
The Utility of level-of-service F will start from 0. 00 - 0. 15.

From each overall level-of-service we will find the average utility, to represent the utility of that level-of-service. *

For example, the average utility of L-O-S A might = 0. 91.
" ______ " " L-O-S B might = 0. 73.
" ______ " " L-O-S C might = 0. 59.
" ______ " " L-O-S D might = 0. 40.
" ______ " " L-O-S E might = 0. 25.
" ______ " " L-O-S F might = 0. 10.

*The interval over the range need not be linear, however, as shown in Figure 5. 2.

TABLE 5.16

EXAMPLE OF THE UTILITY TRIP MATRIX FOR CONVENIENCE FOR THE AVERAGE PEOPLE'S WORK TRIP

Trips (Tij)	Convenience Subattributes					Utility
	$X_1 = x_1^{\cdot w}$	$X_2 = x_2^{\cdot w}$	$X_3 = x_3^{\cdot w}$	$X_4 = x_4^{\cdot w}$	$X_5 = x_5^{\cdot w}$	
1	A	A	A	A	A	$\sum_{i=1}^{5} x_i^{\cdot w} X_i (\cdot$ A-
2	A	A	A	A	B	"
3	A	A	A	A	C	"
4	A	A	A	A	D	"
5	A	A	A	A	E	"
6	A	A	A	A	F	"
7	B	A	A	A	A	"
8	B	B	A	A	A	"
9	B	B	B	B	A	"
10	B	B	B	B	B	"
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
7776	F	F	F	F	F	"

5.11 Quantification of Security and Safety

The quantification of security and safety follow along similar lines as comfort, and convenience, without, however, the development of various subattributes. Here, five distinct levels of service are assumed to exist for security and safety, and they are labeled I through V. A distribution of the ridership across these levels of security and safety are obtained. Knowledge of the utility of security and safety for the ridership for each level of security and safety can then be used to develop the overall utility of security and safety for the plan at hand. This is illustrated in Chapters 6 and 7.

5.12 The Quantification of Accessibility

Accessibility that is provided by a design plan option is classified into five categories for each ridership group. Table 5.17 illustrates the levels of accessibility and the utility estimates for each level. The distribution of trips into each level of accessibility improvement for the design plan option is then obtained and the corresponding utility of accessibility improvement is then calculated. This procedure is illustrated in the Astoria case study area, Chapter 7.

TABLE 5.17

UTILITY OF ACCESSIBILITY FOR DIFFERENT GROUPS OF PEOPLE AT DIFFERENT LEVEL OF ACCESSIBILITY

Level of Accessibility	Elderly and Handicapped	Average People
I (0-20%)	0.20	0.10
II (21-40%)	0.45	0.35
III (41-60%)	0.65	0.60
IV (61-80%)	0.90	0.85
V (81-100%)	0.99	0.97

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CHAPTER 6

EVALUATION METHODOLOGY

6.1 Introduction

Decisions concerning a choice of alternative transportation investments require some systematic means of contrasting all the alternatives in terms of potential benefits relative to costs incurred. Benefit-Cost Analysis has been frequently employed to assist decision-makers in making the most rational decision. Benefit-Cost Analysis can help the decision-maker with the following kinds of decision, Crumlish (1).

- Should money be spent for a given purpose? and
- Is this the most profitable way to spend that money?

To reach these decisions, the analyst must be able to assess the economic characteristics of a particular project or program, to determine which of a number of projects designed to serve a given purpose achieves the purpose at minimum cost, and to determine which of a number of projects designed to serve different purposes confers the largest net benefit on the people of the area it serves. In other words, Benefit-Cost Analysis is based on the concept of the so-called "Pareto-Optimal Improvement" which is defined as a change in an economic organization that makes everyone better off without making anyone worse off, or a change which produces gains that exceed in value the accompanying losses; Mishan (2).

However, this method, as conventionally applied, suffers from a serious shortcoming in that it measures and compares (both benefits and costs) solely in monetary units. Consequently, the resulting decision frequently contains a bias in favor of choosing projects with the highest level of monetary performance. Intangible benefits which can be highly significant are generally not included due to the problems involved in applying monetary measurements to intangibles, Sheldon & Brandwien (3). Any attempt to assign dollar estimates to these intangibles is highly subjective, and possesses the potential of significantly distorting the resulting value of net benefits.

Transportation improvement needs for the Elderly and Handicapped, which often require a high quality of service at reasonable fares (this results in a greater net cost of service and thereby inadequate revenues for the operator), would not be economically viable if they were evaluated merely on a monetary benefit-cost analysis without consideration to such intangible features as accessibility, comfort, convenience, etc. Hence, it becomes necessary for government or planners to take an active role by providing needed subsidies to operators of transportation for the elderly and handicapped, so as to insure that acceptable service is provided.

To determine the amount of money to be allocated for subsidies, evaluations must be made which adequately reflect the benefits of the transportation system to the users and to the community as a whole. Benefits derived by the users can be referred to the users' account (see Figure 6.1), which includes intangible factors such as:

- Comfort,
- Convenience,
- Safety and Security,
- Accessibility,

and the tangible element of travel time. To arrive at a measure for these factors we have developed in this study a UTILITY-COST ANALYSIS to adequately relate intangible as well as tangible benefits and costs which cannot be expressed merely in monetary terms, and have been measured in terms of UTILITY.

To evaluate the usefulness of the system, it is necessary to understand the interrelationships between the types of impacted groups. These include:

- the operator
- the users, and
- the community.

The relationship between these groups of people is shown in Figure 6.1. The operator provides transportation to the elderly and handicapped and other special-interest groups at an acceptable level of quality of service, which may be economically not profitable. The operator will likely require a subsidy based upon the direct benefits received by the users, and the indirect benefits which the community receives in terms of an improved overall quality of life and stimulation

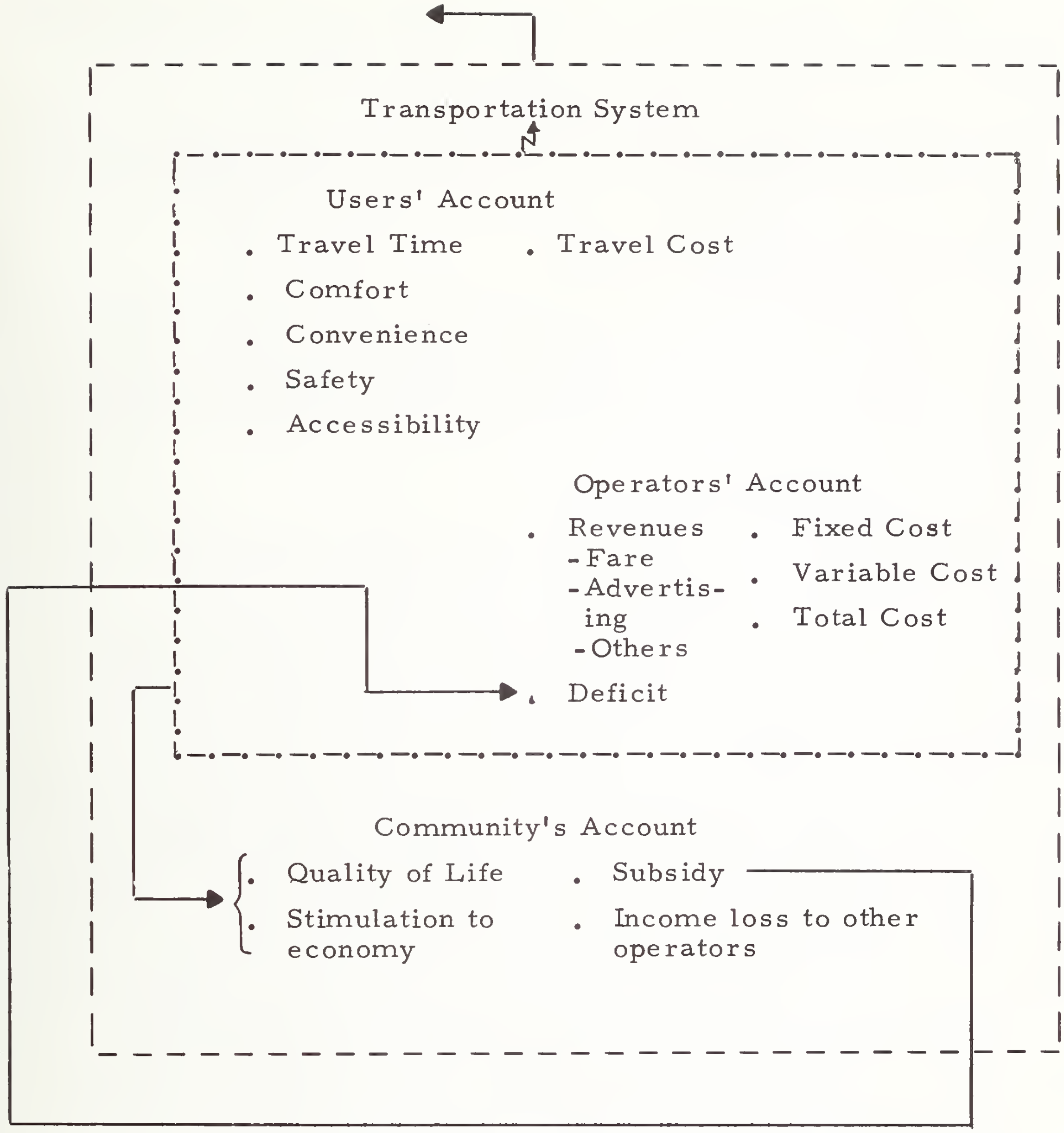

FIGURE 6.1: INTERRELATIONSHIP BETWEEN USERS, OPERATORS, AND COMMUNITY

to its economy. Of the many available alternatives, the community will subsidize the one which maximizes user utility and the community's benefit derived from the selected alternative.

The three groups of people comprising the transportation system and community are further described in the section which follows.

6.2 Operators' Account

In providing the service the operator has to be able to estimate a cost to operate the service and a revenue from the service. A transportation system's operating costs can be classified into two categories:

- Fixed Cost, and
- Variable Costs.

Fixed Costs: are typically those costs that are not necessarily increased or decreased as the service increases or decreases. They include such items as vehicles, equipment, office buildings, garages or parking lots, general supervision, overhead and administration, etc. Fixed costs are differentiated from variable costs because they represent those costs that must be met whether the service operates or not.

Variable Costs: are those costs that are increased or decreased as the service increases or decreases. They are usually affected by the vehicle-hours, the vehicle-miles, passenger trips, etc. Variable costs typically include such items as fuel, oil, tires, driver's wages, and other items of expense that are sensitive to the level of operation.

For methods of preparing budget estimate for transportation services for the elderly and handicapped, see the Institute of Public Administration (4). An illustration of these costs is seen in Table 6.1.

