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Passenger Transportation Characteristics in Urban Areas

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Subject Areas

11 Transportation Administration
15 Transportation Economics
84 Urban Transportation Systems

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CONTENTS

FOREWORD

The papers in the RECORD discuss different aspects of passenger transportation characteristics in urban areas.

Balkus explores individuals' attitudes toward transportation services by employing the Delphi technique for obtaining information from a group of experts. The study examined value preferences for necessities, recreation and entertainment, improvements of the residence, and miscellaneous items such as major appliances. The report also examines current use and future preferences relating to the use of automobiles and mass transit systems.

Martin and Flynn analyze the cost components and travel time relations for several configurations of automated, large-bus, dual-mode systems in a hypothetical high-level service urban transportation network. Major conclusions of the study are that the dual-mode system does appear to offer high-speed line-haul capability combined with the local street flexibility necessary in low-density passenger service at a reasonable cost. Significant time savings occur with the first 20 percent line-haul guideway at relatively low cost. Rail and local feeder bus combined are more costly than a dual-mode system in terms of cost-time trade-offs.

Silence and Chesshir summarize data on the central business district and airport highway connections in 1972 in terms of peak and off-peak travel time and travel speed. These are compared against similar travel data collected in 1968.

Fort explores the "final walk" element on trips within the New York City/tri-state area. The paper analyzes the effects of the density of the area and variations of walking time by mode both within the CBD and in the less dense areas. The findings of the paper are that, though the final walk to the trip destination represents only 5 percent of the total trip time, final walk has a strong influence on travel decisions. Eighty-five percent of all trips involve a walk of 4 or fewer min. The average walking time where automobiles are the mode of travel is 0.4 min in non-CBD areas and 1.2 min in the CBD. Use of transit requires 4.4 min walk in non-CBD and 4.6 min in the CBD. It appears that people prefer to be transported rather than walk for more than 10 min.

TRANSPORTATION ISSUES IN CONSUMER MOTIVATION

Kozmas Balkus, Florida State University

Consumer motivation regarding a number of transportation issues has been explored. Instead of isolating such issues from the cultural context, the study explores the patterns of consumer motivation regarding all goods and services and then observes how the transportation issues appear among them. Such a viewpoint makes it possible to see the issue in a more comprehensive way. The study employed the Delphi technique for obtaining information from a group of experts.

•A NUMBER of studies have dealt with the attitudes of individuals toward services of the several transportation modes (1). Most such studies employ questionnaires as research instruments, in which not only the questions but also the format of answers are prepared by the researcher. Hence, the respondent reacts to such questionnaires in a prescribed way, and the results of such studies represent mainly the reactions of the respondents to the researcher's attitudes.

A more general study of attitudes and motivations has been performed under the concept of the quality of life (2). This study is more comprehensive than attitude surveys. It works with a deductively developed concept of the quality of life, and data obtained from experts are interpreted within the framework of this concept.

This study explores still another way of studying an individual's attitudes toward transportation services. It begins with the premise that consumer motivations ultimately result in cultural patterns, both behavioral and organizational, and that the motivation toward one kind of service is interrelated with the motivation toward other services. If some service system loses patronage, it may not mean that it is disliked by its customers but that the entire preference matrix has shifted in another direction. Such an outlook requires broadening and changing the approach of attitudinal surveys.

ISSUE AND THEORY

Topics dealing with motivation and choices are posing issues that are broader than just the popular meaning associated with these two words. Motivation and choices are processes of man's mind; however, they ultimately take overt forms. Cultures and man-made environment are the results of man's motivation and choices.

In dealing with motivation and choice, the issues are frequently reduced to specific questions such as whether human actions are logical or nonlogical. Analyzing such a question invariably leads the inquiry into unknown areas, and, finally, the inquiry stops with some fragmentary explanation that is known to the researcher and to others. The issue of motivation and choices is integrative; it embraces all aspects of human behavior. Therefore, even if these aspects are considered separately, they must be dealt with in a manner that enables the integration of research findings into a comprehensive explanation of cultural pattern formation. Culture is the system that provides the background for motivation and choices; however, culture changes its forms as a result of such choices.

Theories attempting to explain human actions from psychological beginnings to cultural pattern formations are few. The topic of motivation and choices spans three disciplines of social sciences: psychology, sociology, and political science. In the final phase, however, the question transcends these disciplines and gets grounded in artifacts. Consequently, the more inclusive the explanation is, the more helpful it can be for the understanding of motivation and choices.

Alfred Pareto has advanced a theory that envisions the social order as being rooted in man's mind. In his explanation, Pareto envisions the processes by which the society attains and maintains a tenable equilibrium; he also provides a plausible explanation regarding the psychological foundations for this equilibrium. By focusing attention to that aspect of culture, an explanation could be developed that interrelates the patterns of thought and behavior with the patterns of social and artifact organization.

Pareto's sociological theories are expounded in Treatise on General Sociology, first published in Italian in 1916. The English translation, published in two volumes, is entitled The Mind and Society (3). The Treatise is a lengthy work, repetitious and wordy. The gist of Pareto's arguments can be more easily comprehended from a screened but comprehensive selection of Pareto's arguments and postulates (4).

Transportation as a psychological, social, and cultural issue can be perceived only by means of a holistic system of explanation such as the one presented by Pareto. In studying the transportation issue in consumer motivation, the internal elements of the system consist of factual behavior of the individuals with respect to the transportation system. The external elements comprise the impact on transportation by other systems.

According to Pareto, the core of internal elements of a social system, which emerges from observations of human behavior, consists of two kinds of forces: residues and derivations. These two words have no other meaning except that they designate two behavioral aspects.

> Residues are manifestations of sentiments and instincts just as the rise of the mercury of a thermometer is a manifestation of the rise of temperature (4).

Residues are manifestations of the fundamental predispositions for action, generally described as instincts and sentiments. Instincts and sentiments are viewed as underlying forces of human conduct.

Derivations, on the other hand, are explanations.

> Where there is no explaining there is no derivation; but the moment an explanation is given or thought, a derivation comes into play. The animal does not reason, it acts exclusively by instinct. It uses no derivation therefore (4).

Thus, one can imagine residues as facts that can be observed from the objective point of view. Residues also include the potential for the occurrence of such facts under a given set of circumstances. Derivations begin with the explanations of these facts. In Pareto's explanation, most human acts are of a nonlogical nature (not to be confused with illogical). But man tries to make them logical by providing logical explanations. To cover up the acts with logical explanation, man uses theories, popularly accepted wisdom, and the like.

In addition to the dual aspects of motivation, one representing the way we are inclined to act and the other the way we explain our actions, in social systems there are hierarchies of aggregations, such as households, neighborhoods, communities, and states, to which individual actions have relevance. Pareto accounts for the instinctive tendencies to act in accord with the interests of such aggregates and for the desire to seek explanations of these acts. Hence, in studying consumer motivation, both the factual aspect of the issue and the articulations regarding consumer views are to be considered.

DELIMITING THE STUDY

One cannot expect to get a concise answer or a single set of answers to a general question as it has been posed by the topic of this study. However, some answers may be more inclusive, others less so. The validity of answers depends a great deal on the orientation and delimitation of the study.

The transportation issue rests with the majority of population in urbanized areas. Traffic congestion in medium- and high-density areas, inadequate parking space, air and environmental pollution, false economy, inefficiency, deterioration of aesthetic

quality in traffic-congested areas, and questions of ethics resulting from the denial of mobility to those who either do not possess or cannot handle an automobile all represent the gist of the contemporary transportation issue.

For the preceding reasons, the study is to be limited to the sector that, at present, constitutes the majority of urban populations, namely, suburban households. This sector is characterized by suburban forms of living, such as the utilization of the major portion of household resources for maintaining a single-family dwelling, reliance on privately owned transportation, seeking privately owned things for leisure activities, and striving to expand the household realm and possessions.

The motivation of the average suburban household, which interacts with the core city for work and other activities but which styles home life for the consumption of maximum space and maximum mobility, is a significant factor in the urban transportation issue. The study is to disclose ramifications of this motivation regarding the transportation issue.

Hence, the study will be dealing with the average suburban household earning between $10,000 and $20,000 a year and maintaining a private residence outside of the core city.

SOURCE OF INFORMATION AND MEANS OF OBTAINING IT

Information Source

A large amount of information would be required for answering a general question, such as how the transportation issue relates to consumer motivation. In dealing with such issues, information sources other than statistical data are to be sought.

Among alternatives, experts are one source of information. Specialists possess integrated knowledge and are aware of the approximate dimensions of parameters of a given issue. Most decisions are made on the basis of such general but integrated knowledge.

Delphi (5) is a technique for extracting information from specialists. The technique requires selecting a panel of experts and interrogating them by a letter or questionnaire. After obtaining the first round of answers, the questions are recycled. With each successive round of interrogation, the panel is provided with information on the relative consensus of the panel estimates in the previous round. The interrogation is repeated until an acceptable consensus on the estimates is attained.

The questionnaires must be designed with four factors in mind: the issues under consideration, what is generally known by the selected experts and what kinds of estimates they can provide, the scheme of analysis, and the form of analysis outcome.

For this study the information was obtained from a panel of 11 knowledgeable individuals in the field of urban and transportation planning. The individuals were faculty and graduate students in the Department of Urban and Regional Planning, Florida State University, but had various academic backgrounds.

Questionnaire

A questionnaire was the study instrument. In accordance with Pareto's notion of residues and derivations, the questionnaire was designed to interrogate the respondents on two aspects of average household behavior. First, the respondent is asked to estimate a number, such as percentage of population possessing a given item. Next, the respondent is asked to write down several factors, in order of importance, that he can associate with the number. For instance, if there is an estimated change in automobile ownership during a period of time, the respondent is asked to give factors that motivate the household to seek additional automobiles. If there is an estimated change in a rank number, the respondent is asked to give factors behind this change.

This strategy of interrogating a respondent extracts information both on the factual behavior represented by numbers and on what the respondent has to say about these events. The respondent is made to concentrate on estimating the number and then justifying (or theorizing) it. Such an interrogation approach requires that the respondent himself articulate the factors rather than the researcher suggest them. The questionnaire makes the respondent think first of the individual's behavior. Next, he

must think of how the average individual would discuss such behavior and of what factors he would consider in his explanation.

Questions were grouped in three major parts. The purposes of the first part were to reveal the thrust of household preferences in utilizing income, time, and energy resources and to determine how the relative utilities are perceived for the various categories of preferences. The next two parts disclosed consumer motivation regarding transportation services: first, regarding the use of the automobile and, second, how the average suburban household regards the mass transit services. The three major parts are as follows:

1. Household utilization of income, time, and energy resources;
2. Use of automobiles; and
3. Consumer regard for mass transit.

These three parts, representing the major issues of the topic, are subdivided further. The subsequent tables give these subdivisions. From these tables, one can also see how the questions have been structured.

FINDINGS

The findings of the study are given in Tables 1 through 6. Each pair of tables (i.e., 1 and 2, 3 and 4, and 5 and 6) represents a major issue of the topic. The numerical information on each question is represented by three figures. The middle figure, which is underscored, represents the median value of the panel estimates, the left-hand side number represents the first quartile, and the right-hand side number represents the third quartile. The two quartiles indicate how closely the panelists concurred on the estimate represented by the median value. The estimates of 4 of the 11 panelists do not appear in the results given. Two lowest estimates and two highest estimates are outside of the range delimited by first and third quartiles. The median value is to be regarded as the average estimated value of the panel.

Spelled-out factors that appear next to numerical estimates are those that were given most frequently in panelists' responses.

Household Utilization of Income, Time, and Energy

Table 1 gives information on the average suburban household's possessions and what the household is considering buying during the next 5 years. The table also lists explanations that would be given by an average household regarding these possessions. The numbers under the column headings "now" and "5 years from now" indicate how many out of 100 households possess the given item.

