A. KUMAR

COMPARATIVE COSTS OF URBAN TRANSPORTATION SYSTEMS

FINAL REPORT
June, 1978

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U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Office of the Secretary

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Louise E. Skinner
Federal Highway Administration

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Kiran Bhatt, "Comparative Analysis of Transportation Costs," Working Paper 5002-4-2, February 1975, The Urban Institute, Washington, D.C.

Kiran Bhatt and Mary Lou Olsson, "Analysis of Supply and Estimates of Resource Costs," Working Paper 5002-2, November 1973, The Urban Institute, Washington, D.C.

Kiran Bhatt, "Comparative Analysis of Urban Transportation Costs," Transportation Research Record 559, 1976.

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Executive Summary

This report provides an overview of typical time and monetary resources required to provide transportation service by various contemporary modes in large urbanized areas. As such, it is intended as a general guide for planners and decision makers dealing with transportation investment decisions. Its use would be appropriate in a long-range sketch planning environment where a wide range of investment strategies are being considered. Once the list of options has been narrowed through sketch planning, more precise costing procedures would be appropriate. Such methods and unit costs are covered in a companion report "Costing Urban Transportation Alternatives: A Handbook for Transportation Planners." These methods and costs provide a more finely tuned view of the potential cost of the short list of possible systems. For very accurate estimates, engineering studies are required. Engineering studies specific to the area are expensive and are generally undertaken for only those systems with a very real chance of being built.

This report is confined to a study of money spent for resources (capital, operation and maintenance) and time spent traveling. Other aspects of the transportation supply question are specifically excluded from this analysis. These aspects include, but are not limited to, environmental, social, and ecological considerations. In addition, potential use of a transportation system for purposes other than simply moving people or goods between defined destinations is outside the scope of this report.

The provision of transportation services requires expenditures on capital investment[1/] and on operation and maintenance of the systems.[2/]

1/ Specifically, vehicles, rights-of-way, and repair and storage facilities.

2/ These ~~expenses include fuel, labor,~~ tires, oil, insurance, vehicle maintenance, administrative and general costs, and miscellaneous expenses as appropriate to the individual means of transportation.

The travel time is also an important element in the decision making process. Time has a different resource measurement. Within certain limits, time and money can be exchanged. In this research, travel time is defined as the average elapsed time required to travel from the primary origin to the final destination. It includes in-vehicle, waiting, walking, and transfer time as required by the modal characteristics. Access, line-haul, and egress portions of the trip are included in the total door-to-door travel time.

The 25 modal combinations studied are the permutations of the separate modes, combined as necessary to provide door-to-door service. The 12 major modal combinations are designated in Table E-1. The modes that are combined serve all or part of the door-to-door trip. Those modes providing partial service must be supplemented by other modes providing access and/or egress services. Fully integrated modes, which provide door-to-door service without transfers, do not need supplementary services. These fully integrated modes include single occupant automobile, carpool, two forms of rapid bus, and conventional bus. Partially integrated modes requiring access or egress modes include rail rapid transit and some forms of rapid bus. Line-haul only service may be provided by the rail rapid transit and rapid bus, to which both access and egress services must be added. Residential access modes are feeder bus, park-and-ride (PAR) auto, and kiss-and-ride (KAR) auto. The central business district (CBD) egress modes are feeder bus and rail rapid downtown distributor. Light rail transit (LRT) is not included in these comparative costs.

The major modes studied in this report have been costed for an abstract city corridor, one-eighth of a circular city, with a 10-mile radius, serving a 1 square mile CBD. The population of the entire city is assumed to be between one and two million inhabitants. All money and time costs are deter-~~minel using~~ this abstract city's requirements. These requirements are costed using average values of available data pertaining to each of the modes in use.

Table E-1

Major Modal Combinations

Mode Combination	ACCESS	LINE-HAUL	EGRESS
* 1.		Single Occupant Automobile	
* 2.		Carpool (4 members)	
* 3.		Conventional Bus on Arterial Streets	
* 4.		Fully Integrated Rapid Bus on Exclusive Busway, Surface Distribution	
* 5.		Fully Integrated Rapid Bus on Exclusive Busway, Underground Distribution	
9.	Park-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
10.	Kiss-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
11.	Feeder Bus	Partially Integrated Rapid Bus with Underground Distribution	
19.		Partially Integrated Rapid Bus with Surface Collection	Rapid Rail Loop
* 20.	Park-and-Ride	Rail Rapid Transit Line-Haul and Underground Distribution Loop	
21.	Kiss-and-Ride	Rail Rapid Transit Line-Haul and Underground Distribution Loop	
* 22.	Feeder Bus	Rail Rapid Transit Line-Haul and Underground Distribution Loop	

* Designates subset of 7 common modes for summary purposes.