Data that the operator must collect or estimate is traffic data, and these data are:

- Vehicle-miles.......... VM
- Vehicle-hours.............. VH
- Revenue passengers............RP
- Revenue passenger-miles..........RPM

From the operators' account and traffic data we can calculate unit revenues and unit costs:

Unit Revenue

- Revenue per vehicle miles..... $= \frac{R}{VM}$....... (1)

TABLE 6.1

ILLUSTRATION OF OPERATORS' ACCOUNT

. Revenues...... R - Fare - Advertising - Others . Deficit........ D	. Fixed Costs............. F - Vehicles and Equipments (annual expense) - Office building (annual expense) - Garages or parking lots (annual expense) - General supervision and fringe benefits - Overhead cost - Interest - Others . Variables Costs......... V - Driver Salaries and Fringe Benefits - Fuel and Oil - Tire and Tube - Maintenance & Repairs - Cleaning - Insurance - Others . Total Cost............. T

- Revenue per vehicle hour..... = $\frac{R}{VH}$ ....(2)

- Revenue per revenue passengers..... = $\frac{R}{RP}$........(3)

- Revenue per revenue passenger-miles..... = $\frac{R}{RPM}$......(4)

Unit Costs

- Cost per vehicle-miles..... = $\frac{T}{VM}$........(5)

- Cost per vehicle-hours..... = $\frac{T}{VH}$..........(6)

- Cost per revenue passengers..... = $\frac{T}{RP}$........(7)

- Cost per revenue passenger-miles..... = $\frac{T}{RPM}$......(8)

For this study we will use cost per vehicle-hours and cost per revenue passengers as a key for evaluation. Cost per vehicle-hours can be compared with vehicle productivity (defined as the average number of passengers per vehicle per hour), and cost per revenue passenger can be compared with the average revenue per passenger trip.

6.3 Users' Account

Of the benefits which may develop from the transportation improvement for the elderly and handicapped, the most often cited is the ability of the transportation system to provide, to the elderly and handicapped, mobility and accessibility. Other benefits expected from the improvement are: reduced travel time, increased comfort and convenience, and increased security and safety. From the users' point of view, a reduction in fare is considered as a benefit. However, with regard to the transportation system and the community, a reduced fare may not necessarily imply a benefit, because of higher subsidies needed to provide the service. To include it as a user benefit would be "double-counting." It should be noted that while the fare may not be proper for inclusion in evaluating the system, it has a drastic effect on the overall planning of transportation improvements, as the fare will affect demand of the riders.

From Chapter 5 we have shown how to measure these benefits in terms of utility. Utility of these benefits is different for different groups of people (elderly and handicapped and average people), and for different purposes of trip (work trip and non-work trip). Therefore we have considered these variables separately for each group and for each purpose of trip. Figure 6. 2 is an illustration of the structural measurement of users' utility. We obtained the utility for each level of quality of service for each factor of users' benefit.

6. 4 Demand Pattern Determination

An important aspect in the evaluation of a proposed service is the establishment of the ridership demand both before and after the service is implemented. For the purposes of this study, the ridership is subdivided into the following categories:

1. Elderly, non-handicapped (E-N-H)
2. Wheelchair handicapped (WC)
3. No step handicapped (NS)
4. Step handicapped (S)

A study can then be undertaken to determine the demand intensity in each of these categories by time of day and trip purpose, which would involve a survey for the existing service and an extrapolation for the proposed service. The extrapolation can also be based on survey data but should include the designer and perhaps a panel of experts who can easily relate to the needs and desires of the specialized populations to be served.

Inherent time characteristics may lead to two distinct cycles, namely an hourly demand that can be considered to be either of a peak or non-peak nature. However, it should be noted that as more of the handicapped and elderly population become attracted to the service, a latent demand type phenomenon, there may be less a distinction between peak and off-peak periods, since this latent ridership may have more use for the service during the currently considered off-peak periods. A demonstration project may yield more insight into this aspect. Other characteristics of demand, such as diversity of trip patterns and degree of certainty of trips made, are also necessary to be estimated in order to effectively evaluate the proposed service.

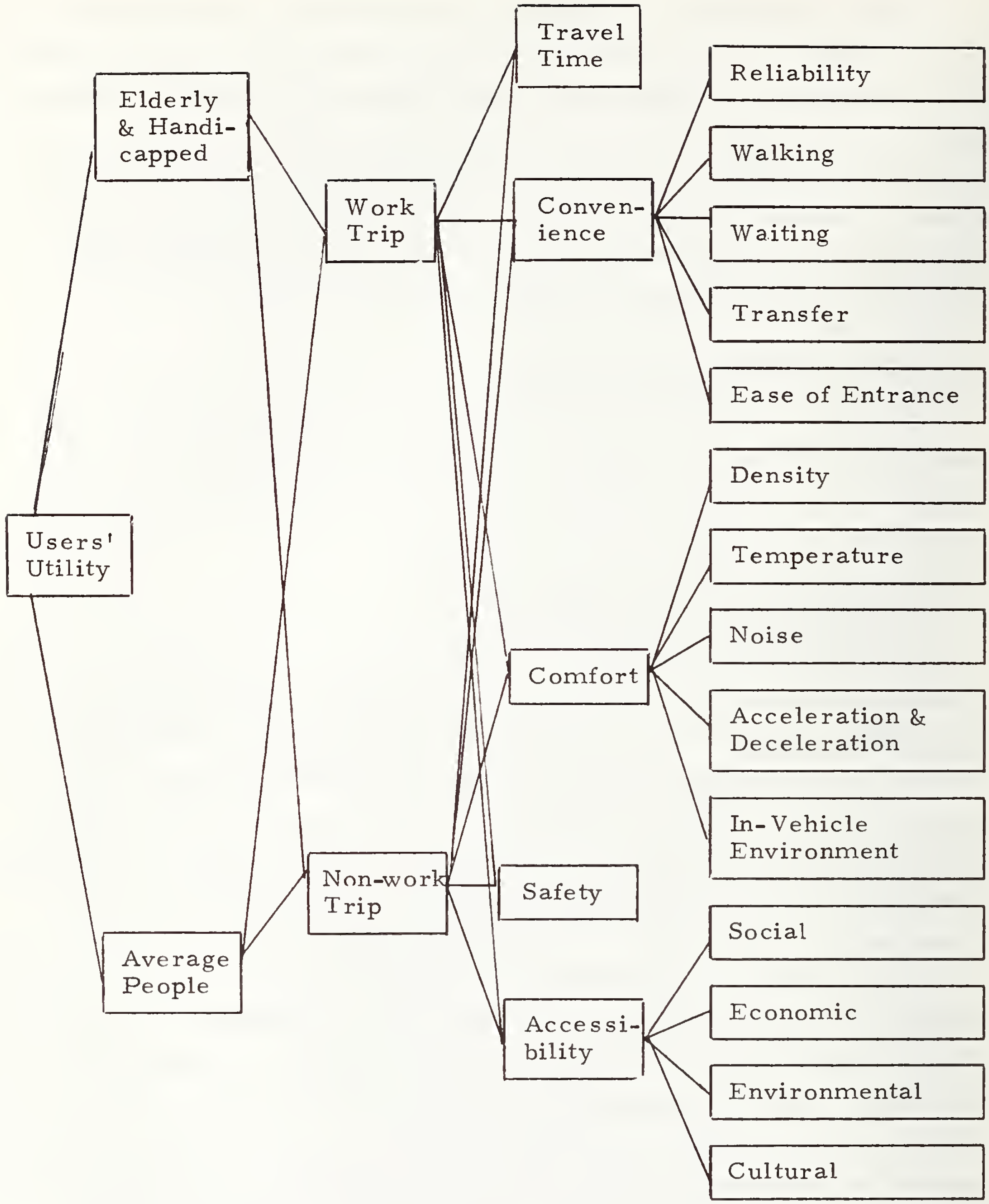

FIGURE 6. 2: THE STRUCTURE OF USERS' UTILITY FOR DIFFERENT GROUPS OF PEOPLE AND FOR DIFFERENT PURPOSES OF TRIP

For the purposes of evaluation of a proposed service, the demand studies lead to distributions of each category of ridership into each performance level of service for each service attribute (travel time saved, comfort, convenience, security and safety, accessibility) by time of day. The time of day variation may simply be a distinction of peak versus off-peak, or work versus non-work trips as previously mentioned. These are typically illustrated as in Figure 6. 3.

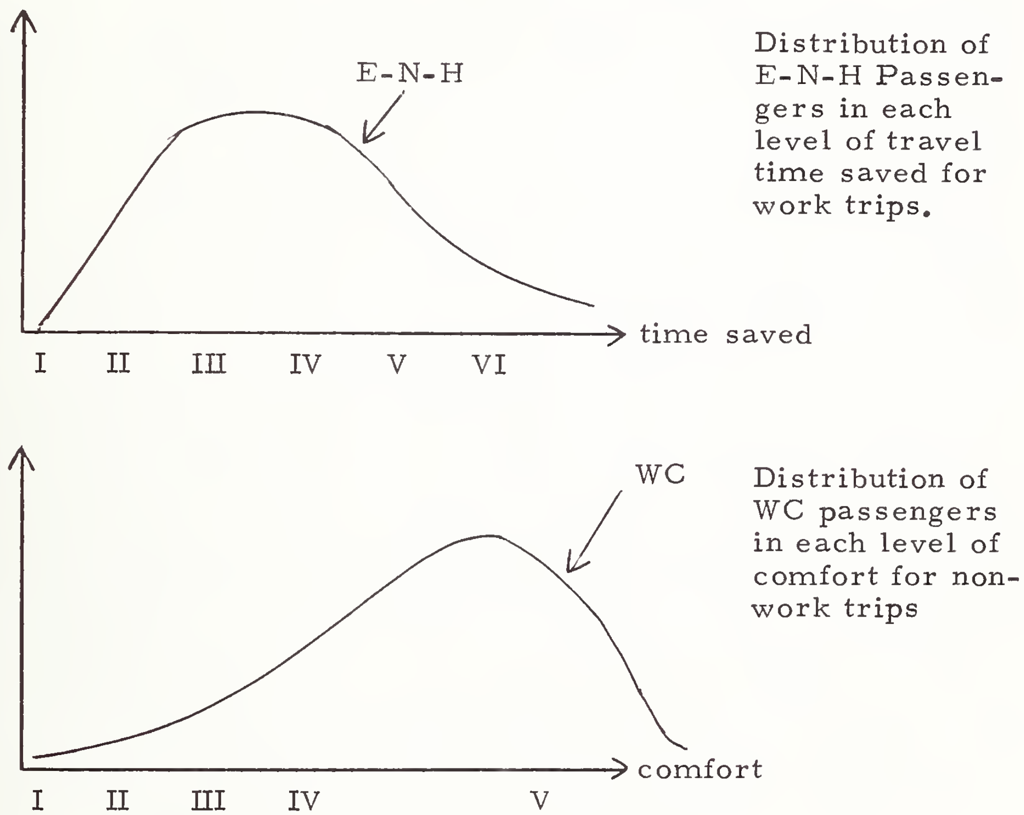

FIGURE 6. 3: SAMPLE DISTRIBUTION OF PASSENGERS BY CATEGORY IN EACH LEVEL OF QUALITY OF SERVICE FOR A PROPOSED SERVICE

6. 5 Utility Evaluation

Once demand patterns have been established for a given existing or proposed service, we next proceed to the evaluation of the utility return provided by the service. These can be most easily developed by use of a series of tables for each level of Quality of Service. Consider Table 6. 2 which can represent any component of the measure of