The list of goods is subdivided into four groups. Group 1 represents necessities; group 2 recreation, enjoyment, and entertainment items; group 3 capital and technological improvements of the residence; and group 4 miscellaneous items.

Following are the general observations made on the basis of the data given in Table 1.

The percentage of typical suburban households owning homes and at least one automobile will change only insignificantly in the near future. Ownership of the second automobile, however, is to increase sharply. Convenience, mobility, necessity, and enjoyment are factors for increasing automobile ownership.

The major thrust for increasing possessions in the future is in group 2 items, pertaining to recreation, enjoyment, and entertainment. Ownership of these items is to increase from two to four times. Factors behind group 3 possession drives represent several forms of enjoyment and indicate the direction of household thrust toward the "good life."

Possession group 3 represents additional capital investments. Factors behind this drive are innovation in living form, such as less shopping, changing needs, and cleanliness. This group of possessions is to be increased about 70 percent during the next 5 years.

Table 2 gives the weekly time allocation patterns for husband and wife of an average suburban family. The weekly time allocation pattern is stable in time. No radical change in time allocation is to be expected in the next 10 to 20 years.

The husband's working hours will reduce, and the time saved will be allocated for rest and sleep. Wives are expected to spend less time attending to household members needing care, preparing meals, and traveling. Wives are to gain time in main activities as a result of more organized society. They will use this time for other activities. No significant time allocation changes are expected for off-hour activities for either husband or wife.

By looking at Tables 1 and 2 together, one can gain insight regarding the general motivation and choices in establishing and improving the household realm. Information on goods ownership indicates the spending patterns of the average household. Weekly time schedules show how the household spends its time. Factors given in Table 1 indicate the intangible payoffs that make the individuals feel better in a number of respects. The factors may be looked on as a variety of ways by which human beings tend to retain and conserve energy. The home and the automobile are two major elements of the suburban household realm. Their possession is motivated by a number of factors such as security, convenience, economy, mobility, amenity, enjoyment, and prestige; i. e., the utility of these two elements is multidimensional.

The ownership of the second car is to increase sharply, and the home concept is to be broadened in the future. This is to be accomplished by adding group 2 goods. However, the time allocated for recreation is not to increase significantly. Hence, these activities must become more intensive during a given time. For this reason, the consumer strives to possess more of group 2 goods.

Group 3 and group 4 goods represent the technological updating of the household. The expansion of the home and the desire to intensify off-hour activities represent the motivation of the average suburban household in choosing new possessions. All activities, however, are expected to remain within the present time allocation patterns. Technological innovations are necessary to intensify these activities.

However, in this motivation emerges a contradiction regarding travel. Although the household tends toward a spatial expansion, travel to work and other activities is expected to consume less time. Hence, either travel speed will have to be increased or jobs will have to be located closer to residences. Some spatial shifting of jobs is taking place at present, and this trend may continue in the future.

Use of Automobiles

Table 3 gives information, which was obtained from the panel of experts, on the average travel time per trip, the preferred time limit, and the maximum travel time for various trip purposes. The trips are further subdivided by urban subspaces: neighborhoods, community-city, city-region, and region. Table 4 gives the relative cost of the automobile to households and indicates how the ownership rate would change with increasing automobile cost. This table also shows to what extent the automobile is associated with pleasurable moments.

The general findings from Table 3 are as follows.

In interactions within the community and city, households would wish to spend about 30 percent less time. For travel to work, about 40 percent time saving would be desired. On the other hand, households seem to be content with the travel time for neighborhood trips and for trips associated with leisure.

Travel time for school, personal business, and work trips appears to be less elastic than for others. The ratio between average and maximum travel times for those trips is 1:2 and for the rest 1:3.

The average time per trip in the neighborhood takes about 10 min. Such trips are made for household chores and for taking children to school. Community-city range trips take about 15 min, and city-region trips average about 25 min.

Table 4 provides the following information on the automobile as a possession.

Questions 1 through 4 indicate the relative cost of automobile transportation to an average household and the approximate cost-ownership relation. The automobile cost amounts to 39 percent of the expendable income after providing for food, clothing, housing, health care, education, and transportation. Although the second car is cost-sensitive, the cost of automobiles would have to rise 200 percent before 50 percent of first car owners would give up their cars.

Table 1. Percentage of households holding possessions.

Group	Possession	Now	5 Years From Now	Ratio	Factor
1	Home	75, 80, 85	75, 85, 85	1/1.1	Security, economy, prestige/amenity
	First automobile	90, 95, 99	95, 95, 99	1/1.0	Convenience, necessity, mobility
	Additional automobiles	35, 40, 60	60, 70, 72	1/1.7	Convenience, mobility, enjoyment
2	Swimming pool	1, 2, 5	5, 8, 20	1/4.0	Enjoyment, entertainment, prestige
	Boat	9, 10, 15	20, 25, 35	1/2.5	Sport, enjoyment, prestige
	Summer place	4, 5, 10	5, 10, 20	1/2.0	Recreation, enjoyment, change
	Additional living space	20, 25, 30	30, 50, 55	1/2.0	Convenience, privacy, crowdedness
	Color television	35, 40, 55	70, 80, 80	1/2.0	Enjoyment, status
3	Central air conditioning	30, 30, 40	35, 50, 50	1/1.7	Comfort, cleanliness
	Remodel home	1, 9, 10	10, 15, 20	1/1.7	Necessity, changing needs
	Deep freeze	20, 25, 40	30, 40, 50	1/1.6	Less shopping, economy
4	Dishwasher	40, 50, 60	60, 75, 80	1/1.5	Convenience, less work
	Larger lot	5, 19, 20	20, 25, 27	to	Privacy, space
	Country home	1, 5, 10	2, 6, 13	1/1.0	Recreation, change
	Washing machine	75, 80, 92	75, 85, 95		Economy, less work
	Dryer	55, 70, 80	55, 80, 85		Convenience, less work
	Wall-to-wall carpet	40, 50, 60	50, 55, 65		Comfort, appearance
	Sound system	25, 50, 60	40, 60, 80		Relaxation, entertainment
	Airplane	1, 1, 1	1, 1, 4		Enjoyment, thrill

Table 2. Weekly time allocation.

Activity	Husband (hours)		Wife (hours)		Factor
	Now	Future	Now	Future	
Core					
Sleep	49, 50, 55	50, 54, 56	50, 52, 55	50, 54, 56	–
Work	40, 42, 50	30, 38, 40	10, 19, 20	10, 20, 22	–
Preparing meals	2, 2, 2.5	2, 3, 3	12, 14, 15	10, 12, 15	–
Eating meals	12, 14, 14	10, 14, 14	12, 12, 14	10, 13, 14	–
Care of young, sick, aged	3, 4, 4	3, 4, 4	6, 10, 15	5, 6, 8	Progress
Travel to work	4.5, 5, 7	3, 4, 7	2, 2, 3	2, 2, 3	Faster travel
Travel to other core activities	2, 2, 3	2, 2, 4	4, 5, 7	2, 2, 4	–
Subtotal	119	119	114	109	
Off-hour					
Music and television	7, 9, 10	7, 8, 10	8, 8, 10	8, 9, 10	–
Family hours	2, 5, 6	5, 5, 8	5, 5, 6	5, 5, 8	–
Social intercourse	5, 5, 6	6, 6, 6	7, 8, 8	8, 8, 8	–
Reading and study	4, 5, 5	6, 6, 10	5, 5, 6	6, 6, 10	–
Recreation and sport	4, 4, 5	4, 5, 6	1, 3, 4	4, 4, 5	–
Property maintenance	2, 4, 4	3, 4, 4	1, 1, 1	1, 1, 1	–
Organizations and religion	2, 2, 3	2, 4, 5	2, 3, 4	3, 4, 6	–
Other	15	11	21	22	
Subtotal	49	49	54	59	
Total	168	168	168	168	

Table 3. Travel time by purpose for one-way trips.

Trip Purpose	Preferred Time Limit	Average Travel	Maximum Time Limit	Advantage	Disadvantage
Neighborhood					
School	10, 10, 10	10, 10, 14	20, 20, 25	Only way, flexible schedule	Waste driver's time, risk
Household chores	10, 12, 15	10, 10, 15	20, 30, 40	Serves needs, personal vehicle	Unsafe, expensive
Community-city					
Personal business	10, 10, 15	10, 14, 15	20, 30, 60	Accessibility, flexibility	Parking, too big
Shopping	5, 10, 15	10, 15, 20	30, 45, 50	Increases options, independence	Traffic, parking
Social events	15, 15, 20	15, 18, 20	40, 50, 60	Personal vehicle	None
City-regional					
Work	10, 15, 15	20, 25, 30	50, 55, 60	Convenience, comfort	Cost, parking
Regional					
Eat meals	15, 20, 30	15, 16, 20	35, 45, 60	Convenience, accessibility	Risk
Recreation	30, 30, 40	30, 30, 40	80, 100, 120	Flexibility, privacy	Safety, too small
Pleasure rides	30, 40, 90	30, 30, 60	90, 120, 180	Mobility, speed	Unsafe, costly

Question 5 gives an estimated measure regarding the extent to which the automobile is associated with the experience of pleasure. Automobile use is involved in 1 out of 10 pleasurable moments of household experience. Hence, automobiles are not the foremost means in pleasure seeking.

The outcome of question 6 suggests that verbalized factors free of concrete data lack structure and are meaningless in planning.

The automobile has established travel time standards for current urbanization forms. The spread of urbanization and the horizontal expansion of household realms were permitted by the automobile.

Factors that are given in Table 3 indicate both the quality of travel that has been established by the automobile and the shortcomings of this transportation mode. Briefly, the automobile is a personal, flexible, convenient, private, and fast mode of travel. On the other hand, it is expensive, risky, and problematic with respect to parking.

Consumer Regard for Mass Transit

Mass transit issues in consumer motivation are given in Tables 5 and 6.

Table 5 gives the potential for mass transit demand by giving first the percentage of households that would consider using mass transit if it existed and second the number of trips by purpose for which the mass transportation would be used.

In the first part, Table 6 gives the percentage of households that can locate their residences within easy accessibility to mass transit. In the second part, the table indicates the conditions under which households would migrate to higher density areas, where mass transit services are available.

Table 5 indicates that 30 percent of households feel that the automobile is troublesome for some travel purposes. These households would consider using mass transit if such existed. The other 70 percent of suburban households see no utility for mass transit.

Those who consider riding mass transit would utilize such facilities for work, shopping, school, and recreation trips. The number of trips given amounts to about 75 percent of all work trips and 50 percent of shopping, school, and recreation trips.

Factors in favor of using mass transit range widely. Most of them reflect the negative aspects of the automobile mode of travel.

The following can be concluded from Table 6.

Where mass transit facilities exist in urban areas, only a minority (15 percent) of households can locate themselves within easy access to such facilities.

Reasons given for low chances of locating within easy access to mass transit are weak. Evidently, knowledge required to relate housing with transportation systems is weak. The individual knows that the chances are low but cannot explain why this is so.

In the second part, Table 6 indicates the circumstances under which households would consider living in high-density areas. These conditions include the major features of the suburban conception of "good living."

Only 18 percent of households would think it proper to finance mass transit by taxes (Table 5). The remaining 81 percent is divided nearly equally between pay-as-you-go approach and tax-plus-fare financing. The ethics outlook appears to be a strong factor in this issue.

If only 15 percent of households can locate their residences within easy access to mass transit lines, another 15 percent of households would either walk longer than "easy" distances or would use automobiles for getting to mass transit (Table 5). However, in considering the market for mass transit, 15 percent of households is the more critical figure.