The money costs have a common base year (1976) and are derived with identical procedures. They are thus comparable across the modes.

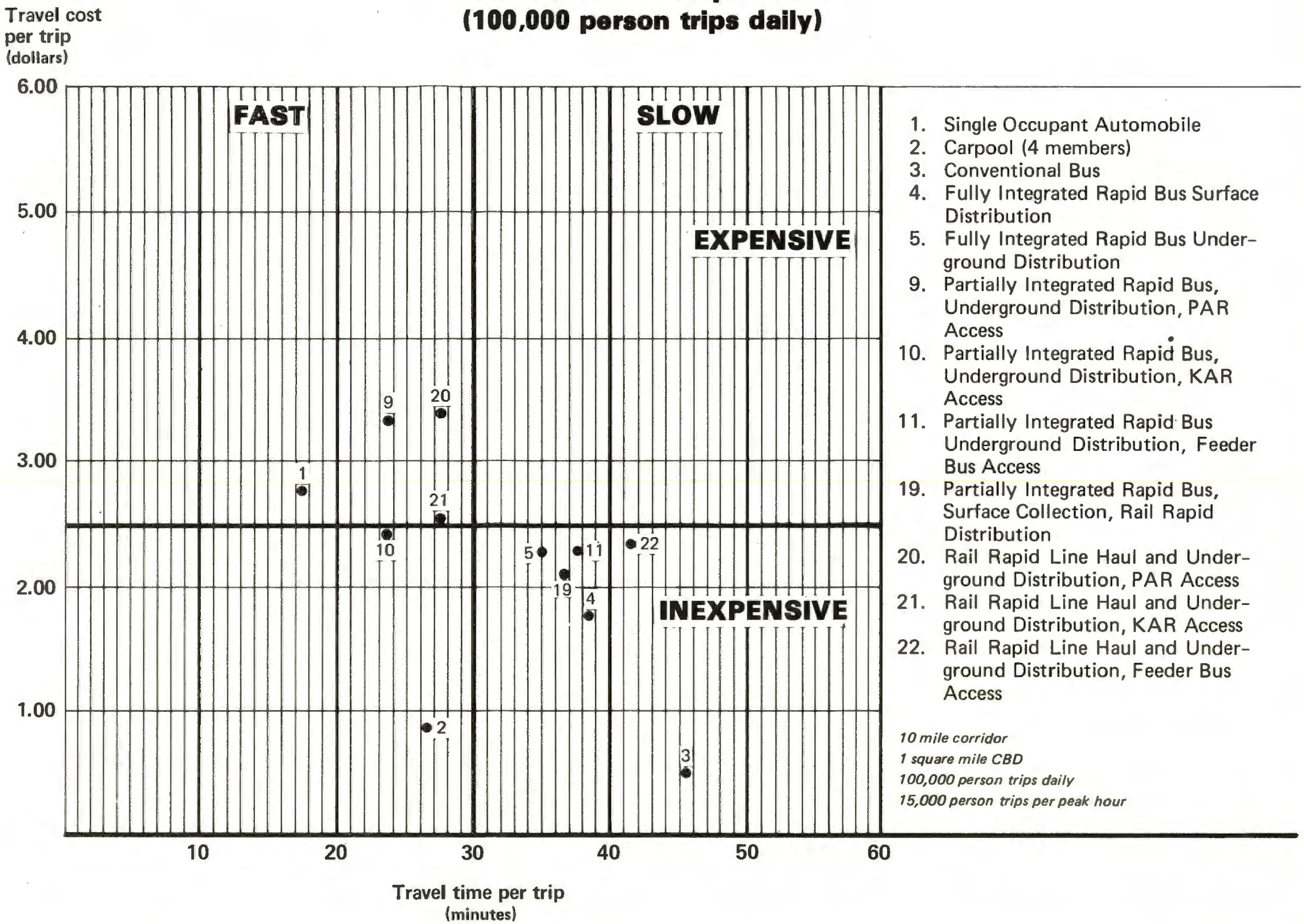
For the 12 major modal combinations, the time versus cost per trip (of 100,000 daily trips) trade-offs have been plotted (Figure E-1). The individual points show the relative positions of the separate modal combinations to each other and their characterization as fast or slow and expensive or inexpensive. Any mode falling in the slow, expensive quadrant (cost over $2.50 per person trip, travel time exceeding 30 minutes) is an inefficient choice. Four modal combinations are found to minimize time and/or cost. These are single occupant automobile (fastest, expensive), carpool (fast, inexpensive), fully integrated rapid bus with surface distribution (slow, inexpensive), and conventional bus (slowest, most inexpensive). Rail rapid modes are expensive, but fast. Those modes falling into the fast, inexpensive or slow and inexpensive require further scrutiny. For all potential choices, other characteristics and impacts of the modes should be considered in the decision making process. One of these considerations should be the probable demand for each, given current knowledge about ridership and attitudes ascribed to the modes by the potential users.