TABLE 6.2

A TYPICAL TABLE DISPLAYING THE RIDERSHIP DISTRIBUTION AND UTILITY VALUES FOR A COMPONENT OF THE QUALITY OF SERVICE MEASURE (#L)

Level of Service (i)	Work Trip (k = 1)				Non-work Trip (k = 2)			
	ENH (j=1)	WC (j=2)	NS (j=3)	S (j=1)	ENH (j=1)	WC (j=2)	NS (j=3)	S (j=4)
1	N_{111} u_{111}	N_{121} u_{121}	N_{131} u_{131}	N_{141} u_{141}	N_{112} u_{112}	N_{122} u_{122}	N_{132} u_{132}	N_{142} u_{142}
2.	N_{211} u_{211}	N_{221} u_{221}	N_{231} u_{231}	N_{241} u_{241}	N_{212} u_{212}	N_{222} u_{222}	N_{232} u_{232}	N_{242} u_{242}
3.	N_{311} u_{311}	N_{321} u_{231}	N_{331} u_{331}	N_{341} u_{341}	N_{312} u_{312}	N_{322} u_{322}	N_{332} u_{332}	N_{342} u_{342}
4	N_{411} u_{411}	N_{421} u_{421}	N_{431} u_{431}	N_{441} u_{441}	N_{412} u_{412}	N_{422} u_{422}	N_{432} u_{432}	N_{442} u_{442}
5	N_{511} u_{511}	N_{521} u_{521}	N_{531} u_{531}	N_{541} u_{541}	N_{512} u_{512}	N_{522} u_{522}	N_{532} u_{532}	N_{542} u_{532}
6.	N_{611} u_{611}	N_{621} u_{621}	N_{631} u_{631}	N_{641} u_{641}	N_{612} u_{612}	N_{622} u_{622}	N_{632} u_{632}	N_{642} u_{642}
	S_{11}/u_{11}	S_{21}/u_{21}	S_{31}/u_{31}	S_{41}/u_{41}	S_{12}/u_{12}	S_{22}/u_{22}	S_{32}/u_{32}	S_{42}/u_{42}

S_1/u_1	S_2/u_2	S_3/u_3	S_4/u_4

S / u

the quality of service, such as travel time saved. The utility, u_{ijk}, of providing the ith level of service (L-O-S) for the jth ridership category and kth time cycle may be obtained via the survey techniques previously discussed, while the distribution N_{ijk} of the ridership in the ith level of service the the jth ridership category, and kth time cycle has been discussed in the preceding section on demand pattern determination. Then the various entries in this table are the approximate products $N_{ijk}u_{ijk}$; and the average utility U_{jk} by category (j) and time cycle k is

$$U_{jk} = \frac{1}{S_{jk}} \sum_i N_{ijk} u_{ijk}$$

$$S_{jk} = \sum_i N_{ijk}$$

while the average utilities U_j and U, by category j and overall are respectively

$$U_j = \frac{1}{S_j} \sum_k S_{jk} U_{jk}$$

$$S_j = S_{j1} + S_{j2}$$

$$U = \frac{1}{S} \sum_j S_j u_j$$

$$S = \sum_j S_j$$

These tables would then be developed for the components of quality of service, yielding U_{jk}, U_j and U for travel time saved, comfort, convenience, security and safety, and accessibility as shown in Table 6.3. Appropriate weightings to be obtained from survey data are also illustrated. This leads to various overall measures of performance of the service under study, which can easily be calculated by a summation of appropriate row and column terms. For example, a weighted column sum,

$$U_{jk} = \sum_L A^L_{jk} U^L_{jk}$$

TABLE 6.3

COMPONENT SERVICE ATTRIBUTES AND THEIR WEIGHTS

Component	Work Trip (k = 1)				Non-work Trip (k = 2)				Component Measures		
	ENH (j=1)	WC (j=2)	NS (j=3)	S (j=4)	ENH (j=1)	WC (j=2)	NS (j=3)	S (j=4)	Work	Non-Work	Combined
travel time saved (L = 1)	S^1_{11} U^1_{11} A^1_{11}	S^1_{21} U^1_{21} A^1_{21}	S^1_{31} U^1_{31} A^1_{31}	S^1_{41} U^1_{41} A^1_{41}	S^1_{12} U^1_{12} A^1_{12}	S^1_{22} U^1_{22} A^1_{22}	S^1_{32} U^1_{32} A^1_{32}	S^1_{42} U^1_{42} A^1_{42}	S^1_1 U^1_1	S^1_2 U^1_2	S^1 U
comfort (L = 2)	S^2_{11} U^2_{11} A^2_{11}	S^2_{21} U^2_{21} A^2_{21}	S^2_{31} U^2_{31} A^2_{31}	S^2_{41} U^2_{41} A^2_{41}	S^2_{12} U^2_{12} A^2_{12}	S^2_{22} U^2_{22} A^2_{22}	S^2_{32} U^2_{32} A^2_{32}	S^2_{42} U^2_{42} A^2_{42}	S^2_1 U^2_1	S^2_2 U^2_2	S^2 U^2
convenience (L = 3)	S^3_{11} U^3_{11} A^3_{11}	S^3_{21} U^3_{21} A^3_{21}	S^3_{31} U^3_{31} A^3_{31}	S^3_{41} U^3_{41} A^3_{41}	S^3_{12} U^3_{12} A^3_{12}	S^3_{22} U^3_{22} A^3_{22}	S^3_{32} U^3_{32} A^3_{32}	S^3_{42} U^3_{42} A^3_{42}	S^3_1 U^3_1	S^3_2 U^3_2	S^3 U^3
security and safety (L = 4)	S^4_{11} U^4_{11} A^4_{11}	S^4_{21} U^4_{21} A^4_{21}	S^4_{31} U^4_{31} A^4_{31}	S^4_{41} U^4_{41} A^4_{41}	S^4_{12} U^4_{12} A^4_{12}	S^4_{22} U^4_{22} A^4_{22}	S^4_{32} U^4_{32} A^4_{32}	S^4_{42} U^4_{42} A^4_{42}	S^4_1 U^4_1	S^4_2 U^4_2	S^4 U^4
accessibility (L = 5)	S^5_{11} U^5_{11} A^5_{11}	S^5_{21} U^5_{21} A^5_{21}	S^5_{31} U^5_{31} A^5_{31}	S^5_{41} U^5_{41} A^5_{41}	S^5_{12} U^5_{12} A^5_{12}	S^5_{22} U^5_{22} A^5_{22}	S^5_{32} U^5_{32} A^5_{32}	S^5_{42} U^5_{42} A^5_{42}	S^5_1 U^5_1	S^5_2 U^5_2	S^5 U^5
	S_{11}/U_{11}	S_{21}/U_{21}	S_{31}/U_{31}	S_{41}/U_{41}	S_{12}/U_{12}	S_{22}/U_{22}	S_{32}/U_{32}	S_{42}/U_{42}	S^6_1/U^6_1	S^6_2/U^6_2	S^6/U^6

S_1/U_1 | S_2/U_2 | S_3/U_3 | S_4/U_4

S/U

yields the overall utility of service for a particular ridership class, such as WC and for a particular trip purpose, such as a work trip, while a row sum,

$$U_k^L = \frac{1}{S_k^L} \sum_j S_{jk}^L U_{jk}^L$$

$$S_k^L = \sum_j S_{jk}^L$$

yields the utility of service provided by a component for all ridership classes by trip purposes.

6.6 Benefit-Cost Analysis Procedures

With the benefits provided by a proposed service quantified in terms of a utility measure and the operating costs also previously developed, we next proceed to compare the various alternative services and select the "best" among them. A difficulty immediately arises, however, in defining what is the criterion for "best service." This could, for example, be stated as that service providing the greatest level of security and safety for the E-N-H group, or that service that provides the highest level of accessibility for the WC group. In general, some combination of levels of service for the various components must be selected to measure optimality, and this arbitrary selection is to be done by the decision-maker, or a panel of experts, or through community opinion as expressed in survey data.

For the given objective selected, one can then proceed toward a numerical comparison of the various alternative service plans under consideration. One technique involves the use of incremental benefit-cost ratio in the comparison of alternatives. Here the ratio of the difference in utility to the difference in cost for an alternative plan is calculated, with respect to that of a nominal service, for each alternative and the plan with the highest incremental benefit-cost ratio is selected as optimal.

Other approaches are also available for selecting the optimal among several alternatives. Linear programming techniques can be incorporated and are especially useful when the number of alternatives is large. Stochastic programming can be used when the risk due to the inherent uncertainty of the survey data and of the specifications of the various utility levels is to be taken into account.

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CHAPTER 7

OPERATIONAL GUIDELINES: APPLICATION OF EVALUATION METHODOLOGY TO THE ASTORIA CASE STUDY

7.1 Overview

A set of operational guidelines for improvements to the present structure of transportation services is developed in this chapter. We begin by presenting a technique for evaluating the impact of various vehicle types and designs on the quality of service provided. This essentially involves measuring the utility of the various design modifications. Then, several plans for improvement to the existing structure of services are presented and a development of the benefits derived from these alternatives, in terms of the utility measure, is given. Finally, an assessment of the "best" alternative is given in terms of the returns from and the costs of the various alternatives under consideration.

The illustration of this application uses the area of Astoria, Queens, in New York City. Astoria contains 195,402 persons (1) living in 6.3 square miles. The estimated ambulatory handicapped population (eight years of age or older) is 13,700 persons, of whom 3,500 are elderly (2). The study area is served by 26 miles of bus lines and 18 miles of subway lines, and most of the handicapped and elderly (75%) live within two city blocks from a bus line (3).

The aggregate travel demand estimates for the Astoria case study were derived using the methodology of Chapter 4. For the purpose of this example, latent demand estimates, however, were not considered because it was assumed that the proposed system improvements would not approximate the level of service available to car drivers. The travel demand estimates used in the case study example are shown in the appendix to this chapter, together with modal split assumptions and travel demand allocation by time of day.

7.2 Application of Methodology

Perhaps the first aspect to consider is the impact of the various vehicle types or designs that are currently available for use in the transportation system. Table 7.1 illustrates the cause-effect relation between vehicle designs and the service level components for small vehicles (up to 16 seats).