The mass transit issue finds itself in a three-way dilemma:

1. Although about one-third of all households are inclined to use mass transit, only one-half of them could reside within a short distance to mass transit. This is a problem of spatial design. The current urban development practice produces urban design unsuitable for mass transit service.

Table 4. Automobiles as possessions.

Question	Factor	Panel Value
1. Total automobile cost per year	$1,200	1,000-1,300
2. After food, clothing, housing, medical education, and transportation expenses, of the remaining income this cost amounts to	39 percent	35-54
3. 50 percent of all two-car owners would abandon second car if automobile expenses would increase by	50 percent	35-75
4. 50 percent of all single-car owners would abandon first car if automobile expenses would increase by	200 percent	150-200
5. Pleasurable moments, household experiences where the use of automobile is involved	10 percent	
6. Reasons for reluctance to give up automobiles: presumed necessity; flexibility, accessibility; assumed economy, convenience; kids like it; privacy, prestige; and status		

Table 5. Potential mass transit demand.

1. Percentage of households that would consider using mass transit if such existed:

Yes—30 Percent (20-40)	No—70 Percent (57-80)
Reasons—problems traveling to work; economy, no second car; and parking problems	Reasons—disuse, not available; inadequate for access to services; and inconvenient

2. Mass transit would be used for the following purposes and reasons:

One-Way Trips per Week	Purpose	Factor
6, 10, 10	Work	Parking, ineffective use of car; cost, avoid second car; and simplicity
2, 4, 5	Shopping	Independence for children, convenience; saves parents time, parking; and avoid congestion, simplicity
3, 4, 5	School	Convenience for wife, save time; independence; and avoid congestion
1, 1, 2	Recreation	Childrens' activities, release parents; parking; and safety
2, 2, 3	Other	Economy, less risk; parking; and safety, pollution

3. Preferences for ways of mass transit financing:

Preference	Range	Factors
Pay-as-you-go fares	41 percent (40-50)	American ethic; lower cost to taxpayers
Taxes and fares	40 percent (30-50)	Equitable distribution, practical; small marginal cost
Complete tax financing	19 percent (10-25)	Socialistic; most rational

Table 6. Mass transit and urbanization forms.

1. Can households find housing located within easy accessibility to transit:

Yes—15 Percent (10-20)	No—85 Percent (80-90)
Reasons—if land available, luck; near CBD; if land cost reasonable; and where transit available	Reasons—desire more land, lack of accessibility; unsuitable density; and no transit service

2. Potential household migration to more intensively urbanized areas where mass transit is possible:

Migration	Range	If the Following Were There
Initial	10 percent (10-10)	Convenience, space; urban beauty, safety; and travel economy, close to friends
Additional	10 percent (7.5-10)	Economy, culture; flexibility; and moderate density, good schools
Still additional	10 percent (5-10)	Anonymity, ecology; off-hour activities; and space for children, better housing

2. Should densities be increased along the lines of mass transit routes, such developments would have to be extensive enough to satisfy the conditions expressed in part 2 of Table 6. The second dilemma pertains to creating quality of life comparable to low densities.

3. The preferred ways of financing mass transportation require either high ridership rates or high fares. High fares, however, tend to detract ridership. Hence, the ethical tinge in the financing outlook precludes a wide acceptance of mass transit services.

The motivations regarding mass transit use are inconsistent and foggy. The reasons for this are that there is a general commitment to automobile travel and the environment that is created by other consumer preferences is not receptive to mass transit services.

From Tables 5 and 6 one can draw a general conclusion that mass transit use is associated with high-density urbanization forms. Hence, planning for mass transit travel requires planning for urbanization that could maintain mass transit. By such means, the households that now are located in high-density areas and are not included in this study, plus the 30 percent who are already receptive to mass transit, would have a choice of living styles that include mass transit travel.

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ECONOMIC FEASIBILITY OF DUAL-MODE BUS TRANSIT SYSTEMS

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The success of several exclusive-lane bus demonstrations in effectively attracting and moving urban peak-hour commuters has brought more attention to the concept of large dual-mode buses as a realistic near-term solution to the increasing urban transportation problem. This paper analyzes the cost components and travel time relations for several configurations of such automated, large-bus, dual-mode systems in a hypothetical high service level urban transportation network. There is a twofold output: order-of-magnitude cost estimates for implementing and operating dual-mode bus systems for comparison with other types of new urban transportation systems and order-of-magnitude comparative cost estimates for various configurations within the dual-mode system. Several major conclusions are reached. The dual-mode system appears to offer high-speed, line-haul capability combined with the local street flexibility necessary in low-density passenger service areas at levels that make it attractive and economically viable. Significant travel time reductions occur with the introduction of the first 20 percent of line-haul guideway at relatively low cost. In comparison to dual-mode systems, public street nonguideway systems are less costly, but the great increases in travel time over just a 20 percent line-haul guideway would seem to make them unattractive in a cost-time trade-off. The rail rapid line-haul, feeder-bus local service configuration is proportionately more costly than a dual-mode system and, thus, would likewise fail a cost-time trade-off.

•THE success of several exclusive-lane bus demonstrations in effectively attracting and moving urban peak-hour commuters has brought more attention to the concept of large dual-mode buses as a realistic near-term solution to the economic and service difficulties of supporting effective urban transit service. A dual-mode bus system would operate on public streets as a conventional bus to pick up and discharge passengers in the trip-end portions of the route. On line-haul portions of the route it would operate as a fully automated high-speed vehicle on a grade-separated private guideway. Thus, it offers a new transportation system that combines the high-speed capability of a rail system on a private guideway over the long line-haul distances with the flexibility and adaptability of a city transit bus in the passenger pickup and discharge areas.

The combination of high-speed line-haul, public street pickup and distribution convenience, and elimination of vehicle transfers would make it possible for the dual-mode system to serve, with reasonably attractive travel times, those areas where the cost of extensive fixed guideways cannot be justified. Such a system seems especially appropriate for the peak period radial work trip from the low population density outlying residential areas to the city central business district (CBD).

This concept of public transportation as a solution to increasing radial peak-hour work trip problems has received more attention as the benefits of exclusive-lane demonstrations become more apparent. Projects such as the Shirley Highway in Washington, the Blue Streak in Seattle, and the I-495 exclusive lane in New York-New Jersey have proved to be effective methods of attracting and moving peak-hour commuters. This paper upgrades the exclusive-lane system to various configurations of an automated

dual-mode bus system and analyzes the travel time and cost component relations in a hypothetical urban transportation network.

THE SYSTEM

The hypothetical urban public transportation network designed for analysis consists of a total of 96 miles of line-haul routes, equally divided into eight 12-mile routes radiating from a presumed CBD. A system of this length was selected because it approximates several systems planned or under construction and because it offers full benefits of large-scale implementation and operation. Eighty-two stations are contained within the line-haul system when it is fully private guideway equipped. Sixty-four of these stations, eight per line, have integrally operating feeder service routes, operating on public streets, radiating from them to a 10-min travel time radius. The remaining 18 stations are located within the center city core, within walking distance of their service radius, and offer no feeder service (Fig. 1).

The dual-mode vehicles have immediate easy access and egress to and from the line-haul guideway at each station, with no passenger transfer to another vehicle required. When operating in the guideway mode, the vehicle is controlled automatically as to speed, headway, steering, and braking. Bus operators would remain with the vehicles while they are operating in the guideway mode. (Substantial labor savings could be realized here, however, because, by design, operators are not required when the vehicles are in the automated guideway mode.) The vehicle would be propelled by electric-motor supplied power from an external source on the guideway. Operating in the public street mode off the guideway, the vehicle would be electrically propelled by the same motor utilizing power stored in batteries or fuel cells. Battery-powered transit buses are now operated in Germany and have speeds up to 43 mph and a range of 40 miles. The power storage devices for our hypothetical system are presumed to be recharged concurrently with the vehicle's operation on the guideway and to store sufficient energy to operate off the guideway for the periods required in the feeder service.

The service level set for the system provides for 4,000 available passenger seats to depart from each of the network's 64 ten-min feeder zones during a 2-hour morning peak period. A like number depart from the CBD for each zone during a 2-hour evening peak period. Lower service levels are provided during the remainder of the service day. The dual-mode vehicles have been calculated to have a seating capacity of 50 passengers. A sufficient number of feeder routes are operated in each service zone to provide a bus to each of the 4,000 seated passengers within a walking distance of 1,500 ft at headways of 10 min. The 10-min service radii range from 2.5 miles at the outermost zone on each line to 1.25 miles at the innermost zone where travel congestion and population densities are higher.

It must be emphasized that these analyses in no manner consider the relations of service to demand or what demand is required to economically support the various system configurations. The purposes of the analyses are to compare the capital investment and operation and maintenance costs of alternative system configurations within a given route system, given a set service level, and to determine the travel times produced by each configuration. Thus, capacity, headways, and route-miles are held constant in these analyses. The variables are system configuration, cost, and travel time. This approach allows trade-off analyses of cost versus travel time, depending on system configuration, given a set level of service.

COST-ESTIMATING METHODOLOGY

The unit costs assigned to the various components in these analyses were determined to be typical of several recent or proposed systems in various metropolitan areas. In most cases they are near the midpoint of the cost range for each component. Significant variances from the midpoint exist where costs of a majority of the systems examined tended to be much higher or lower than the midpoint of the range (2). The order-of-magnitude context of the paper must be emphasized, and the reader is cautioned that the costs developed for these analyses of a hypothetical system are typical

of a widely divergent group of existing and proposed systems and cannot be used for estimating system costs for any specific proposed transportation system.

In costing the system components, no consideration was given to the research and development costs involved to achieve successful operational level development of the new facilities and equipment. Costs were assigned to components with the assumption that all potential cost reduction methods available or in sight were instituted and that all new technologies were operationally available. Where new technologies are required, such as the dual-mode vehicle itself, the assigned costs are based largely on current market prices of similar equipment and/or components, with an additional cost factor added in most cases.

Capital investment costs were reduced to annual capital costs by use of conventional engineering economy capital recovery factors. The rate of interest is assumed to be 6 percent. Salvage values of retired capital equipment are not considered. The assumed service lives are as follows:

Item	Years
Right-of-way	Infinite
Route construction	50
Guideway construction	50
Stations	50
Yards and shops	50
Electrification	50
Vehicles	
Dual-mode	15
Rail	30
Diesel bus	12
Control and communication	30

Although estimation of service lives in any analysis is always open to question, the lives selected here are considered reasonable for transit systems in the United States.

Operation and maintenance costs for the most part are based on the data for typical new systems, again with representative costs being at or near the range midpoint. Significant modifications were made in the dual-mode operating expense category because of the combined guideway-nonguideway nature of these systems. Cost-estimating relations for that category consider the operating cost characteristics of both modes, including nonguideway public street use tax payments in lieu of the Highway Trust Fund motor fuel tax applicable to diesel bus operation.

ALTERNATIVE CONFIGURATION COSTS AND PERFORMANCE

Five configurations within the 96-mile line-haul route system are developed for analysis, each with the same line-haul routes and 10-min feeder zone service:

1. Rail rapid line-haul, 100 percent guideway equipped with diesel feeder bus service in each of the 64 feeder zones;
2. Dual-mode bus system, 80 percent of the line-haul portion private guideway equipped;
3. Dual-mode bus system, 50 percent guideway line-haul;
4. Dual-mode bus system, 20 percent guideway line-haul; and
5. Diesel bus system, 100 percent public street line-haul.

Capital investment costs, operation and maintenance costs, total annual cost, annual cost per line-haul route-mile, number of vehicles required, and travel times for the end-of-line passenger and for the average passenger are given in Tables 1 and 2. Because route construction in general, and subsurface route construction in particular, weighs so heavily in total system costs, three alternative subsurface, at-grade, and elevated configurations are postulated within each of the five basic comparative configurations. Vehicle requirements include a 10 percent spare-vehicle component in all fleets.