The conclusions determined through the analysis and comparison of the modes are as follows:

1. No single system is optimal over all conditions. Trade-offs are required among times, money, and other environmental and societal costs.

2. The construction costs of fixed capital investment for transit modes are a major determinant of the feasibility of transit services in a given corridor. Densely developed corridors, with high person trip volumes daily, have more person trips over which these costs may be spread and have less excess capacity than low-volume corridors. This is especially true for rail rapid transit, where the minimum two tracks of line-haul are capable of carrying more than 300,000 persons per day and for rapid bus on exclusive busway, where the 44-foot wide busway is sufficient for all realistic volume levels. Volume impact shows dramatically in the per trip costs of providing these services - rail rapid transit with PAR access drops from $4.98 per trip at 50,000 person trips daily to $2.64 per person trip at 200,000 person trips daily. For a fully integrated rapid bus on an exclu-

Figure E-1
Cost vs. Time Comparisons
(100,000 person trips daily)



sive busway with underground CBD distribution, the equivalent drop is from $4.09 to $1.38 over the same range of volumes. Door-to-door travel time is constant at 27.4 minutes for the rapid rail transit/park-and-ride combination over all volumes, while the fully integrated rapid bus times drop from 41.9 minutes to 30.9 minutes as the volume increases.

3. Automobile based modes are land hungry (see Chapter 4). Even with the assumption of reversible freeways (in which the same lanes serve both in-bound a.m. and out-bound p.m. travel), the automobile based modes require ten times the land for line-haul service than is required by the transit modes. In addition, much of this land is needed in the CBD (to store the cars) and in the inner section of the corridor. This means that the land required is in the locations where it is the most expensive and difficult to obtain. This land acquisition cost is included in the comparative money costs presented in this research. The fixed capital costs of line-haul automobile facilities increase incrementally. Additional lanes of freeways are needed as the volume of vehicles rises. For this reason, the great economies of scale evident in the rapid transit modes do not exist for automobile modes. The cost per trip by single occupant automobile falls by 19 cents (from $2.92 to $2.73) as the volume rises from 50,000 person trips daily and $0.80 at 200,000. The travel time for this mode is also constant at 26.2 minutes.

4. The costs presented in this report are for providing service in a single corridor. The costs of underground loops, required for rapid rail transit and by rapid busways for CBD distribution, are assigned only to trips from that corridor. The cost per person trips for those modes requiring the underground loop may be lowered by broadening the base user population to include possible uses as a downtown distributor and/or as a distributor for other city corridors. Additional fixed capital investment in the loop is not needed until the passenger volume exceeds 350,000 per day. As such, these fixed capital costs are spread over more trips, and the per trip cost falls. However, additional rolling stock and operating and maintenance costs will accrue in direct proportion to the added traffic.

1/ For a 1 square mile CBD, these per trip capital costs are $0.77 for 50,000 person trips, $0.39 for 100,000 person trips, and $0.21 for 200,000 person trips.