Table 7.1: Benefit-Cost Associated with Vehicle (E&H and Average People)

Vehicle Types	Seats	Costs Include Air-Condition	CONVENIENCE										COMFORT										Security & Safety		Travel Time		Accessibility	
			E&H					Normal People					E&N					Normal People										
I. Small Vehicles (up to 16 seats)		$10,000 14,000	X_1	X_2	X_3	X_4	X_5	X_1	X_2	X_3	X_4	X_5	Y_1	Y_2	Y_3	Y_4	Y_5	Y_1	Y_2	Y_3	Y_4	Y_5	E&H	N	E&N	N	E&N	N
1. Air-Condition & Good Heating	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No
2. No Air-Condition & Poor Heating	No	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No
3. Option not available for handicapped and elderly	No	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	Yes	No
4. Option available for handicapped and elderly																												
4.1 Steps, height and number	No	No	Yes	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	No
4.2 Lift on Ramp/ Acc. WC	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes	No
4.3 Both E&H	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes	No
5. Doors: Number, Width and Height	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	Yes	No	No
6. Length of Vehicle Width	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	No	Yes	No	No
7. Fuel and Engine Types	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	Yes	Yes	No	No
8. Average Fuel Consumption	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No
9. Estimated Life Expectancy	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Small vehicle sizes are typically considered for demand-response transportation systems, although similar tables can be established for medium- and large-size vehicles. Also shown is the estimated cost increment and the effect on seating capacity for each design option. The effects for the various design options are considered on a subcomponent basis for each service level component, and according to each ridership group, where appropriate. An example of those cells exhibiting a cause-effect relationship is displayed in Tables 7.2 and 7.3. These tables display the distribution and utility return for the design option under consideration, and are estimates obtained for the Astoria test area. Thus, Table 7.2 displays the effect that the step height and number, and lift-ramp vehicle design option has on the ridership, while Table 7.3 transforms these into utility levels of return, where the data again refers to the Astoria test area. Thus, we anticipate that the overall utility return or gain for providing ease of entrance and exit for the elderly and handicapped population is 0.90 and 0.97 for work and non-work trips. This may be partially explained by the fact that more people would prefer a higher level of service (L-O-S) for ease of entrance and exit for work trips than for non-work trips, where the pressure of time is somewhat relaxed. These types of tables 7(1-3) are useful in assessing a vehicle design that is cost-

Table 7.2: Estimated Distribution of E&H in Each Level of Satisfaction - Ease of Entrance and Exit from Vehicle

L-O-S	Option available for E&H				Option not available for E&H			
	Work		Non-Work		Work		Non-Work	
	%	#	%	#	%	#	%	#
A	40%	2,956	55%	4,064	5%	370	7%	517
B	40%	2,956	35%	2,586	15%	1,108	20%	1,478
C	20%	1,478	10%	739	35%	2,586	40%	2,956
D	-	--	-	--	25%	1,848	20%	1,478
E	-	--	-	--	15%	1,108	10%	739
F	-	--	-	--	5%	370	3%	222

Table 7.3: Utility of Ease of Entrance and Exit from Vehicle

L-O-S	Options Available						Options Not Available					
	Work			Non-Work			Work			Non-Work		
	U	#	T. U.	U.	#	T. U.	U	#	T. U.	U	#	T. U.
A	1.00	2,956	2,956.00	1.00	4,064	4,064.00	1.00	370	370.00	1.00	517	517.00
B	0.90	2,956	2,660.40	0.95	2,584	2,454.80	0.90	1.108	997.20	0.95	1,478	1,404.10
C	0.69	1,478	1,019.82	0.95	739	628.15	0.69	2,586	1,784.34	0.85	2,956	2,512.60
D	0.47	--	--	0.65	--	--	0.47	1,846	867.62	0.65	1,478	960.70
E	0.24	--	--	0.45	--	--	0.24	1,108	265.92	0.45	739	332.50
F	0.00	--	--	0.00	--	--	0.00	370	--	0.00	222	--
Total			6,636.22			7,146.95			4,285.08			5,726.90
Average			0.90			0.97			0.58			0.77

effective in terms of providing improved service levels for the various components of ridership, and should be incorporated in selecting an overall service plan.

Table 7.4 illustrates the accessibility provided by the alternative plans under consideration. These plans are considered to highlight the technique and Table 7.5 illustrates the cause-effect impact of various

Table 7.4: Alternative Plans Under Consideration

		Handicapped Accessibility			
Plan	System Structure	None Provided	NS Provided	WC Provided	NS and WC Provided
I	present	x			
IIa	present		x		
IIb	present			x	
IIc	present				x
III	DRTS				x

Table 7.5: Benefit-Cost Associated with Type of Service

	CONVENIENCE								COMFORT												SECURITY & SAFETY				Travel Time	ACCESSIBILITY			
	X_1	X_2	X_3	X_4	X_5				Y_1	Y_2	Y_3	Y_4				Y_5				F&H								
						Handicapped							Handicapped				Handicapped									Handicapped		
Alternative Plans	F&H	E&H	F&H	E&H	E	WC	NS	S	F&H	E&H	E&H	E	WC	NS	S	E	WC	NS	S	E	WC	NS	S	E&H	E	WC	NS	S
Plan I Do Nothing: Public Transit	-	-	-	•	•	-	•	•	•	•	•	•	-	•	•	-	•	•	•	•	-	•	•	•	•	-	•	•
Plan II Improved the existing A. Lower steps, slanted handle bars for support while boarding or alighting, and seating arrangement	no	no	no	no	yes	no	yes	yes	no	no	no	no	no	no	no	yes	no	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes
B. Make buses accessible to WC group - use lift or ramp	yes	no	yes	no	no	yes	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	no	yes	no	no	yes	no	yes	no	no
C. Make bus accessible to both F&H	yes	no	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Plan III DRTS 3.1 Many-to-one A. Lower steps, slanted handle bars for support while boarding or alighting, and seating arrangement	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes
B. Make buses accessible to WC group - use lift or ramp	yes	yes	yes	yes	no	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	no	no
C. Make bus accessible to both F&H	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Plan 3.2 Many-to-Many A. Lower step	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes
B. Wheelchair	yes	yes	yes	yes	no	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
C = A + B	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

options. Plan I essentially is to leave the current system intact. This will serve as a base for measuring the improvements provided by the other plans. Plan II provides for the improvement of the existing system. Here there are three levels of improvement:

(a) lower steps and slanted handle bars for support, and provide an appropriate vehicle interior design to make system accessible to the no-step (NS) handicapped ridership.

(b) provide lifts or ramps to make system accessible to wheel chair (WC) handicapped ridership.

(c) apply (a) and (b) to make system accessible to both NS and WC handicapped populations.

Plan III provides a DRTS using options a, b, c, as in Plan II. However, the character of the service, such as many-to-many, or many-to-one, will also affect the component levels of service and thus needs to be considered.

The various tables that follow develop the levels of service for design plan options I, IIa, IIc, and III. 2C; namely an evaluation of the current system, improvements to the current system for either the NS or both the WC and NS handicapped, and many-to-many, demand-responsive transportation service for the general handicapped population, for the Astoria test area. It is assumed that the NS group will exhibit a mode-use pattern and trip rate similar to that currently exhibited by the S group for plan IIa and IIc, while the WC group trip rate will increase by 20% and exhibit the following mode-use pattern for plan IIc:

20% of trips by use of wheelchair
15% of trips by use of bus
20% of trips by use of paratransit
4% of trips by use of auto (as driver)
41% of trips by use of auto (as passenger)

It is assumed that the trip rates of the NS and WC groups will be similar to the S group under plan III. 2c and their mode use will change as follows:

20% of trips by walking or wheelchair
55% of trips by paratransit (DRTS)
5% of trips by auto (as driver)
29% of trips by auto (as passenger)

Table 7. 6 displays the daily travel demand by mode and user group under these assumptions. Also, an estimate of the number of vehicles N required at a specified level of service LOS,* demand density D and service area A is given by Kirby (4):

$$N = \frac{(.68 - 072D)A}{\sqrt{LOS} - 1}$$

*This equals the ratio of trip time, including wait, on a public transportation vehicle to the equivalent time for the same trip by car.

Table 7. 6: Daily Travel Demand by Mode and User Group After Introducing DRTs

Mode of of Travel	Elderly N-H	Handicapped											
		Elderly				Non-Elderly				Total			
		WC	NS	S	Σ	WC	NS	S	Σ	WC	NS	S	Σ
Walk	2, 802	X	282	429	711	X	686	1, 662	2, 348	X	968	2, 091	3, 059
Wheelchair	X	39	X	X	39	153	X	X	513	192	X	X	192
Public Transit	3, 000	-	-	250	250	-	-	2, 269	2, 269	-	-	2, 519	2, 519
DRTs	1, 900	69	71	80	220	72	142	87	301	141	213	167	521
Paratransit	3, 999	-	375	490	1, 085	159	1, 187	1, 830	3, 176	159	1, 562	2, 320	4, 041
Auto-Driver	1, 100	7	20	33	60	27	200	600	827	34	220	860	1, 114
Auto-Passenger	3, 079	93	485	630	1, 198	400	1, 399	2, 300	4, 099	493	1, 884	2, 920	5, 297
Total	14, 898	208	1, 235	1, 902	3, 345	811	3, 614	8, 748	13, 173	1, 019	4, 849	10, 650	19, 519

This is an empirical relationship whose parametric values were obtained by use of the available data for existing DRTs for the average population and these should be recalibrated with respect to a DRTS for the handicapped and elderly populations. As an estimate of N for the Astoria test area, with an LOS of 2. 5, we have

A = 6. 3 miles
D = 38 passengers/square mile/hour
N = 8 vehicles

The development of these tables would proceed as follows: The aspects of convenience and comfort require special consideration. There are essentially two approaches developed herein for the quantification of these variables. The first considers, for example, the five subattributes of convenience (reliability, walking time, waiting time, transfers, ease of access and egress from vehicle) and requires the distributions of the ridership by category (e. g., elderly non-handicapped, wheelchair, no step, and step handicapped) across the six levels of service for each subattribute, as shown in Table 7. 7. For example, it is estimated that 15% of the handicapped with the ability to climb steps would perceive a level B of reliability of service, where reliability and the associated levels were discussed in Chapter 5. The average utility of each subattribute would then be calculated using the appropriate utilities for each level of service per subattribute, as shown in Table 7. 8 and the total average utility of convenience is found

Table 7. 7: Estimated Distribution of Reliability: Travel by Existing Public Transit

L-O-S	WORK								NON-WORK							
	% of E N-H	% of Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	5%	-	2%	30%	29	-	1	15	7%	-	7%	9%	226	-	7	183
B	9%	-	11%	15%	51	-	3	76	21%	-	22%	20%	680	-	23	406
C	19%	-	21%	20%	108	-	5	101	23%	-	24%	25%	745	-	25	507
D	47%	-	52%	51%	268	-	14	258	30%	-	30%	29%	971	-	32	588
E	15%	-	12%	7%	86	-	3	35	15%	-	14%	13%	486	-	15	264
F	5%	-	2%	4%	29	-	1	20	4%	-	3%	4%	129	-	3	81

Estimated Distribution of Walking Time: Travel by Existing Public Transit

L-O-S	WORK								NON-Work							
	% of E N-H	% of Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	50%	-	50%	47%	286	-	13	238	55%	-	57%	54%	1780	-	60	1095
B	27%	-	29%	25%	154	-	8	126	38%	-	39%	27%	1230	-	41	548
C	17%	-	17%	15%	97	-	4	76	5%	-	3%	17%	162	-	3	345
D	3%	-	4%	8%	17	-	1	40	2%	-	1%	2%	65	-	1	41
E	2%	-	-	4%	11	-	-	20	-	-	-	-	-	-	-	-
F	1%	-	-	1%	6	-	-	6	-	-	-	-	-	-	-	-