Figure 1. Schematic representation of hypothetical urban transportation network.

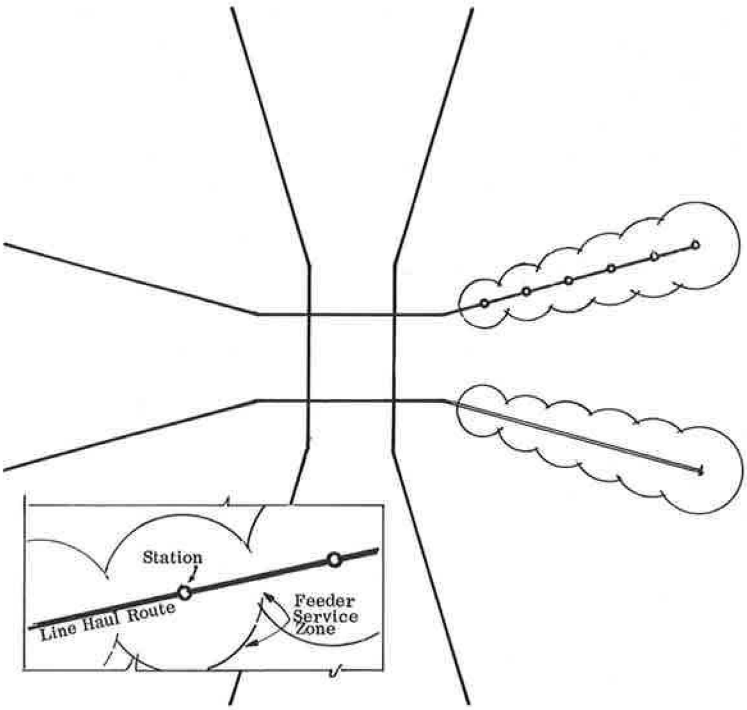


Table 1. Comparative costs and travel times of alternative network configurations.

Item	Rail Rapid Transit Feeder Bus, 100 Percent Guideway, 96 Miles			Dual-Mode, 80 Percent Guideway, 77 Miles		
	40 Subsurface, 51 At-Grade, and 5 Elevated	20 Subsurface, 71 At-Grade, and 5 Elevated	96 At-Grade	30 Subsurface, 43 At-Grade, and 4 Elevated	15 Subsurface, 58 At-Grade, and 4 Elevated	77 At-Grade
Capital investment costs (in thousands of dollars)						
Right-of-way	5,040	6,840	8,640	4,230	5,580	6,930
Route construction	48,659	30,937	13,699	37,184	23,892	10,988
Guideway construction	2,414	2,304	1,633	1,923	1,841	1,310
Stations	30,537	20,799	12,458	24,403	17,505	8,565
Yards and shops	1,956	1,956	1,956	271	271	271
Electrification	6,018	6,018	6,018	4,633	4,633	4,633
Vehicles	26,620	26,620	26,620	14,388	14,388	14,388
Control and communication	1,752	1,752	1,752	1,405	1,405	1,405
Subtotal	122,996	97,226	72,776	88,437	69,515	48,490
Operation and maintenance costs (in thousands of dollars)						
Operating expense	40,513	40,513	40,513	50,456	50,456	50,456
Power	6,240	6,240	6,240	5,005	5,005	5,005
Vehicle maintenance	6,110	6,110	6,110	3,043	3,043	3,043
Guideway maintenance	3,072	3,072	3,072	2,464	2,464	2,464
Subtotal	55,935	55,935	55,935	60,968	60,968	60,968
Total annual cost (in thousands of dollars)	178,931	153,161	128,711	149,405	130,483	109,458
Number of vehicles required	1,056 (rail) 1,126 (diesel bus)	—	—	2,149	—	—
Cost per line-haul route-mile (in thousands of dollars)	1,864	1,595	1,340	1,556	1,359	1,140
Travel time (min)						
End-of-line passenger	39	—	—	41	—	—
Average passenger	28	—	—	26	—	—

In all cases, the line-haul route-mile cost is computed by dividing the total annual cost by 96 (the length of the total line-haul system), regardless of the percentage that the line-haul is conducted in the guideway mode versus on public streets. This is done so that the relation to travel time remains constant. The guideway in any configuration is always assumed to start at the center of the eight radial routes and radiate outward. This alleviates the slowest portion of the line-haul trip if it is conducted on the public streets. Public street line-haul average speeds range from 10 to 15 mph.

In those configurations where the number of vehicles required exceeds the practical limits of headways when loaded individually on the guideway system, it is assumed that the individual dual-mode vehicles can be combined into trains and operated on the guideway. Optimum scheduling is assumed so that minimum travel time is lost in physically assembling trains and waiting for individual vehicles in order to assemble trains.

Travel time computations include the average wait for the bus in the feeder zone (5 min), the average feeder-zone ride (5 min), transfer time if required (2 min), dual-mode train assembly time, and line-haul travel time. Walk time to the bus in the feeder zone and walk time to the destination are not included. The following analyses and comments are based on system configurations of approximately 40 percent subsurface guideway and 60 percent at-grade or elevated.

Tables 1 and 2 and Figure 2 show that travel times are considerably reduced when the guideway mode is introduced to alleviate the slower portions of the line-haul trip. For the end-of-line passenger, the total trip time is reduced from 82 min on a totally nonguideway system to 54 min on a system equipped with private guideway for 20 percent of the line-haul portion. This 28-min reduction for a 20 percent line-haul private guideway constitutes a reduction of 34 percent in travel time. Extending the guideway to 50 percent of the line-haul reduces end-of-line travel time to 47 min, a reduction of 35 min (43 percent). For the average passenger on the system—the passenger at the median of all feeder service passenger travel times—travel time is reduced by 14 min (27 percent) by the introduction of the 20 percent line-haul guideway. Extending the guideway to 50 percent reduces travel time from 52 to 27 min, a reduction of 25 min (48 percent).

The average passenger gains a reduction of only 1 min by extension of the guideway beyond 50 percent because at 50 percent his line-haul trip is almost completely on the guideway mode. The end-of-line passenger, of course, continues to gain a reduction in comparative travel time with every addition to the guideway portion. It is important to note that the significant reduction in travel time for the end-of-line passenger occurs in the introduction of the first 20 percent of guideway.

The costs associated with achieving these reduced travel times for the end-of-line passenger and the average passenger are also given in Tables 1 and 2 and shown in Figure 3. Here we see that the significant reductions in travel time effected by the introduction of the first portions of the guideway occur at relatively low cost in comparison to the latter additions of guideway, which reduce travel time at a much lower rate.

The analysis of percent line-haul guideway versus cost is continued in Figure 4, which shows the relation of annualized investment costs and operating and maintenance costs. Although annualized investment costs increase with increases in percentage of guideway, it is especially useful to note here that operation and maintenance costs decrease approximately 27 percent between the nonguideway configuration and the full guideway line-haul configuration. This reduction in operation and maintenance costs occurs primarily because the lower trip times on the guideway mode produce higher vehicle efficiencies and allow smaller vehicle fleets. This can be a very important factor in system configuration decision-making when considering long-range operation and maintenance costs because it is these costs that are subject to escalation in future years, especially in the area of labor costs. Nonguideway configuration vehicle requirements are nearly 50 percent greater than the 80 percent guideway dual-mode configuration requirements, which directly require a much greater labor component subject to wage escalation. This would seem to bear out recent planning criticisms that more consideration should be given to operation and maintenance costs when evaluating total system costs and trade-offs.

Table 2. Alternative network configuration costs and travel times.

Item	Dual-Mode, 50 Percent Guideway, 48 Miles			Dual-Mode, 20 Percent Guideway, 19 Miles			
	20 Subsurface, 25 At-Grade, and 3 Elevated	10 Subsurface, 35 At-Grade, and 3 Elevated	48 At-Grade	19 Subsurface	9 Subsurface, 8 At-Grade, and 2 Elevated	19 At-Grade	Nonguideway Street Transit Bus (public streets)
Capital investment costs (in thousands of dollars)							
Right-of-way	2,520	3,420	4,320	0	990	1,710	–
Route construction	24,281	15,420	6,849	19,547	10,493	2,711	–
Guideway construction	1,263	1,208	816	427	597	323	–
Stations	15,065	11,008	5,321	9,104	6,263	2,206	–
Yards and shops	291	291	291	354	354	354	382
Electrification	2,888	2,888	2,888	1,191	1,191	1,191	–
Vehicles	15,452	15,452	15,452	18,853	18,853	18,853	13,332
Control and communication	876	876	876	347	347	347	–
Subtotal	62,498	50,425	36,813	49,823	39,088	27,695	13,714
Operation and maintenance costs (in thousands of dollars)							
Operating expense	49,852	49,852	49,852	55,879	55,879	55,879	60,560
Power	3,120	3,120	3,120	1,235	1,235	1,235	–
Vehicle maintenance	16,156	16,156	16,156	19,712	19,712	19,712	15,140
Guideway maintenance	1,536	1,536	1,536	608	608	608	–
Subtotal	70,664	70,664	70,664	77,434	77,434	77,434	75,700
Total annual cost (in thousands of dollars)	133,162	121,089	107,477	127,257	116,522	105,129	89,414
Number of vehicles required	2,308	–	–	2,816	–	–	3,028
Cost per line-haul route-mile (in thousands of dollars)	1,387	1,261	1,120	1,326	1,214	1,095	931
Travel time (min)							
End-of-line passenger	47	–	–	54	–	–	82
Average passenger	27	–	–	38	–	–	52

Figure 2. Effect of guideway on travel time.

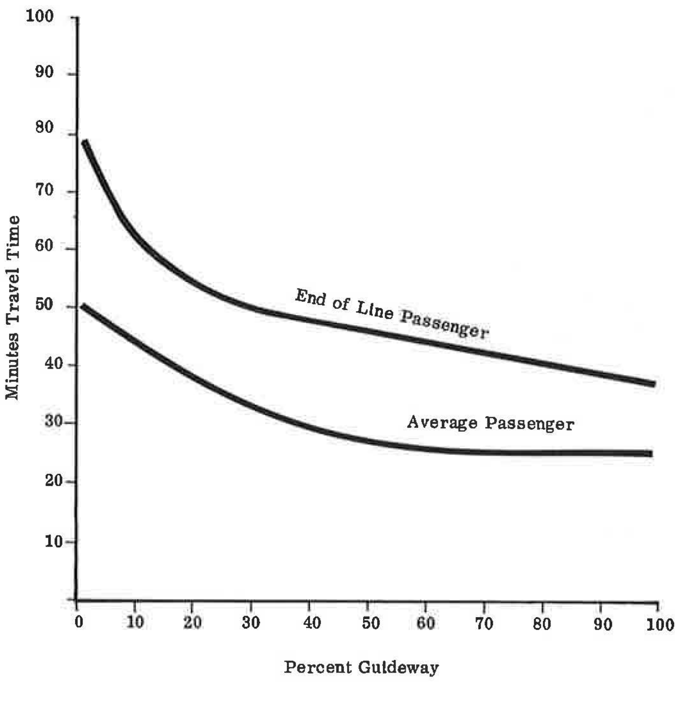


Figure 3. Annual cost of travel time levels.