Chapter 1

Introduction

In recent years, when decision makers and planners have faced the problem of providing transportation systems to meet the needs of the traveling public, the resource costs of those systems tended to receive little attention in the decision making process. The choice of transportation systems often was made on the grounds of benefits to society, which include pollution control, urban rejuvenation, and improved quality of life for specific population groups. However, there is an increasing awareness of the limited capital available to invest in transportation. In addition, the resource costs of building, operating, and maintaining transportation service are rising due to higher design standards as well as to inflation. Decreased investment funds and increased provision costs have combined to force the closer inspection of the various transportation modes to determine the most effective and efficient choices in the broader context.

Decision makers and planners facing these problems are hampered by a scarcity of information. Even when information on the resource costs of the available modes is available, it is calculated on different bases. Cost comparisons based on different sources, with different underlying assumptions, cause inconsistencies, which may lead to the choice of a less efficient transportation system to meet the travel demand.

This report is confined to a study of money spent for resources (capital, operation and maintenance) and time spent traveling. Other aspects of the transportation supply question are specifically excluded from this analysis. These aspects include, but are not limited to, environmental, social, and ecological considerations. In addition, potential use of a transportation system for purposes other than simply moving people or goods between defined destinations is outside the scope of this report.

This report provides an overview of typical time and monetary resources required to provide transportation service by various contemporary modes in large urbanized areas. As such, it is intended as a general guide for planners and decision makers dealing with transportation investment decisions. Its use would be appropriate in a long-range sketch planning environment where a wide range of investment strategies are being considered. Once the list of options has been narrowed through sketch planning, more precise costing procedures would be appropriate. Such methods and unit costs are covered in a companion report "Costing Urban Transportation Alternatives: A Handbook for Transportation Planners." These methods and costs provide a more finely tuned view of the potential cost of the short list of possible systems. For very accurate estimates, engineering studies are required. Engineering studies specific to the area are expensive and are generally undertaken for only those systems with a very real chance of being built.

The provision of transportation services requires expenditures on capital investment[1/] and on operation and maintenance of the systems.[2/] The travel time is also an important element in the decision making process. Time has a different resource measurement. Within certain limits, time and money can be exchanged. In this research, travel time is defined as the average elapsed time required to travel from the primary origin to the final destination. It includes in-vehicle, waiting, walking, and transfer time as required by the model characteristics. Access, line-haul, and egress portions of the trip are included in the total door-to-door travel time per person trip.

The modal combinations studied are the 25 possible permutations of the separate modes, combined to provide door-to-door service. Some modes, such as

1/ Specifically, vehicles, rights-of-way, and repair and storage facilities.

2/ These expenses include fuel, labor, tires, oil, insurance, vehicle maintenance, administrative and general costs, and miscellaneous expenses as appropriate to the individual means of transportation.

single occupant automobile, carpool, conventional bus, and fully integrated (i.e., door-to-door with a change of vehicle required) rapid bus service on exclusive busways, provide door-to-door service and need not be combined with any other modes to provide access and/or egress. Others, such as rail rapid transit and line-haul rapid bus on exclusive busways, require access and/or egress modes. The residential access modes are feeder bus, park-and-ride (PAR) auto, and kiss-and-ride (KAR) auto. The CBD egress modes are feeder bus and rail rapid downtown distributor. Twelve of the possible 25 modal combinations are discussed in depth in Chapter 4. These are the major mode combinations. Seven of these 12 are subjected to further detailed description in Chapter 4. The modes given detailed descriptions are those designated in Table 1-1. The definitions of the modes and the underlying assumptions are discussed in Chapter 2.

The money component costs used to derive these comparative cost relationships are obtained from existing data. Where possible, data from operational modes have been analyzed to obtain the unit cost values. If this was not possible, extrapolation from other modes with similar characteristics is used. In the case of Light Rail Transit (LRT), neither existing data nor similar modal data existed in an equivalent form to that available for the other modes. LRT costs have, therefore, been omitted from this report. This omission does not imply that LRT is not a viable alternative to the other modes.