Estimated Distribution of Waiting Time: Travel by Existing Public Transit

L-O-S	WORK								NON-WORK							
	% of E N-H	% of Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	10%	-	7%	12%	57	-	2	61	11%	-	8%	14%	356	-	8	284
B	15%	-	14%	17%	86	-	4	86	14%	-	17%	19%	453	-	18	385
C	45%	-	41%	42%	257	-	11	213	37%	-	35%	33%	1198	-	37	669
D	25%	-	30%	22%	143	-	8	111	20%	-	22%	19%	647	-	23	385
E	5%	-	8%	7%	29	-	2	35	15%	-	11%	10%	486	-	12	203
F	-	-	-	-	-	-	-	-	3%	-	7%	5%	97	-	7	101

Estimated Distribution of Transfer: Travel by Existing Public Transit

L-O-S	WORK								NON-WORK							
	% of E N-H	% of Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	20%	-	25%	22%	114	-	6	111	15%	-	27%	24%	486	-	29	487
B	35%	-	40%	37%	200	-	10	187	32%	-	44%	35%	1036	-	47	410
C	20%	-	17%	21%	114	-	4	106	18%	-	19%	20%	583	-	20	406
D	15%	-	15%	13%	86	-	4	66	15%	-	7%	14%	486	-	7	284
E	7%	-	3%	5%	40	-	1	25	17%	-	3%	5%	550	-	3	101
F	3%	-	-	2%	17	-	-	10	3%	-	-	2%	97	-	-	47

Estimated Distribution of Ease of Access and Egress from Vehicle

L-O-S	WORK								NON-WORK							
	% of E N-H	% of Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	3%	-	-	-	17	-	-	-	4%	-	-	-	129	-	-	-
B	9%	-	-	3%	51	-	-	15	10%	-	-	4%	324	-	-	81
C	30%	-	7%	15%	171	-	2	76	29%	-	8%	14%	939	-	8	284
D	40%	-	59%	47%	228	-	15	238	39%	-	55%	45%	1262	-	58	913
E	15%	-	24%	29%	86	-	6	147	14%	-	29%	33%	453	-	31	669
F	3%	-	10%	6%	17	-	3	30	4%	-	8%	4%	129	-	8	81

Table 7. 8: Utility of Convenience Subattributes for Different Groups of People and Different Purposes of Trip at Different Levels-of-Service

Level of Service	Elderly & Handicapped										Normal People									
	Work trip					Non-work trip					Work trip					Non-work trip				
	X_1	X_2	X_3	X_4	X_5	X_1	X_2	X_3	X_4	X_5	X_1	X_2	X_3	X_4	X_5	X_1	X_2	X_3	X_4	X_5
A	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00	1. 00
B	0. 85	0. 70	0. 95	0. 80	0. 90	0. 90	0. 75	0. 90	0. 85	0. 95	0. 80	0. 90	0. 80	0. 90	0. 95	0. 81	0. 95	0. 75	0. 91	0. 57
C	0. 69	0. 35	0. 70	0. 59	0. 69	0. 75	0. 45	0. 79	0. 65	0. 85	0. 59	0. 80	0. 60	0. 70	0. 90	0. 62	0. 85	0. 55	0. 75	0. 73
D	0. 51	0. 00	0. 60	0. 34	0. 47	0. 55	0. 10	0. 65	0. 44	0. 65	0. 37	0. 70	0. 40	0. 40	0. 85	0. 40	0. 75	0. 30	0. 45	0. 47
E	0. 26	0. 00	0. 30	0. 40	0. 20	0. 30	0. 00	0. 40	0. 22	0. 45	0. 13	0. 40	0. 20	0. 10	0. 75	0. 15	0. 45	0. 10	0. 15	0. 18
F	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00

X_1 = Reliability
X_2 = Walking Time
X_3 = Waiting Time
X_4 = Transfers
X_5 = East of Access and Egress from Vehicle.

by the weighted sum of the average utility for each subattribute, where the weightings are shown in Table 7. 9. Thus, using the value . 85 for

Table 7. 9: Ranking and Rating Subattributes of Convenience for Different Groups of People and Different Purposes of Trip

Convenience Substitutes	Elderly & Handicapped		Normal People	
	Work	Non-Work	Work	Non-Work
Reliability (X_1)	0. 18	0. 15	0. 28	0. 30
Walking time (X_2)	0. 40	0. 45	0. 16	0. 16
Waiting time (X_3)	0. 10	0. 05	0. 25	0. 27
Transfer (X_4)	0. 12	0. 10	0. 21	0. 19
Ease of Entrance and Exit from Vehicle (X_5)	0. 20	0. 25	0. 10	0. 08

utility of the B level of reliability of service for elderly and handicapped work trips, obtained for the Astoria area, and 76 handicapped with the ability to climb stairs obtaining a B level of reliability of service (see Table 7.7) we calculate the associated total utility for this level and subattribute of comfort to be 76 x .85 = 64.6. The average utility for each subattribute is found by summing these products down the various columns and dividing by the number of riders (see Chapter 6, Table 6.2). Finally, the average utility for convenience is found as a weighted sum, as explained in Chapter 6 (see Table 6.3).

The other approach would be to develop distributions of the ridership by category across the six levels of service for the convenience attribute directly, as in Table 7.10. Then the utility of convenience is

Table 7.10: Estimated Distribution of Convenience for the Elderly and Handicapped: Travel by Public Transit

L-O-S	WORK [1103]								NON-WORK [5371]							
	% of E N-H	% Handicapped			# of E N-H	# of Handicapped			% of E N-H	% of Handicapped			# of E N-H	# of Handicapped		
		WC	NS	S		WC	NS	S		WC	NS	S		WC	NS	S
A	3%	-	-	4%	17	-	-	20	5%	-	-	5%	162	-	-	101
B	7%	-	6%	10%	40	-	2	51	15%	-	13%	15%	486	-	14	304
C	10%	-	58%	30%	57	-	15	152	30%	-	25%	39%	971	-	26	791
D	45%	-	27%	40%	257	-	7	202	25%	-	50%	30%	809	-	53	608
E	25%	-	8%	12%	143	-	2	61	17%	-	10%	7%	550	-	11	142
F	10%	-	-	4%	57	-	-	20	8%	-	2%	4%	259	-	2	81
Total					571	-	26	506					3237	-	106	2028

found by averaging the utility over the service levels using an average utility per service level as in Table 7.11. These average-utility-per-service-levels are found from a study enumerating all the possible combinations of service levels attainable from the five subattributes by trip purpose and ridership category, as in Table 7.12, and then ranking these (by equal utility increments of 0.17 into six overall levels of service). The average utility per level of service is then found by averaging the utilities within each level. The advantage of the latter approach is that only one estimate of the distribution of the ridership components is

Table 7.11: Utility of Overall Level-of-Service of Convenience for Different Groups of People and Different Purposes of Trips at Different Levels-of-Service

Level of Service	Elderly-Handicapped		Normal People	
	Work	Non-Work	Work	Non-Work
A	0.91	0.90	0.88	0.87
B	0.73	0.72	0.70	0.69
C	0.59	0.57	0.55	0.52
D	0.40	0.37	0.38	0.36
E	0.25	0.22	0.20	0.18
F	0.10	0.08	0.09	0.05

Table 7.12: A Typical Utility Trip Matrix of Convenience for a Particular Trip Purpose and Ridership Category

Trips (T_{ij})	Convenience Subattributes					Utility Σ
	$X_1=0.18$	$X_2=0.40$	$X_3=0.10$	$X_4=0.12$	$X_5=0.20$	
1	1.00(A)	1.00(A)	1.00(A)	1.00(A)	1.00(A)	1.0000
2	1.00(A)	1.00(A)	1.00(A)	1.00(A)	0.90(B)	0.9800
3	1.00(A)	1.00(A)	1.00(A)	0.80(B)	0.90(B)	0.9560
4	1.00(A)	1.00(A)	0.95(B)	0.80(B)	0.90(B)	0.9510
5	1.00(A)	0.70(B)	0.95(B)	0.80(B)	0.90(B)	0.8310
6	0.85(B)	0.70(B)	0.95(B)	0.80(B)	0.90(B)	0.8040
7	0.85(B)	0.70(B)	0.95(B)	0.80(B)	0.69(C)	0.7620
8	0.85(B)	0.70(B)	0.95(B)	0.59(C)	0.69(C)	0.7368
9	0.85(B)	0.70(B)	0.80(C)	0.59(C)	0.69(C)	0.7218
10	0.85(B)	0.35(C)	0.80(C)	0.59(C)	0.69(C)	0.5818
11	0.69(C)	0.35(C)	0.80(C)	0.59(C)	0.69(C)	0.5530
12	0.69(C)	0.35(C)	0.80(C)	0.59(C)	0.47(D)	0.5090
- -	- - -	- - -	- - -	- - -	- - -	- - -
- -	- - -	- - -	- - -	- - -	- - -	- - -
- -	- - -	- - -	- - -	- - -	- - -	- - -
- -	- - -	- - -	- - -	- - -	- - -	- - -
- -	- - -	- - -	- - -	- - -	- - -	- - -
7776	0.00(F)	0.000(F)	0.00(F)	0.00(F)	0.00(F)	0.000

required as compared to five in the former approach. Table 7.13 develops the utility of convenience for Plan I along these lines. A similar development follows for the comfort attribute and its five subattributes.

Table 7.13: Utility of Convenience: Existing Public Transit

Level of Service	WORK						NON-WORK					
	Utility	Elderly N-H Utility	Handicapped Utility			Total Utility Work Trip	Utility	Elderly N-H Utility	Handicapped Utility			Total Utility Non-Work Trip
			WC	NS	S				WC	NS	S	
A	0.91	15.47	-	-	18.20	33.67	0.90	145.80	-	-	90.90	236.70
B	0.73	29.20	-	1.46	37.23	67.89	0.72	349.92	-	10.08	218.88	578.88
C	0.59	33.63	-	1.97	89.68	125.08	0.57	553.47	-	14.82	450.87	1,019.16
D	0.40	102.80	-	5.60	80.80	189.30	0.37	299.33	-	19.61	224.96	543.90
E	0.25	35.75	-	1.25	15.25	52.25	0.22	121.00	-	2.42	31.24	154.66
F	0.10	5.70	-	-	2.00	7.9	0.08	20.72	-	0.16	6.48	27.36
Grand Total		222.55	-	10.28	243.16	475.99		1,490.24	-	47.09	1,023.33	2,588.02
Average per Passenger		0.39	-	0.40	0.48	0.43		0.46	-	0.44	0.50	0.48

The second approach is used to evaluate the convenience and comfort utilities under the various design plans. Similarly, the utility of the security and safety, accessibility and travel time saved service attributes have also been calculated. Tables 7.14 to 7.17 display the Quality of Service for each design alternative, as well as the weightings by user category.