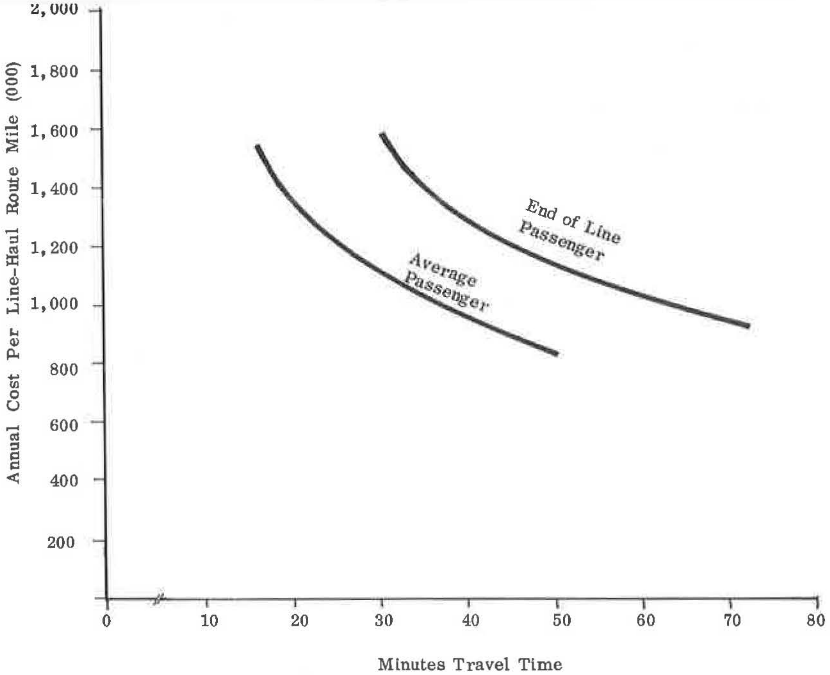
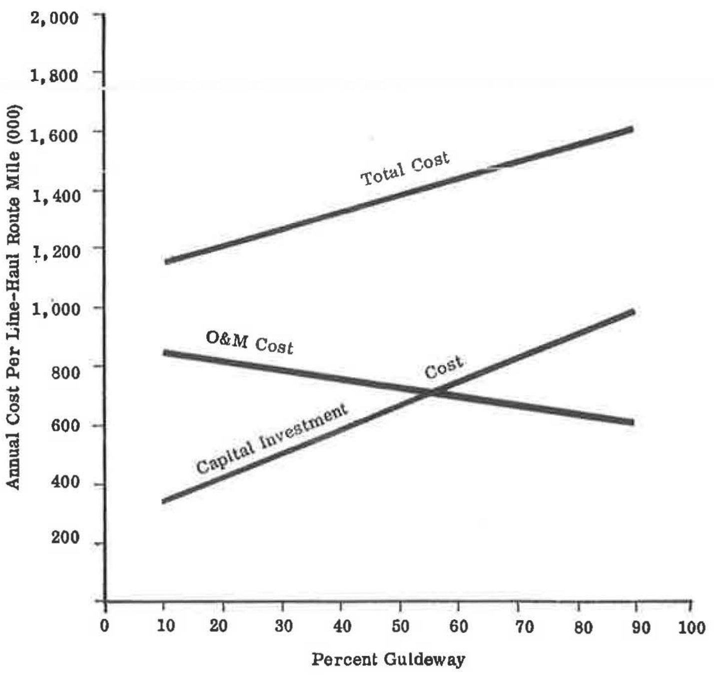


Figure 4. Effect of guideway on annual cost.



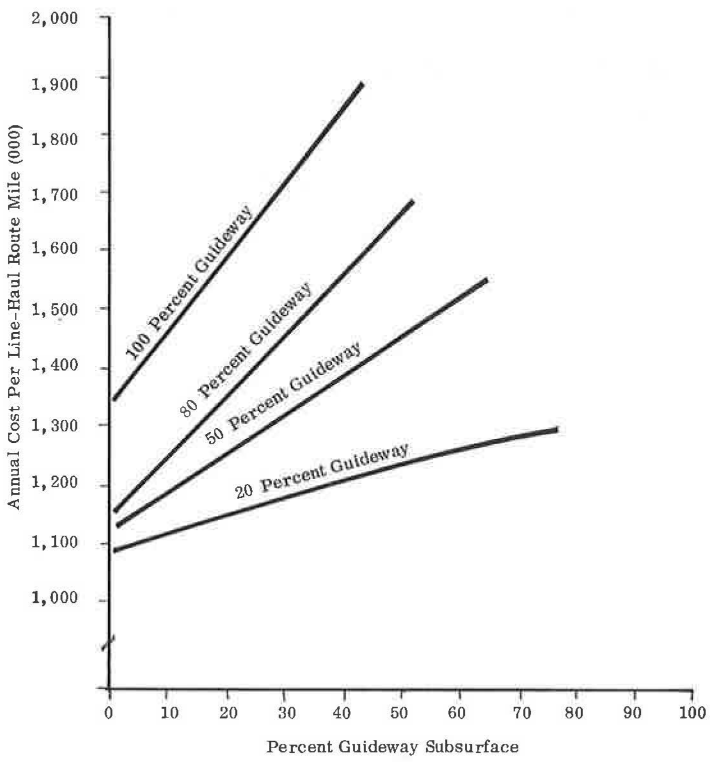
The importance of route construction costs, especially the single subcomponent of subsurface (tunnel) route construction, in total system investment costs is well known. In some recent urban rail systems, total route construction costs make up 40 to 55 percent of total system capital investment costs. In these systems subsurface route construction alone typically represents 35 to 50 percent of total system investment costs. The cost relations of the various line-haul guideway configurations to the percentage of subsurface route construction in our system are shown in Figure 5. Costs are seen to increase greatly in the higher percentage guideway configurations when subsurface construction is used to a large extent.

When comparing the costs of the three types of route construction, at-grade, elevated, and subsurface, one should note that, when route construction and guideway construction are combined, at-grade and elevated systems costs are approximately equal. Subsurface systems costs, in contrast, are approximately six times greater than those of at-grade or elevated systems. The same relations are true in general for at-grade, elevated, and subsurface stations.

CONCLUSIONS

The purpose of these analyses was twofold: to develop cost estimates of dual-mode transit systems for comparison with other types of urban public transport systems and to develop cost comparisons of various configurations within a dual-mode system, which could be applied in general to other types of urban public transport systems. In drawing conclusions from these analyses, several factors affecting urban transportation system cost immediately become evident. First, the dual-mode system does appear to offer high-speed line-haul capability combined with the flexibility and adaptability necessary in low-density passenger pickup and discharge areas at relatively low increased cost. Significant travel time reductions occur with the introduction of the first 20 percent of guideway at relatively low cost in comparison to later additions of

Figure 5. Effect of subsurface guideway construction on annual cost.



guideway, which reduce travel times at a much lower rate.

The advantage of dual-mode transit in not requiring the passenger to transfer to another vehicle when entering the line-haul portion of the trip is not of significant importance in overall trip travel time reduction. It could be very important, however, in eliminating the negative factor of the inconvenience of physically transferring from one vehicle to another and the interrupting waiting period involved therein, as is encountered in subway-feeder bus systems.

In comparison to dual-mode systems, public street nonguideway systems are less costly, but the great increases in travel time over just a 20 percent line-haul guideway would seem to make them unattractive in a cost-time trade-off. The rail rapid line-haul bus-feeder service configuration is proportionately more costly than a dual-mode system and, thus, would seem to also fail in a cost-time trade-off.

It is clear that long-range operation and maintenance costs should receive serious analysis in system planning, especially in those aspects subject to escalation. Likewise, it is clear that subsurface construction, such as that involved in typical urban subway systems, is the one design variable that contributes most heavily to increased cost. Significant cost reduction can be achieved by minimizing subsurface construction.

ACKNOWLEDGMENT

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REEVALUATION OF GROUND ACCESS TO AIRPORTS

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This paper summarizes data obtained from states or other local sources on the central business district and airport highway connections in 1972. The main parameters considered are peak and off-peak travel time and travel speed. A comparison was made with similar data collected in 1968 and published in Highway Research Record 274. In addition, two earlier data sets collected by other sources in 1949 and 1965 are displayed and compared with the 1968 and 1972 data sets.

•AN earlier paper (1) summarized data obtained from the states or other local sources on the nature of the connection and existing level of service between the central business districts (CBDs) of major cities and major commercial airports. Data for that paper were collected in early 1968. This report is a similar compilation of data collected in mid-1972 on most of the same CBD-airport connections. The authors contend that the problem of airport accessibility demands continuing scrutiny if both the joint interests of efficient metropolitan transportation and the national air complex are to be fairly and objectively served.

The information presented here is not sufficient to provide a basis for such judgments. For one thing, it does not consider all travel to the airport or vicinity because the majority of airport travel is not directed to or from the CBD (2). In point of fact, no clue is even given as to the amount of or demand for airport travel service. Furthermore, the travel times shown here are averages and do not define the total ranges of travel time that individuals might experience in making their way to this largest of all intercity transportation terminals. Detailed determinations of what measures are required to better serve individual airports should be the subject of special studies, and such studies have been conducted more frequently in recent years.

On the other hand, the CBD is normally the largest single concentration of the "other ends" of trips directed to or from the airport. As such, it seems a logical hub of good public transportation services directed to the airport. Other concentrations of airport-oriented travel demand are seldom of comparable magnitude. The question of how to serve this widely dispersed, nonrepetitive travel pattern most effectively is the overriding question in dealing with airport accessibility problems.

SUMMARY AND ANALYSIS

Data collection for this analysis was conducted much like the previous study, with a few notable exceptions. First, the work was limited to airports serving large and medium hub cities as defined by the Federal Aviation Administration because access problems in smaller cities are of smaller magnitude and can be considered to be primarily matters of local interest. Second, previously submitted mapping was not resubmitted if no change was evident in primary and alternative access routes. Finally, information on travel to and from other CBDs served by some airports was not collected this time in favor of obtaining information on only the primary or major CBD served. These revisions, though addressing a much narrower field of vision than previously, drastically reduced the effort required by field forces from assisting agencies.

The reports received on all large and medium hub airports were summarized and have been included here.

Tables 1 and 2 give distance, travel time, overall travel speed, and percentage of freeway for 25 airports serving large hub cities and 31 airports serving medium hub cities.

Table 1. Connections between CBDs of 25 large hub cities and their primary commercial airport service.

City	Airport	1970 Population (in thousands)	Distance (miles)	Travel Time, Peak	Travel Time, Off-Peak	Speed, Peak (mph)	Speed, Off-Peak (mph)	Percent Freeway
Atlanta		1,173	8.9	22.2	14.1	24.1	37.9	89
Boston	Logan	2,653	5.0	28.5	15.3	10.5	19.6	13
Chicago	O'Hare	5,959	17.5	34.0	23.0	30.9	45.6	90
Cincinnati		1,111	12.8	17.7	17.9	43.4	42.9	70
Cleveland		1,960	14.5	24.7	22.9	35.2	38.0	81
Dallas	Love	1,339	6.1	22.0	16.0	16.6	22.9	75
Denver	Stapleton	1,047	6.2	14.4	14.6	25.6	25.5	0
Detroit	Metropolitan	3,971	22.5	32.0	29.9	42.2	45.2	89
Ft. Worth	Love	677	34.4	43.3	43.3	47.7	47.7	77
Houston	International	1,678	22.3	34.6	24.7	38.7	54.2	59
Kansas City	International	1,102	21.3	40.0	29.0	32.0	44.1	95
Los Angeles		8,351	17.7	40.0	25.0	26.6	42.5	80
Miami		1,219	7.1	11.0	10.0	38.7	42.6	77
Minneapolis-St. Paul		1,704	12.3	17.8	15.3	41.5	48.2	47
New Orleans		962	14.2	32.9	26.8	25.9	31.8	74
New York	Kennedy	16,207	14.3	50.0	30.0	17.2	28.6	49
New York	LaGuardia	16,207	7.8	32.0	19.0	14.6	24.6	87
New York	Newark	16,207	11.0	23.0	16.0	28.7	41.2	95
Philadelphia		4,021	8.9	21.5	16.6	24.8	32.2	40
Pittsburgh		1,846	15.3	28.0	16.0	32.8	57.4	77
San Francisco		2,988	14.3	28.2	19.9	30.4	43.1	91
Seattle	Seatac	1,238	14.3	17.4	16.8	49.3	51.1	98
St. Louis		1,883	14.8	26.0	21.0	34.2	42.3	90
Washington	Dulles	2,481	24.8	38.5	36.8	38.6	40.4	52
Washington	National	2,481	4.7	17.8	18.1	15.8	15.6	10

Table 2. Connections between CBDs of 31 medium hub cities and their primary commercial airport service.