The modal combinations studied have been costed, using the requirements of an abstract city corridor as the determinants of quantities needed. This abstract city corridor is defined as one-eighth of a circular city, with the radius of urbanization surrounding the CBD, the area of the CBD, and the travel volume of person trips per day destined from the corridor to the CBD as the

Table 1-1

Major Modal Combinations

Mode Combination	ACCESS	LINE-HAUL	EGRESS
* 1.		Single Occupant Automobile	
* 2.		Carpool (4 members)	
* 3.		Conventional Bus on Arterial Streets	
* 4.		Fully Integrated Rapid Bus on Exclusive Busway, Surface Distribution	
* 5.		Fully Integrated Rapid Bus on Exclusive Busway, Underground Distribution	
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* 20.	Park-and-Ride	Rail Rapid Transit Line-Haul and Underground Distribution Loop	
21.	Kiss-and-Ride	Rail Rapid Transit Line-Haul and Underground Distribution Loop	
* 22.	Feeder Bus	Rail Rapid Transit Line-Haul and Underground Distribution Loop	

* Designates subset of 7 common modes for summary purposes.

main descriptors. The density of development in the corridor affects the travel volume, and for the purposes of this research, these are defined to be 50,000, 100,000 and 200,000 person trips daily,[1/] as described in Chapter 3.

The components required to provide the separate services are costed with the costing methodology and values presented in "Costing Urban Transportation Alternatives: A Handbook for Transportation Planners." The money costs have a common base year of 1976. The time costs are door-to-door times, including walking, waiting and in-vehicle times.

Only one mode at a time is assumed to meet the travel needs of the corridor. This assumption is made to overcome the intractable analysis problems associated with mixed mode corridors. It also facilitates the comparison of the resource costs and travel time requirements across the available modes. However, if the user is faced with providing transportation services for a corridor of 100,000 person trips per day, for example, and feels that the volume would be divided equally between two modes of travel, it may be viewed as two 50,000-person-trips-daily corridors for purposes of comparison of modes. The travel time requirements and the resource costs expended per trip are higher for 50,000-person-trip corridors. The choice as to the applicability of this viewpoint to the study area is left to the user.

The specific mean values for resource costs and travel time requirements appropriate to the individual modal combinations are presented in Chapter 4 and in Appendix 3. In addition, the resource costs of providing the major modal combinations are broken down into the separate costs of fixed capital, rolling stock capital, and operating and maintenance costs. All costs are given in terms of providing an individual person trip within a specified daily volume.

1/ Examples of these average daily person trip volumes are Lindenwold Rapid Rail Line - 42,000; Lincoln Tunnel Bus Lanes - 100,000 (reverse lane in peak periods only); Santa Monica Freeway - 240,000 vehicle trips daily.

Capital costs are spread over the expected life of the facility, discounted at 10 percent, then divided among the daily person trips. Daily operating costs are divided among the person trips made each day. Providing a completely new transportation system requires all these expenditures. Incremental service on existing systems required only expenditures on rolling stock and/or operation and maintenance.

In the final chapter, the conclusions of this research are presented. No single mode or modal combination is preferable in all situations. Construction costs, land requirements, and traveler demand characteristics all mitigate against the choice of a single mode to serve the study corridor. However, a choice of several modal combinations is probable and would allow the decision makers and planners to proceed to more detailed planning, engineering estimates, and a mixed mode corridor plan to meet the travel needs of the public in the study area. This report is intended to aid in the decision making process.

Three appendices are included in this report. In the first, the methods by which the resource costs were derived are presented. The quantities of each component required to provide each type of service are given. The characteristics that impact the specific values used for construction costs are also given. The second appendix contains the component requirements of the door-to-door travel times and the derivation procedures used to obtain the specific values presented in this report. The third appendix contains the resource costs and door-to-door travel times for all 25 modal combinations and for each individual abstract city configuration (defined by corridor length and CBD size). These specific values are presented in tabular form.

Chapter 2

Comparative Money and Time Costs Development

The basic assumptions in this research relate to the underlying problems of measuring the components of travel. The objective, monetary costs of travel, form the basis of the costing procedures. Time spent traveling is also estimated as a measuring stick for the travel service provided. No attempt is made to define a proxy value of time, through which the travel time spent is converted into money.

Decisions as to the appropriate transportation system to meet the travel needs of a specific corridor are not made solely on money and time costs. Elements for which no common unit of measurement exists, are important in the decision making process, such as pollution (air and noise), congestion, disruption, and quality of life, but are not quantified for entry into this comparative costing process.