Table 7.14: Quality of Service: Existing Public Transit Work Trip (Plan I)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.03	-0	0	0.35	0.39	0.1365	0.30	0.41	0.1230	0.20	0.67	0.1340	0.12	0	0	0.3935
WC	-	0	0	0.56	-	-	0.30	-	-	0.05	-	-	0.10	0	0	0.0000
NS	0.04	0	0	0.34	0.40	0.1360	0.31	0.35	0.1085	0.19	0.55	0.1045	0.12	0	0	0.3490
S	0.09	0	0	0,30	0.48	0.1440	0.27	0.40	0.1080	0.20	0.70	0.1400	0.14	0	0	0.3920
Grand Total			0	-		0.4165	-		-	-		-	-		-	1.1345
Average			0	-		0.1388	-		-	-		-	-		-	0.3872

Table 7.14 (continued): Quality of Service: Existing Public Transit Non-Work Trip (Plan I)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.01	0	0	0.37	0.46	0.1702	0.31	0.48	0.1488	0.19	0.62	0.1178	0.12	0	0	0.4368
WC	-	0	0	0.54	-	-	0.32	-	-	0.04	-	-	0.10	0	0	0.0000
NS	0.01	0	0	0.33	0.44	0.1452	0.33	0.38	0.1254	0.21	0.54	0.1134	0.12	0	0	0.3840
S	0.05	0	0	0.31	0.50	0.1550	0.30	0.45	0.1350	0.20	0.56	0.1120	0.14	0	0	0.4020
Total																1.2228
Average																0.4076

Table 7.15: Quality of Service: Plan IIa (Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(T)	T. U.	W_y	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.3	0.9	0.0027	0.35	0.43	0.1505	0.30	0.43	0.1290	0.20	0.67	0.1340	0.12	-	-	0.4162
WC	-	-	-	0.55	-	-	0.30	-	-	0.05	-	-	0.10	-	-	0.0000
NS	0.04	0.08	0.0032	0.34	0.47	0.1598	0.31	0.40	0.1240	0.19	0.62	0.1178	0.12	0.28	0.0336	0.4384
S	0.09	0.09	0.0081	0.30	0.47	0.1410	0.27	0.42	0.1134	0.20	0.54	0.1080	0.14	-	-	0.3705
Total																1.2251
Average																0.4084

Quality of Service: Plan IIa (Non-Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.01	0.03	0.0003	0.37	0.51	0.1887	0.31	0.50	0.1550	0.19	0.62	0.1178	0.12	-	-	0.4618
WC	-	-	-	0.54	-	-	0.32	-	-	0.04	-	-	0.10	-	-	0.0000
NS	0.01	0.03	0.0003	0.33	0.51	0.1683	0.33	0.49	0.1617	0.21	0.57	0.1197	0.12	0.28	0.0336	0.4836
S	0.05	0.03	0.0015	0.31	0.55	0.1705	0.30	0.48	0.1440	0.20	0.56	0.1120	0.14	-	-	0.4280
Total																1.3734
Average																0.4578

Table 7.16: Quality of Service: Plan IIc (Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and Safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.03	-0.09	-0.0027	0.35	0.41	0.1435	0.30	0.46	0.1380	0.20	0.72	0.1440	0.12	0.37	0.0444	0.4672
WC	-	-	-	0.55	0.36	0.1980	0.30	0.47	0.1410	0.05	0.67	0.0335	0.10	0.28	0.0280	0.4005
NS	0.04	-0.09	-0.0036	0.34	0.46	0.1564	0.31	0.43	0.1333	0.19	0.66	0.1254	0.12	0.34	0.0408	0.4523
S	0.09	-0.09	-0.0081	0.30	0.45	0.1350	0.27	0.48	0.1296	0.20	0.67	0.1340	0.14	0.36	0.0504	0.4409
Total																1.7609
Average																0.4402

Quality of Service: Plan IIc (Non-Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and Safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.01	-0.06	-0.0006	0.37	0.49	0.1813	0.31	0.53	0.1643	0.19	0.72	0.1368	0.12	0.37	0.0444	0.5262
WC	-	-	-	0.54	0.42	0.2268	0.32	0.45	0.1440	0.04	0.61	0.0244	0.10	0.28	0.0280	0.4232
NS	0.01	-0.08	-0.0008	0.33	0.48	0.1584	0.33	0.46	0.1518	0.21	0.67	0.1407	0.12	0.34	0.0408	0.4909
S	0.05	-0.08	-0.0040	0.31	0.52	0.1612	0.30	0.52	0.1560	0.20	0.68	0.1360	0.14	0.36	0.0504	0.4996
Total																1.9399
Average																0.4850

Table 7.17: Quality of Service: DRTs Plan III. 2c (Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(X)	T. U.	W_y	U(Y)	T. U.	W_z	U(Z)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0.03	0.32	0.0096	0.35	0.78	0.2730	0.30	0.75	0.2250	0.20	0.87	0.1740	0.12	0.49	0.0588	0.7404
WC	-	0.34	-	0.55	0.76	0.4180	0.30	0.77	0.2310	0.05	0.90	0.0450	0.10	0.54	0.0540	0.7480
NS	0.04	0.32	0.0128	0.34	0.78	0.2652	0.31	0.76	0.2356	0.19	0.85	0.1615	0.12	0.56	0.0672	0.7423
S	0.09	0.32	0.0288	0.30	0.78	0.2340	0.27	0.79	0.2133	0.20	0.86	0.1720	0.14	0.53	0.0742	0.7223
Total																2.9530
Average																0.7382

Table 7. 17 (continued): Quality of Service: DRTs Plan III. 2c (Non-Work Trip)

Groups of People	Travel time saved			Convenience			Comfort			Security and safety			Accessibility			Total
	W_t	U(T)	T. U.	W_x	U(T)	T. U.	W_y	U(T)	T. U.	W_z	U(Y)	T. U.	W_q	U(Q)	T. U.	
Elderly N-H	0. 01	0. 06	0. 0006	0. 37	0. 78	0. 2886	0. 31	0. 76	0. 2356	0. 19	0. 85	0. 1615	0. 12	0. 49	0. 0588	0. 7451
WC	-	0. 06	-	0. 54	0. 78	0. 4212	0. 32	0. 75	0. 2400	0. 04	0. 85	0. 0340	0. 10	0. 54	0. 0540	0. 7492
NS	0. 01	0. 06	0. 0006	0. 33	0. 78	0. 2574	0. 33	0. 76	0. 2508	0. 21	0. 84	0. 1764	0. 12	0. 56	0. 0672	0. 7524
S	0. 05	0. 06	0. 0036	0. 31	0. 78	0. 2418	0. 30	0. 77	0. 2310	0. 20	0. 85	0. 1700	0. 14	0. 53	0. 0742	0. 7206
Total																2. 9673
Average																0. 7418

These tables are calculated based on estimates obtained for the Astoria area, and proceed along the lines of the development of the previous tables and as discussed in Chapters 5 and 6. Note that those components of the particular design plan, that relate directly to vehicle characteristics or options, can be analyzed by use of Table 7. 5 and its associated tables. Thus, for example, the vehicle modification providing for easier entrance and exit would modify the distribution of the ease of access and egress from vehicle subattribute of the comfort attribute, as in Tables 7. 7 and 7. 3, and this in turn would modify the utility level of the comfort subattribute as described in the first approach to the calculation of the utility of the convenience and comfort attributes. This exemplifies the usefulness of Table 7. 5 and its associated tables in the evaluation of any proposed service design plan.

Table 7. 18 summarizes the quality of service of Plans I, IIa, IIc, and III. 2c. This data could be used in a benefit-cost ratio study, as

Table 7. 18: Summary of Alternative Plans

Alternative Plans	Quality of Service		Average	Cost per passenger
	Work	Non-Work		
Plan I Do Nothing	0. 3782	0. 4076	0. 3948	. 85
Plan II	0. 4084	0. 4578	0. 4331	1. 05
Plan IIc	0. 4402	0. 4850	0. 4626	1. 50
Plan III. 2c DRTs	0. 7382	0. 7418	0. 7400	2. 25

follows: Assume that the plan with the highest average incremental benefit cost-ratio as compared with Plan I is to be selected. Then,

$$\frac{u(IIa) - u(I)}{c(IIa) - c(I)} = \frac{.4331 - .3948}{1.05 - .85} = .1915$$

$$\frac{u(IIc) - u(I)}{c(IIc) - c(I)} = \frac{.4626 - .3948}{1.50 - .85} = .1043$$

$$\frac{u(III.2c) - u(I)}{c(III.2c) - c(I)} = \frac{.74 - .3948}{2.25 - .84} = .2466$$

where the costs are reasonable estimates for the Astoria area. On this basis, Plan III. 2c would be selected.

However, other criteria can also be used to select among the alternate plans. Consider Table 7.19. Here the incremental benefit-cost

Table 7.19: Incremental Benefit-Cost Ratios Using Plan I as a Base

Δ benefit/ Δ cost	ALTERNATIVE PLAN IIa		IIc		III. 2c	
	Work	Non-Work	Work	Non-Work	Work	Non-Work
Elderly N-H	.1135	.1250	.1134	.1375	.2478	.2202
WC	-	-	.6162	.6511	.5343	.5351
NS	.4470	.4980	.0738	.1645	.2809	.2631
S	-.1075	.1300	.0752	.1502	.2359	.2276
Average by plan and trip type	.1133	.1883	.2197	.2758	.3247	.3115
Average by plan	.1508		.2478		.3181	

$$\frac{\Delta \text{ benefit}}{\Delta \text{ cost}} = \frac{u(\cdot) - u(I)}{c(\cdot) - c(I)}$$

where the utilities are either those of the appropriate work or non-work trip.

ratios are calculated for each alternative plan according to trip type (work, non-work) and ridership group, and the averages for each plan by trip type and the overall average are also shown. The form of these ratios are similar to those above. Thus, if the objective is to select the alternative plan which provides the most cost-effective service to WC group, then plan IIc would be chosen. On the other hand, the NS group is most cost-effectively serviced by Plan IIa, while Plan III. 2c yields the most cost-effective overall service.

7.3 Implementation of Procedure

To effectively carry out the evaluation methodology a certain amount of raw and processed data must be obtained. Distributions of ridership among the various component subattributes will be developed. These will be obtained from survey data for an evaluation of existing services. Information obtained from a demonstration project* will be essential toward effectively evaluating proposed services. The next effort will focus on the incorporation of demonstration projects into the evaluation methodology.

Another aspect is the development of the utility levels for each subattribute as well as the weightings among various subattributes. Again, survey data will serve as the primary source of information. Demonstration projects may also indirectly reveal the ridership behavior by observations of their usage of the service.

Finally, the demonstration projects will yield insights into the methodology of simulation and how it can be effectively utilized in the evaluation process.

7.4 References

1. United States Census of Population (1970).

2. Transit Needs of the Elderly and Handicapped, a report to the Tri-State Regional Planning Commission, by Opinion Research Corp, December 1975.

3. Mobility of the Handicapped and Elderly, First Year Final Report, Polytechnic Institute of New York, January 1975.

4. Para-Transit: Neglected Options for Urban Mobility, R. F, Kirby, et al, The Urban Institute, Washington, D. C.

*"Easy Ride" a demonstration project to consolidate transportation services for the elderly and handicapped in the Lower East Side, New York City, by the Vera Institute of Justice.