City	Airport	1970 Population (in thousands)	Distance (miles)	Travel Time, Peak	Travel Time, Off-Peak	Speed, Peak (mph)	Speed, Off-Peak (mph)	Percent Freeway
Albany	Albany County	486	8.4	22.8	21.1	22.1	23.9	0
Albuquerque	International	297	4.3	10.4	9.4	24.8	27.4	33
Baltimore	Friendship	1,580	10.5	19.0	17.7	33.2	35.6	0
Birmingham		558	5.1	19.0	10.0	30.6	30.6	0
Buffalo	International	1,087	9.8	21.3	15.7	27.6	37.4	83
Charlotte	Douglas	279	7.4	18.3	18.0	24.3	24.7	0
Columbus	Port Columbus	790	8.5	27.4	20.3	18.4	25.0	16
Dayton	Cox	686	14.2	21.7	19.1	39.3	44.6	70
Des Moines		256	4.8	12.2	11.1	23.6	25.9	0
El Paso		337	8.3	18.4	17.3	27.1	28.8	72
Hartford	Bradley	465	14.5	30.0	20.0	29.0	43.5	100
Indianapolis		820	8.0	28.0	17.0	17.1	28.2	39
Knoxville	McGhee-Tyson	191	14.2	24.0	16.8	35.5	50.7	6
Louisville	Standiford	739	6.1	12.0	8.5	30.5	43.1	100
Memphis		664	12.3	18.2	16.2	40.5	45.6	68
Milwaukee	Mitchell	1,253	8.2	14.2	14.3	34.0	34.0	65
Nashville	Metropolitan	448	6.9	14.7	10.3	28.2	40.2	72
Norfolk		668	10.7	16.1	15.0	39.4	42.2	70
Oklahoma	Will Rogers	580	10.3	18.9	14.5	32.7	42.6	47
Omaha	Eppley	492	4.0	8.8	8.8	27.3	27.3	0
Phoenix	Sky Harbor	863	7.4	20.0	13.4	22.2	33.1	0
Portland, Ore.		825	10.5	21.7	17.8	29.0	35.4	50
Providence	Green	795	9.4	11.6	12.7	44.4	53.7	98
Raleigh		152	15.5	22.0	20.9	41.8	46.2	57
Rochester	Monroe County	601	4.2	13.0	15.5	19.4	16.2	0
Sacramento	Metropolitan	633	11.4	15.0	14.0	45.6	48.8	78
Salt Lake City		479	8.6	14.0	13.7	36.9	37.7	27
San Antonio		772	8.5	15.0	13.0	34.0	39.2	15
San Diego		1,198	3.1	10.2	9.1	18.2	20.4	0
Syracuse		376	8.3	13.5	11.2	36.9	44.5	90
Tulsa		372	8.7	15.6	12.6	33.5	41.5	88

Distance

The mean travel distance between the 25 large hub airports and their primary CBDs was 12.4 miles in 1968 and is 14.1 miles in 1972. Airports serving large hubs and located more than 15 miles from the CBD include Dulles International Airport (24.8 miles), Kansas City International (21.3 miles), Detroit Metropolitan (22.5 miles), Houston International (22.3 miles), Los Angeles (17.7 miles), and Pittsburgh (15.3 miles). The connection from Fort Worth to Love Field, Dallas, has also been included in the tabulation, but the 34.4-mile distance does not meet our criterion of service to its primary CBD. This connection will, of course, be drastically changed with the completion of the new airport that directly serves Dallas and Fort Worth.

The mean travel distance from CBD to the airport for medium hub cities was 9.1 miles in 1968 and is 8.8 miles in 1972. Raleigh Durham (a regional airport) is the only listed medium hub airport more than 15 miles from the CBD.

Figure 1 shows a frequency distribution of the number of airports located at various distances from CBDs from the 1972 study data.

Travel Time

Because we have defined a single route and a single movement of people within the metropolitan area, travel time over that route is an important indicator of the effectiveness of airport service. Table 3 gives a list of large hub airports having peak-hour and off-peak travel times exceeding an arbitrary service criterion of 30 min.

The only medium hub airport exceeding this criterion is Bradley Field serving Hartford, Connecticut, and Springfield, Massachusetts. This is a regional airport. Table 4 gives all medium hub linkages having travel times greater than 20 min.

Figure 2 shows a frequency distribution of the number of airports having various peak-hour travel times from the CBD to the airport. Figure 3 shows comparable information for the off-peak condition.

For comparative purposes, Figures 4 and 5 show the changes in peak-hour and off-peak travel time from 1968 to 1972 for large and medium hub airports. Most cities' travel times have not changed by more than 5 min, but there have been a number of exceptions.

Overall Travel Speed

Another measure of access service is the overall travel speed. Figure 6 shows a distribution of peak-hour travel speeds from the CBD to large and medium hub airports. Figure 7 shows a similar distribution of off-peak speeds.

A good visual summary of travel impedance can be obtained by relating travel time, speed, and distance on the same chart. Figure 8 shows such a comparison for large hubs only for peak-hour travel. Figure 9 shows a similar off-peak chart. These charts can be readily compared with the charts previously prepared (1).

Accessibility Over Time

In addition to the two data sets for 1968 and 1972 that were collected for this paper and the previous paper (1), we have located two earlier data sets (3, 4). The first (3) lists travel time required based on peak travel condition between airport and downtown business centers in 1949. The second (4) includes data on both peak and off-peak travel time between downtown and the airports. It is realized that these four data sets are not strictly comparable. For example, the starting points in the downtown may be different in the 1949 and 1965 data from the point used in 1968 and 1972 data.

Figure 10 shows the peak-hour travel time for the major hub airports where the data were available. The peak-hour travel time is plotted against the appropriate year.

Figure 11 shows the relative number of increases and decreases in travel time from airport to CBD between 1949 and 1972, based on the new data and data obtained from the 1949 study (3), for those airports on which common data were available. More decreases than increases are shown, but conditions have apparently degenerated in a number of instances.

Figure 1. Distance from CBD to major airports.

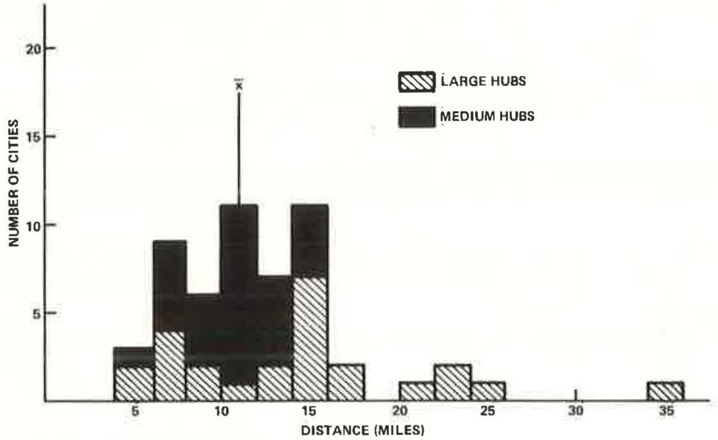


Table 3. CBD linkages having travel times of more than 30 min, large hub airport.

	Peak Hour		Off-Peak	
Rank	Airport	Travel Time (min)	Airport	Travel Time (min)
1	New York Kennedy	50.0	Fort Worth Love	43.3
2	Forth Worth Love	43.2	Washington Dulles	36.8
3	Kansas City International	40.0	New York Kennedy	30.0
4	Los Angeles	40.0		
5	Washington Dulles	38.5		
6	Houston	34.6		
7	Chicago O'Hare	34.0		
8	New Orleans	32.9		
9	Detroit Metropolitan	32.0		
10	New York LaGuardia	32.0		

Table 4. CBD linkages having travel times of more than 20 min, medium hub airport.

	Peak Hour		Off-Peak	
Rank	Airport	Travel Time (min)	Airport	Travel Time (min)
1	Hartford, Connecticut	30.0	Albany, New York	21.1
2	Indianapolis, Indiana	28.0	Columbus, Ohio	20.4
3	Columbus, Ohio	27.7	Hartford, Connecticut	20.0
4	Knoxville, Tennessee	24.0	Raleigh, North Carolina	20.0
5	Albany, New York	22.8		
6	Raleigh, North Carolina	22.1		
7	Dayton, Ohio	21.7		
8	Portland, Oregon	21.7		
9	Buffalo, New York	21.3		
10	Phoenix, Arizona	20.0		

Figure 2. Peak-hour travel time, CBD to major airports.

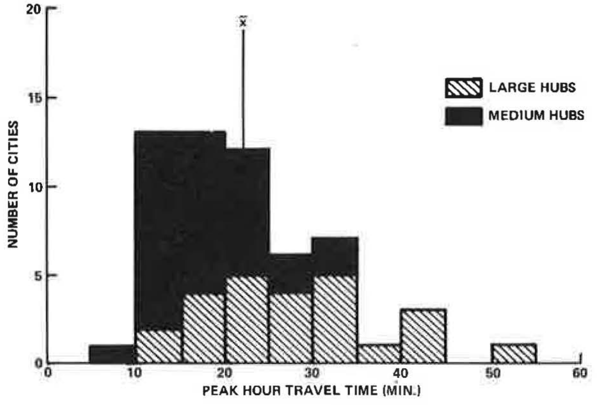


Figure 3. Off-peak travel time, CBD to major airports.

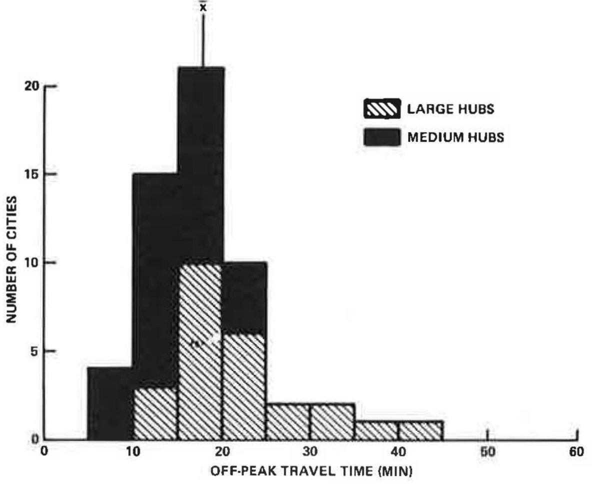


Figure 4. Change in peak-hour travel time, CBD to airport, 1968 to 1972.

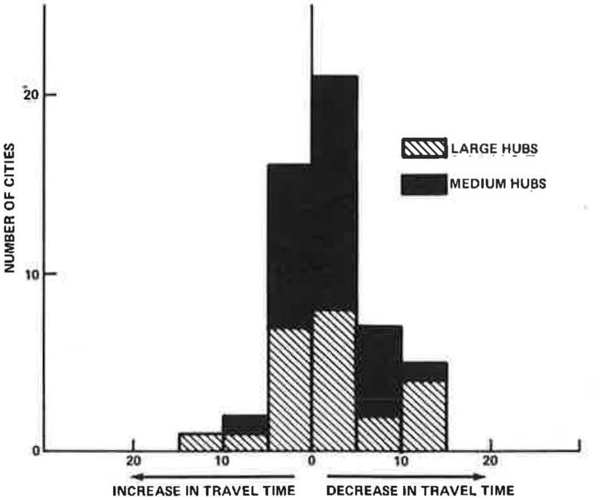


Figure 5. Change in off-peak travel time, CBD to airport, 1968 to 1972.