APPENDIX A (TO CHAPTER 7)
SUMMARY OF TEST AREA STATISTICS
Study Area: Astoria, Queens, New York

Area = 6.3 Square miles

Bus line = 25.8 miles

Subway line = 17.8 miles

Total population (66 Census Tracts) = 195,402 (1970 Census estimate)

Total 8 years and Older = 174,202 (1970 Census estimate)

I. Estimate number of Elderly population

Elderly (handicapped & non-handicapped) = 9% of total population

Total elderly (handicapped & non-handicapped) = 0.09 X 195,402

= **17,586**

II. Estimate number of Handicapped population

Total Handicapped age 8 years & Older = 0.07 X 195,402

= **13,678**

Handicapped: elderly = 0.02 X 174,202

= **3,484**

Handicapped: non-elderly = 13,678 - 3,484

= **10,194**

III. Estimate number of Elderly (non-handicapped)

Total elderly (handicapped & non-handicapped) = 17,586

elderly: handicapped = 3,484

elderly: non-handicapped = 17,586 - 3,484

= **14,102**

IV. Classification types of Handicapped

4.1 Handicapped: Elderly

wheelchair users (WC) = 0.10 X 3,484 = **348**

who can not climb stairs (NS) = 0.40 X 3,484 = **1,394**

who can climb stairs (S) = 0.50 X 3,484 = **1,742**

4.2 Handicapped: Non-elderly

wheelchair users (WC) = 0.10 X 10,194 = **1,019**

who cannot climb stairs (NS) = 0.30 X 10,194 = **3,058**

who can climb stairs (S) = 0.60 X 10, 194= **6,116**

V. Mode used by the Elderly & Handicapped

Table A.1: Mode used by the Elderly & Handicapped

Modes	Elderly	Handicapped	
		Elderly	Non-elderly
Walk	20%	23%	19%
Transit (Bus/ Subway)	27%	14%	26%
Paratransit (Taxi/Car Service)	23%	27%	21%
Auto	30%	36%	34%

VI. Trip Rate of the Elderly & Handicapped

Table A.2: Trip Rate of the Elderly & Handicapped

Functional Mobility Classification	Trip/Day
I. Elderly: non-handicapped	1.30
II. Handicapped	
2.1 Elderly	
WC	0.56
NS	0.88
S	1.07
2.2 Non-Elderly	
WC	0.75
NS	1.18
S	1.43

VII. Estimate of Total Travel Demand for Study Area's: Elderly & Handicapped

Table A.3: Estimate of Total Travel Demand for Study Area's: Elderly & Handicapped

Functional Mobility Classification	Trip/Day
I. Elderly : non-handicapped	14,102 X 1.30 = 18,333
II. Handicapped	
2.1 Elderly	
WC	348 X 0.56 = 195
NS	1,394 X 0.88 = 1,227
S	1,742 X 1.07 = 1,864
2.2 Non-elderly	
WC	1,019 X 0.75 = 764
NS	3,058 X 1.18 = 3,608
S	6,116 X 1.43 = 8,746

Table A. 4: Trip Purpose of the Elderly & Handicapped

Trip purpose of the E & H	Elderly Non-handicapped	Handicapped
1. Work	10%	12%
2. School	-	7%
3. Shopping	32%	27%
4. Medical/Dental	15%	11%
5. Social & Recreational	22%	22%
6. Religous Service	10%	4%
7. Personal Business	5%	10%
8. Others	6%	7%

Table A. 4(a): Trip purpose of the Elderly & Handicapped

Trip purpose of the E & H	Elderly Non-handicapped	Handicapped
Work Trip	15%	20%
Non-Work Trip	85%	80%

Table A.5: Time of Travel of the Elderly & Handicapped

Time	Elderly: N-H		Handicapped			
	Total	Average per hr.	Elderly		Handicapped	
			Total	Average /hr	Total	Average /hr
6:00-10:00 A.M. A.M. (4 hrs)	30%	7.50%	29%	7.25%	30%	7.5%
10:00-4:00 A.M. P.M. (6 hrs)	44%	7.33%	46%	7.67%	60%	10%
4:00-7:00 P.M. P.M. (3 hrs)	19%	6.33%	20%	6.67%	8%	2.67%
7:00-10:00 P.M. P.M. (3 hrs)	7%	2.33%	5%	1.67%	2%	0.67%

Table A.6: Design Hourly Travel Demand on System
(Operating daily from 6 A.M.-10P.M.)

Time	Percent of Total Daily Demand (Hourly Demand)
6 A.M. - 8 A.M.	10%
8 A.M. - 4 P.M.	13%
4 P.M. - 7 P.M.	7%
7 P.M. - 10 P.M.	2%

Table A.7: Estimate of Existing Mode Usage by Type of Handicapped and Elderly

Mode	Elderly	Handicapped					
		Elderly			Non-elderly		
	N-H	WC	NS	S	WC	NS	S
Walk/Wheelchair	20%	20%	23%	23%	20%	19%	19%
Public Transit	27%	-	2%	14%	-	3%	26%
Paratransit	23%	22%	33%	27%	22%	33%	21%
Auto Driver	22%	4%	2%	2%	4%	6%	7%
Auto Passenger	8%	54%	40%	34%	54%	39%	27%

Table A.8: Daily Travel Demand by Mode & User Group

Mode of Travel	Elderly N - H	Handicapped											
		Elderly				Non-Elderly				Total			
		WC	NS	S	Σ	WC	NS	S	Σ	WC	NS	S	Σ
Walk	2,820	X	282	429	711	X	686	1,662	2,348	X	968	2,091	3,059
Wheelchair	X	39	X	X	39	153	X	X	153	192	X	X	192
Public Transit	3,808	-	25	261	286	-	108	2,274	2,383	-	133	2,535	2,668
Paratransit	3,243	43	405	503	951	168	1,191	1,837	3,196	211	1,596	2,340	4,147
Auto Driver	1,128	9	25	37	71	31	216	612	859	40	241	649	930
Auto Passenger	3,103	105	491	634	1,230	413	1,407	2,361	4,181	1,518	1,898	2,995	6,405
TOTAL	14,102	196	1,228	1,864	3,288	765	3,608	8,746	13,119	3,804	4,836	10,6.0	19,250

Table A.9: Hourly Travel Demand for the Elderly & Handicapped

Mode of Travel	Elderly				Handicapped (Elderly & Non-elderly)											
	N-H				WC				NS				S			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Walk	282	367	197	56	X	X	X	X	97	126	68	19	209	272	146	42
Wheelchair	X	X	X	X	19	25	13	4	X	X	X	X	X	X	X	X
Transit	381	495	267	76	-	-	-	-	13	17	9	3	254	330	177	51
Paratransit	324	422	227	65	21	27	15	4	160	207	112	34	234	304	164	47
Auto Driver	113	147	79	23	4	5	3	1	24	31	17	5	65	84	45	13
Auto Passenger	310	403	217	62	52	67	41	10	190	247	133	38	300	389	210	60

1 = 6 A.M. - 8 A.M.

2 = 8 A.M. - 4,P.M.

3 = 4 P.M. - 7 P.M.

4 = 7 P.M. - 10 P.M.

CHAPTER 8

DEMONSTRATION PROJECT PLANNING

8.1 Introduction

The preceding chapters have focused on the development of a set of analytical tools for the evaluation of alternative transportation plans and the choice of a transportation improvement most likely to succeed in meeting the needs of the handicapped and elderly population. The ultimate test in measuring the effectiveness of recommended improvements, however, rests with a field validation of their impacts. This is done usually through a demonstration project which yields a measure of responsiveness to the transportation improvements by the target population.

When the merit of an hypothesis is decided with a demonstration project, it is normally assumed that such an hypothesis may be proven or disproven through the evaluation of the results provided by the monitoring and analysis of the demonstration project. Such results typically contain comparisons between the "before" and "after" states of the variable or variables under consideration.

Recent experiences with demonstration projects have not been encouraging in their ability to conclusively prove or disprove an hypothesis. In some cases the size of the transportation improvement may not have been sufficiently large to affect the desired changes (2) and in others, the project may not have been tested long enough to account for the lag-time required by the subject population to eventually adjust to the changed conditions provided by the improvement.

Thus it has become apparent through a series of case histories that there is need to approach the planning of demonstration projects more carefully through the use of analytical and predictive techniques (1, 2).

This chapter presents some principles of demonstration project planning which were derived by Stephanis (1) in his doctoral dissertation at the Polytechnic.

8.2 The Demonstration Planning Process

Of the issues to be considered in demonstration project planning, the ones dealing with project duration and detectability of change affected by the demonstration are of critical importance in evaluating the outcome of an implementation. Stephanis' (1) work contains a thorough analysis of the factors to be considered in demonstration project planning and design. Figure 8.1 summarizes the methodology which he proposes for the planning and design of demonstration projects. The methodology requires as a first step, the specification of the area of study as regards the size of the Elderly and Handicapped population and its characteristics (i.e., type of handicaps, socio-economic data, employment, social service and other opportunities, existing transportation facilities, etc.). This information will give the planner a knowledge of the overall transportation-related conditions of the subject population. From these statistics, and with inputs by elected officials and community groups, a set of objectives for transportation may be specified. One of these objectives could include the need to reduce the unemployment of the Handicapped. Given the set of specified objectives, the process requires measurement of variables which describe, in numerical terms, each of the objectives so identified.

Thus, if unemployment is to be considered, the planner must measure the level of the unemployment rate in the area. This step requires a sampling methodology which will provide the needed information. The third step illustrated in Figure 8.1 addresses itself to data collection techniques, which are available to the planner, and recommends the most effective technique which he can use to measure the variables related to the objective of concern.

The next step (Figure 8.1) relates to the detectability assessment. This is a critical step because it has a key role in the overall process of demonstration planning. This assessment allows the planner to determine whether or not the demonstration project can meet the objectives and criteria of the transportation improvement. The assessment uses statistical techniques which specify levels of improvements which can be detected, given the characteristics of the variable in question. Essentially, detectability involves a comparison of the test variables for the before-the-improvement situation and the situation-after-the-improvement.