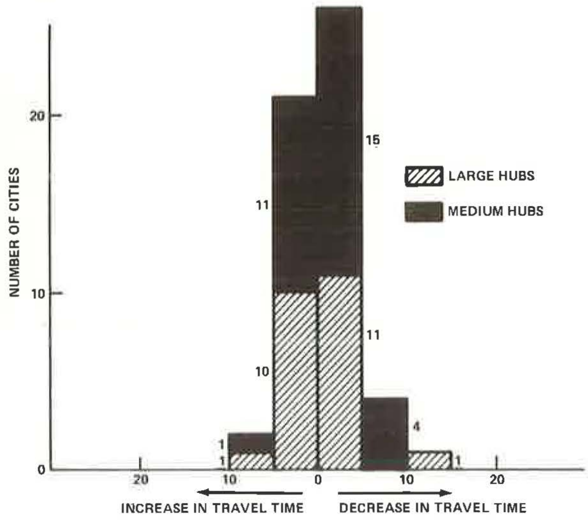


Figure 6. Peak-hour travel speed, CBD to major airports.

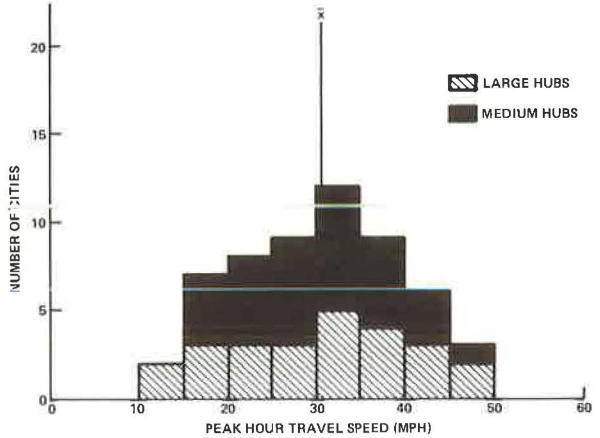


Figure 7. Off-peak travel speed, CBD to major airports.

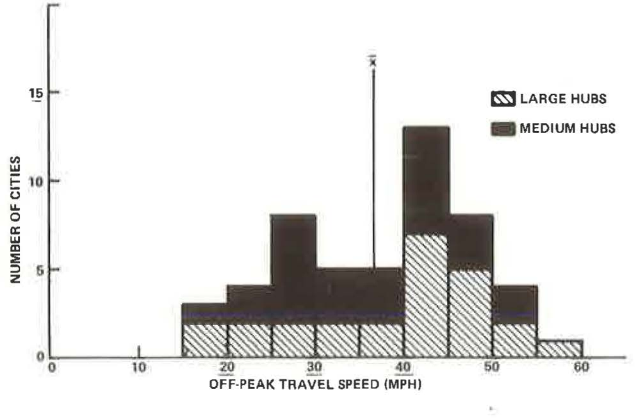


Figure 8. Peak-hour travel time versus distance for major cities.

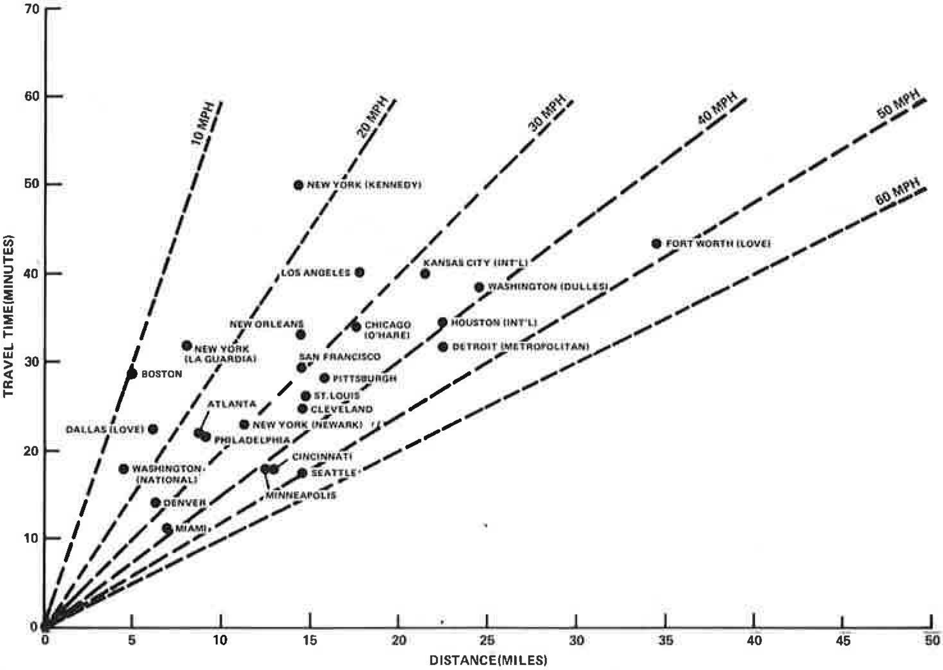


Figure 9. Off-peak travel time versus distance for major cities.

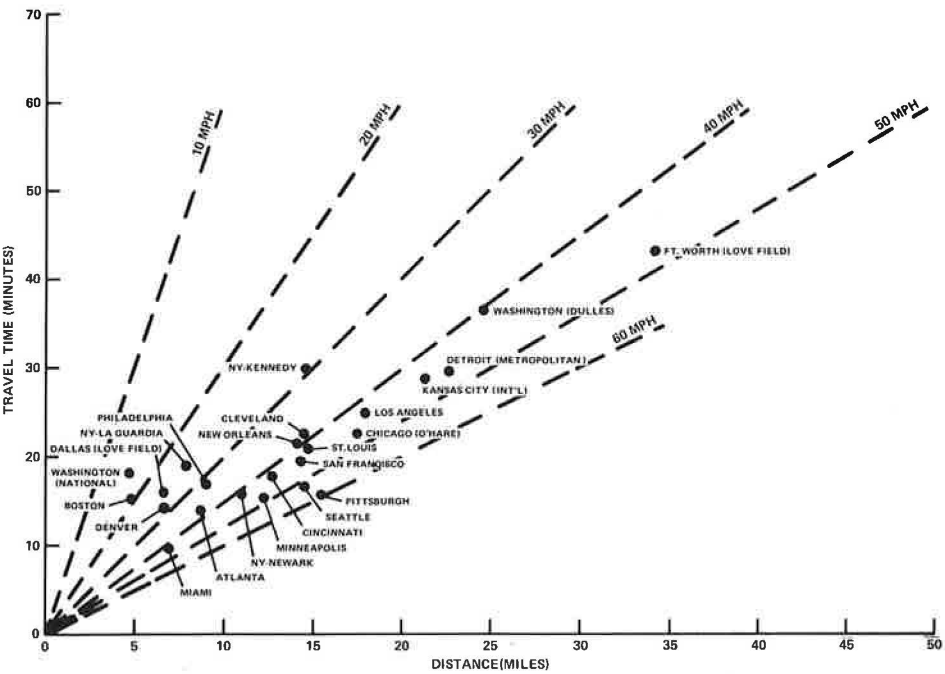


Figure 10. Peak-hour travel time versus year.

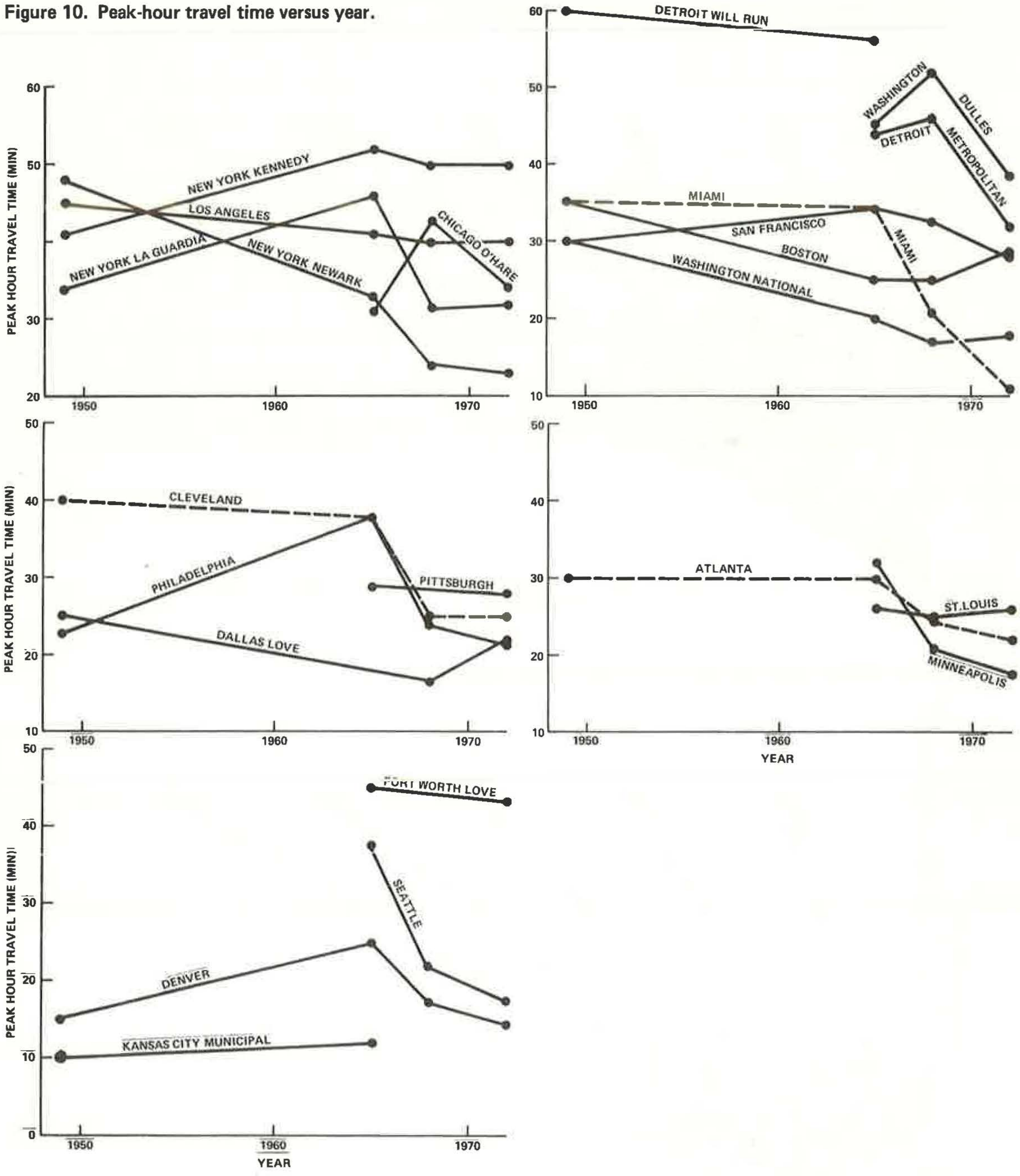
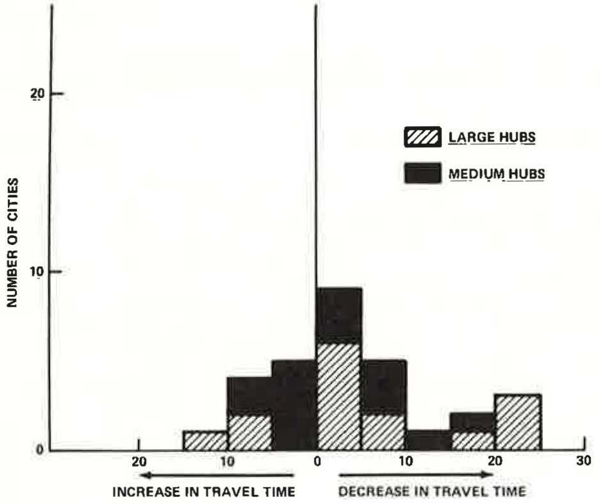


Figure 11. Increase or decrease in travel time, airport to CBD, 1949 to 1972.