Inputs into the detectability assessment for the 'before' condition are obtained through the surveys mentioned above. The inputs for the 'after' condition are derived from sampling the ridership using the

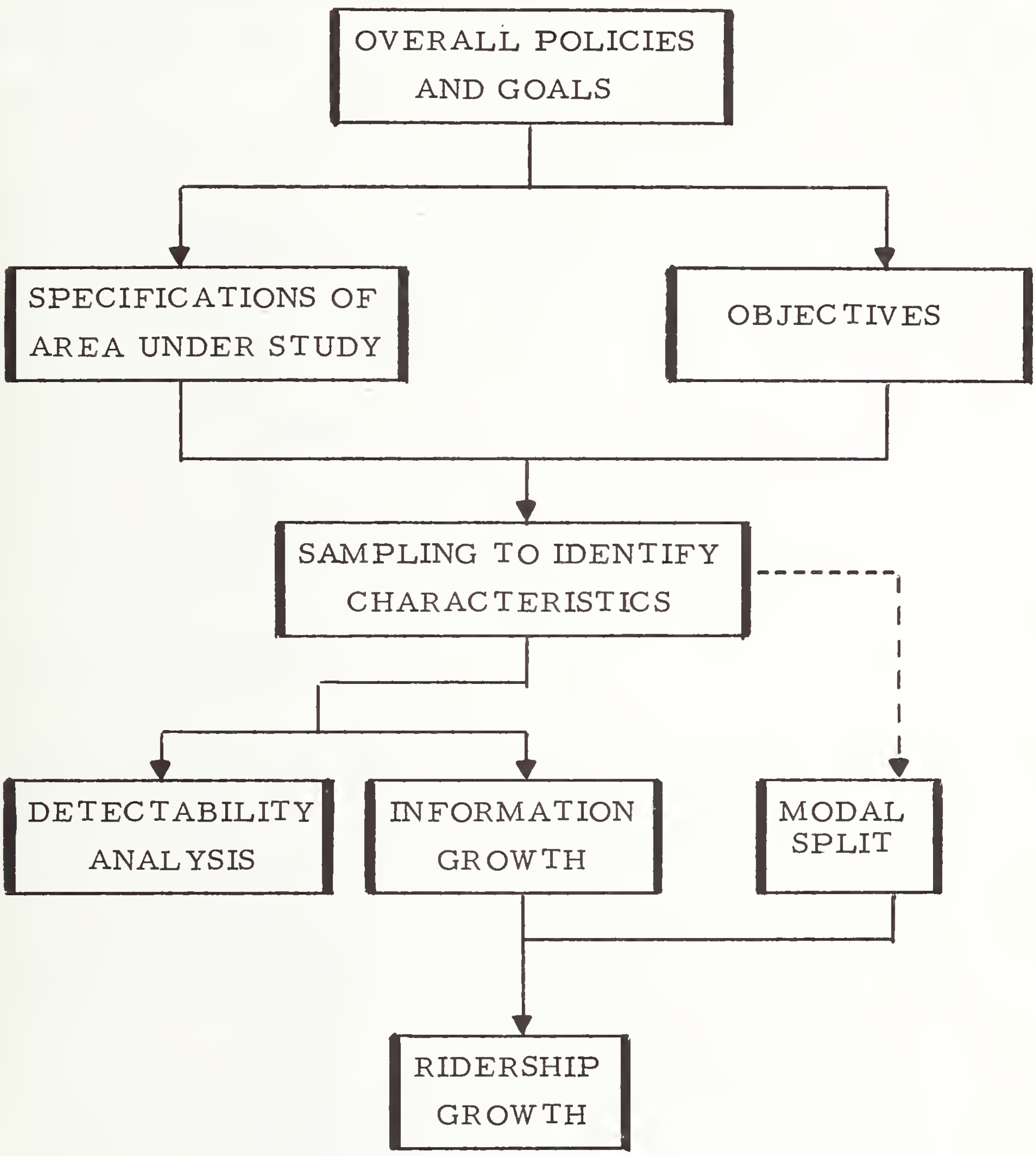

FIGURE 8.1
DEMONSTRATION PROJECTS' PLANNING PROCESS

improved transportation service (i.e., DRT). Estimates of DRT volumes are obtained through a modal split methodology.

The expected DRT demand is a function of the level of service provided by the DRT service; therefore, the steps of the process dealing with modal split and level of service are interdependent. Thus, the output of the modal split process will give the expected demand of the DRT service. Past experience in this area indicates that transportation demand is time dependent. This fact creates some difficulties in the planning and management of demonstration projects. To aid in the solution of this problem a ridership model has been developed. This model uses epidemic-type dynamics to describe the growth in the weekly number of system users. In this way it is possible to estimate the amount of time that must be allocated to the demonstration project to realize the demand estimate predicted by the modal split process. Therefore, the ridership model developed by Stephanis may be regarded as a significant contribution in the planning process of demonstration projects because it enables an estimate of the elapsed time from the inception of the demonstration project which must be observed prior to making a system effectiveness evaluation.

The modal split process in turn is dependent on the output of the information process. The information model has been derived from Kendall's studies on information diffusion. Kendall and all successors in the information propagation field, used the logistic formula, which they found expresses reality accurately, to predict information dynamics (3, 4). This same basic approach is used for the Elderly and Handicapped population and its characteristics.

Essentially, what the process entails is the establishment of a core group of informed persons who, through meetings with their peers, will transmit information about an event. This will create a chain reaction of information propagation which in time will transmit knowledge of such an event to the entire Elderly and Handicapped population. The event of interest in this study is the implementation of a DRT system in a particular area.

The total number of Elderly and Handicapped in the study area who must be informed about the implementation of a DRT service is estimated through surveys of a sample of the total population. An estimate of the time required to inform the total Elderly and Handicapped population about the implementation or the existence of such a service is based on the information process. The output of the information analysis is then used to determine the timing between the announcement of the DRT service and its actual implementation to insure a reasonable level of ridership.

The result of this methodology is an estimate of cost-effective duration for the demonstration project. This duration is determined to be the sum of the information spread duration and ridership growth duration. The cost of the demonstration project is determined as the sum of sampling cost and the transportation system operating cost. The outlined methodology does not attempt to give exact numbers for planned duration and cost; rather, it gives an approximation which will indicate whether the demonstration project is viable or not, and if the money and time which will be spent are adequate, thus minimizing the risks of financial loss and time waste.

8.3 Measure of Effectiveness

In designing and implementing a DRT system for the Elderly and the Handicapped, the planner tries to satisfy some trip needs of the community under study. Essentially, he tries to transport people to their most desirable destinations, which they could not reach using existing public transportation. These trips are to areas containing job opportunities, to medical facilities and recreational opportunities (i.e., trips to friends, church, club meetings, sports, movies, etc.). On these grounds, measures of effectiveness would include fluctuations in unemployment rates, and in recreational or medical trips.

During the primary 'before' survey, which establishes the existing characteristics of the Elderly and Handicapped population, the planner asks questions about unemployment, skills available within the population, medical and recreational trips, location of recreational and medical facilities, and how these trips are satisfied. In addition, an assessment is made of trip frequencies and modes used for current travel. An estimate will also be developed of the expected additional number of trips which will be made if the transportation service were improved.

Sampling for unemployment characteristics may be done in two distinct groups. One would be the group of non-users, and the other is the group of users, or the ridership group. The non-users and the users comprise the community population. The community is considered a closed system, and the statistical evaluation assigns no migration. The sampling process is exhibited by the following hypothetical example:

	NON-USERS		USERS		TOTAL COMMUNITY	
	Emp.	Unemp.	Emp.	Unemp.	Emp.	Unemp.
Before	450 calc	50 calc	60 calc	40 calc	510 calc	90 calc
After	470 est.	30 est.	80 est.	20 est.	550 est.	50 est.

Estimated figures would come out of the surveys. Those that are calculated are calibrated by using the estimated values. The primary 'before' survey is conducted in the total community. The second 'after' survey is done among the population (i. e., users[1] and non-users, preferably identified) in the total community. The 'before' and 'after' unemployment rates in the users group are collected at the same time, using the same questionnaire.

If Y_B and Y_A are the rates for the 'before' and 'after' situations in the users group, and X_B and X_A for the community group, the statistical significance of the differences $\Delta Y = Y_A - Y_B$ and $\Delta X = X_A - X_B$ as well as conclusions depending upon the outcomes, would be derived through two-factor analysis of the following table of data:

Y_B	X_B
Y_A	X_A

8.4 Summary of Analytical Procedure

The main contribution of the Stephanis work was the identification of the factors which affect the different stages of demonstration project implementation, and the estimation, before-hand, of the uncertainties

[1] An individual who used the system at least once.

that each demonstration project pre-evaluation process step entails. These uncertainties have been proven to be critical in past projects and their impact on the outcomes were dramatically significant. The three focal points of interest are the uncertainties concerning:

1. Sampling from the population under study.
2. Ridership dynamics.
3. Evaluation of results which were received as outputs from the models and procedures used.

For sampling from the population for diversified characteristics, standard methods are employed, specially formulated to give a solution to the specific problem under study. The cost vs. sample size optimization is included which exposes trade-offs between accuracy of results and cost of survey. The ridership dynamics are divided into three main stages:

1. An information model which attempts to predict the way the news about the improved transportation service will spread in the population under study, and the time needed for the population to be informed. The basic model employed is the standard logistic model, which was modified, to better fit the behavior of population under study and to reveal the uncertainties entailed in information dissemination. Sensitivity analysis of the constant parameters was made in detail, to expose possible insights of the model.

2. A ridership model which attempts to predict the project's ridership behavior on a weekly basis. This demand model is novel and is an adaptation of the mathematical theory of epidemics in a transportation-related topic. The model includes demand-related rates, namely attraction rate, dropout rate, and rejoining rate and its results are closely dependent on the accuracy of the estimates concerning these rates, as well as the potential rider's pool size and the first week's ridership. Sensitivity analysis of the constant input parameters was made in detail to develop an order of magnitude of the effects of these parameters on the outputs of the model.

3. A detectability process which attempts to identify and quantify uncertainties related to the derivation of conclusions from sampling data. The approach is novel and is an adaptation of 'signal detection' in a finite, population-related detection problem. A sensitivity analysis of the process versus the input parameters was made to reveal their effect on the output.

8.5 Suggested guidelines for demonstration project planning

The suggested guidelines for demonstration project planning are as follows:

1. Estimate the population of the Handicapped in the population of the specific area under study. Sample for the employment characteristics of the Handicapped.

2. Inform the population of the Handicapped about the implementation of an improved transportation system which will alleviate problems related to their work trips. Estimate, through the information model, the time needed for information dissemination.

3. Input the estimated number of informed in the modal split and get an estimate of the potential users' pool size.

4. Input the estimated pool size multiplied by the expected trip frequency to the ridership model and estimate the time needed for the ridership to reach a steady state.

5. Conduct a survey in the users' group and identify their 'before' and 'after' employment characteristics.

6. Compare the 'before' and 'after' measure of effectiveness (MOE) variable for the users' group.

7. Compare the 'before' and 'after' MOE variable for the community's Handicapped and Elderly population.

8. Conclude as to whether or not the demonstration project confirmed the initial hypothesis.

8.6 References

1. "Planning and Design of Demonstration Projects," Basil Stephanis, doctoral dissertation, Polytechnic Institute of New York, June 1976.

2. "The Effect of Transportation Accessibility on Inner-City Unemployment," John C. Falcocchio, doctoral dissertation, Polytechnic Institute of Brooklyn, 1972.

3. "Deterministic and stochastic epidemics in closed populations," by D. G. Kendall, Proc. Third Berkeley Symposium on Mathematical Statistics and Probability, 4, 1956.

4. "A Simple Growth Model for the Diffusion of a New Communication Service," by Allen Bersho and Debasis Mitra, Transactions on Systems, Man and Cybernetics, Vol. 5, 1975.

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