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WALK TIME FROM VEHICLE TO FINAL DESTINATION

F. William Fort*, Urban Mass Transportation Administration

This report presents data from the linked-trip file of the Tri-State Regional Planning Commission's 1963-1964 home interview survey. It analyzes the elapsed time during a vehicle trip in which a person walks from the final vehicle used to the trip's destination and explores this walk element in both CBD and non-CBD areas. General results show an average time walked from final mode to destination in the survey area of 1.5 min. This varies with the mode last used. Trips from automobile and taxicab average less walk time than those from mass transit. Most trips involve less than a 5-min walk at the destination end. Very few exceed 10 min. Final walks total 40 million min daily within the region out of a total of more than 700 million min of vehicle trip time.

THE average walk from vehicle to destination increases as development becomes more dense. This is a result of the increase of trips being made by transit. Generally, the average number of minutes walked from transit remains at approximately 4.5 min, CBD or non-CBD. The average number of minutes walked from the automobile increases somewhat, from less than 0.4 min in the less dense counties to more than 1.2 min in CBD areas (Table 1). With more people using transit as the final mode in CBD areas and with the average time walked from the automobile increasing, the average minutes walked increase.

VARIATION IN WALK TIME BY MODE

The number of minutes walked to final destination varies substantially depending on the mode involved (Table 2). The longest elapsed times involve walking to CBD destinations from ferry and railroad. In non-CBD areas, the longest times are from railroad and subway. Commercial bus involves less final walk than subway or railroad, and school and charter bus is less than commercial bus. The shortest walks are generally those of the non-CBD automobile user and the CBD and non-CBD truck and taxicab passenger. The automobile passenger has a shorter walk than the automobile driver in the CBD and about the same walk as the automobile driver in the non-CBD.

The difference between CBD and non-CBD ferry and airplane walk times indicates that, at the CBD end of the trip (ferry) there is extensive walking, whereas at the non-CBD end (both ferry and airplane) most persons transfer to a second mode (automobile, bus, or railroad) so that the remainder who walk directly have relatively short walks. An estimated average of the minutes walked from ferry alone at the non-CBD end of the trip is 4.1 min.

VARIATIONS IN LENGTH OF WALK TIME

The length of walk time from final mode ranges up to more than 1 hour, but the majority of all walk trips involves an average of less than 5 min. Approximately 1 percent (260,000) of all trips involve a walk from final mode of 15 min or longer. An additional 3 percent (846,000) of all trips involve a final walk of 10 to 14 min. Eleven percent (2,815,000 trips) involve 5 to 9 min of walking, and 85 percent (22.3 million trips) involve less than 5 min of walking (Table 3).

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*The author was employed by the Tri-State Regional Planning Commission when he wrote this paper.

Nearly 90 percent of all trips with a non-CBD destination involve less than 5 min of walk, whereas for CBD destinations 60 percent of the trips involve less than 5 min. The majority of trips from mass transit involve final walks of 5 min or more, whereas a substantial majority of all nontransit trips involve final walks of less than 5 min (Table 4).

COUNTIES AND CENTRAL BUSINESS DISTRICT

Walk Time by County as Related to Mode and Density

From a comparison of counties totally within the survey area, it is apparent that the CBD/non-CBD relation among density of development, final mode used, and the length of time that people walk from final mode is borne out on a county basis. The more developed (floor space/net developed land area) counties tend to have higher transit use and in turn tend to have the higher walk times. Manhattan stands far above the density of the other counties; however, the average walk is not much more than that in other dense New York counties because the percentage of trips by transit is only a little higher. Richmond, a relatively undeveloped borough of New York City, has an abnormal amount of transit trips and a high walk average. Hudson, Essex, and Union have relatively low walk averages compared with equivalent New York counties because of lower transit use (Table 5).

Walk Time in CBD and Trip Density

A comparison of major ¼-square mile trip destination areas in the region indicates that, in the areas of extreme activity, there is a relatively uniform average number of minutes walked. The only major exception to this rule is ¼ square mile in downtown Newark where the average amount of time walked from automobile is quite high (more than 2 min) and the average amount of time walked from transit is exceptionally low (less than 3 min) (Fig. 1).

The CBD in Newark contains the only ¼ square mile in the region having a high level of trip destinations (50,000+) and yet no major subway network feeding it. Newark's heavy transit work is accomplished by bus. Presumably, if there were an effective subway net feeding the downtown area, there would be an increase in walk time from final mode transit as fewer people walked from bus and more from subway. There would also likely be a decrease in walk time from final mode automobile as the competition for available parking spaces diminished because of the shift from automobile to subway.

The Manhattan CBD reveals several interesting relations. In zones where taxicabs represent a majority of total automobile-related travel, the average number of minutes walked from automobile driver trips is very high (2 to 3 min). Apparently taxicabs are used to minimize walk time and other inconveniences. In intense trip destination areas, the amount of time devoted to walk from automobile for the passenger is approximately 1 min less on the average than for the driver. However, the instance of automobile passenger trips does not increase much above that for other CBD areas.

CBD as a Major Stimulus of Final Walk

Of the total of 40 million min of final walk time generated within the region, 10 million min occur in the three CBDs. In addition, a sizable percentage of the non-CBD's 30 million min remaining is generated by the same CBD travelers on their journeys in the opposite direction. Although many of these opposite-direction trips involve automobiles for the final leg of the trip, many also involve walk from transit. Thus, of the total of 40 million min, a good percentage is generated by travel to and from the CBD.

IMPLICATIONS OF STUDY

Walk from final mode represents approximately 5 percent of total elapsed trip time. It apparently is an element in how people make travel decisions. Most people choose

Table 1. Final walk times, CBD and non-CBD.

Item	Final Walk, Non-CBD	Final Walk, CBD
Average walk from all modes (min)	1.26	3.91
Average walk from automobile mode (min)	0.41	1.17
Average walk from mass transit (min)	4.41	4.66
Percent using transit as final mode	20.5	78.6

Table 2. Average walk times (in minutes) from final mode.

Area	Automobile Driver	Automobile Passenger	Truck/ Taxi	School, Charter Bus	Railroad	Subway	Commuter Bus	Ferry/ Plane	Total
Non-CBD	0.4	0.4	0.5	1.1	7.1	5.6	3.4	2.2	1.3
CBD	1.8	1.3	0.4	1.0	8.5	4.7	3.6	10.2	3.9

Table 3. Walk times from final vehicle.

Minutes Walked	Non-CBD Trip Destination (thousands)	CBD Trip Destination (thousands)	Total (thousands)
0 to 4	20,733.0	1,585.4	22,318.4
5 to 9	1,975.6	839.3	2,814.9
10 to 14	582.3	263.9	846.2
15 to 19	136.4	66.5	202.9
20 to 24	26.0	13.3	39.3
25+	10.9	6.6	17.5
	23,464.2	2,775.0	26,239.2

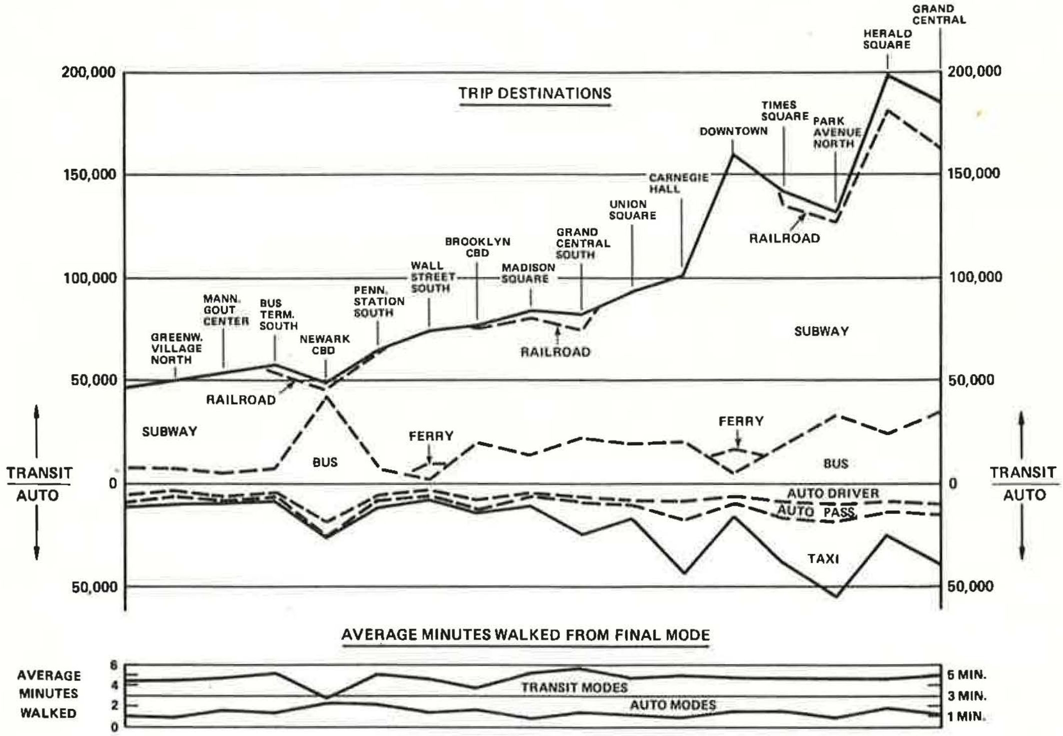
Table 4. Walk times, transit and other modes.

Minutes Walked	Trips From Transit	Trips From Other Modes	Total
0 to 4	3,537.1	18,781.3	22,318.4
5 to 9	2,420.0	394.9	2,814.9
10 to 14	783.7	62.5	846.2
15 to 19	190.9	12.0	202.9
20 to 24	35.5	3.9	39.4
25+	15.1	1.4	16.5
	6,982.3	19,256.0	26,238.3
Total minutes (millions)	31.3	9.0	40.3

Table 5. Density, transit use, and final walk times by counties.

County	Density, Floor Space per Net Developed Land	Mass Transit as Final Mode (percent)	Average Final Walk (min)
Manhattan	4.195	77.1	3.9
Bronx	1.241	56.5	3.3
Kings	1.121	55.0	2.8
Hudson	0.539	25.0	1.4
Queens	0.515	38.1	1.9
Essex	0.288	18.6	1.1
Union	0.173	6.2	0.5
Richmond	0.162	27.4	1.2
Nassau	0.139	3.0	0.4
Bergen	0.137	5.1	0.6
East Connecticut districts	0.106	4.9	0.4
West Connecticut districts	0.092	3.5	0.5

Figure 1. CBD ¼-square mile destination areas.



to walk the minimum possible. More than 85 percent of all trips involve 4 min or less of walk time at the destination end. Use of the automobile permits the minimum walk time, 0.4 min average non-CBD and 1.2 min average CBD. Use of transit demands more walk time, 4.4 min average non-CBD and 4.6 min average CBD.

Because of transit use, density generates walks at both the developed and less developed ends of the trip. However, even these walks have limits. Transit users are willing to walk a substantial amount of time, but still only 15 percent walk 10 min or more.

New areas or buildings or transit routes being laid out without thought to avoiding long walk from final mode of transportation represent an unsatisfactory design. People prefer to be transported rather than walk more than 10 min. If the automobile is any indication, they really do not intend to walk even 5 min. Fewer than 3 percent of total automobile users walk 5 min or more.

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