The central assumptions of this research are divided into two sets. The first relates to the money costs of providing transportation services. The other pertains to the time costs of using that transportation system. There is a fundamental difference in the means of measuring the per trip costs of traveling in money and in time. The money costs pertain to actual provision of facilities and vehicles and the operation and maintenance of those vehicles. These have been quantified as fixed and variable costs to provide an assumed level of service for a given volume of travelers. The total costs or providing the service are divided by the volume level to obtain the per trip cost.

Time costs are measured differently. The traveler going from a primary origin to a final destination requires a given amount of time to achieve the goal. This is not an average over a given volume level. It is an expected length of time based on previous experience with the mode and the time of day.

In addition, the monetary costs defined in this research are for vehicular modes only. Specifically omitted are any money costs for non-vehicular modes such as walking or bicycling. However, walking, waiting, and transfer time associated with the use of the analyzed modes are included. In short, the money costs are for vehicular travel, while the time costs are for all vehicular and non-vehicular modes as needed to make the journey. The central assumptions to the comparison of monetary costs are:

1. The objective costs evaluated for comparison purposes are both privately (e.g., auto purchase costs) and publicly (e.g., highway construction) borne. The total economic costs of providing a service are the sum of both sets of costs. As a result, the economic costs of a specific mode will not equal the cost to the governmental unit making the decision, but will approximate the cost to society in resources consumed.

2. The comparative costs used in this report are mean values. They are relevant to the planning process but not to specific construction requirements. The specific study area will have individual costs, depending upon geological characteristics and existing land uses. This research and the comparative costs resulting from it are designed to present an approximation of the reality of transportation supply costs.

3. The trends in construction costs for facilities for each mode are assumed to be stable over time. This allows extrapolation of past data to estimate current and future costs. The administrative structure of the transit industry, maintenance practices, and working rules and union agreements are assumed to be comparable across cities and to remain stable over time.

4. No technological breakthroughs in the modes defined in this research are assumed. This is essential because the costs used are based upon existing technology and would, of necessity, change if the technology changes.

5. Within the usual scale of operations, variation in that scale is assumed to have no impact on the cost estimates used in the comparisons.

6. For comparative costing purposes, the facilities required by the line-haul modes must be built (i.e., exclusive busways, rapid rail lines, and expressways). The only new facilities required by the CBD distribution are for underground rapid rail or busway loops. No additions to the existing local street system are costed for the comparisons, nor are the costs of providing the existing streets entered into the comparisons. These street costs are "sunk costs," i.e., spent resources for facilities which cannot be retrieved for use elsewhere.

The central assumptions to the time comparative costs are:

1. The times are for door-to-door travel. As such, the clock starts when the traveler leaves the primary origin and stops when the final destination is reached. The times include walking, waiting, transferring, and riding times. They are assumed to have the same characteristics. It is not assumed, as has been found elsewhere, that one type of time (specifically waiting time) is more onerous than any other (specifically in-vehicle time). All are measured in minutes and hours without special weightings by activity to account for varying perceptions of the passage of time.

2. A stable technology is assumed, which means that the modes defined as viable will retain their relative time relationships to each other over the long term.

3. The modal characteristics of the vehicles in which the traveler spends time are assumed to have no effect on that traveler's perception of the elapsed time.

Modal Definitions

The modes used in this report are generally characterized as automobile-based, bus-based, and rail-based, depending upon the vehicle used. Within each base, a set of modes is defined in greater detail. The modes may be used to provide service along any portion of a primary origin to final destination trip (i.e., access, egress, line-haul, fully integrated, or partially integrated at either end[1/]). Modes required for only one type of travel are so specified in the definitions.

The modal definitions are based on the most common methods of operation for that mode. Deviation from these conventional definitions will alter the comparative costs an an unknown extent.

Automobile-Based Modes

The modes in this general set are: single occupant auto, carpool, park-and-ride access and kiss-and-ride access. In general, the automobile-based modes require investments in roads and parking facilities (often private), in

1/ A fully integrated trip is one in which a single vehicle serves access, line-haul, and egress without transfer requirements. Partially integrated trips are those in which a single vehicle serves the line-haul portion as well as either access or egress travel, with the other segment requiring the use of another mode and a transfer.

the maintenance of those facilities, and in the purchase and operation of automobiles (usually private). The operator is unpaid, and no proxy value of time or wage rate for the unpaid driver has been used in the comparative costs. The total cost, for comparison purposes, of the automobile-based modes is the sum of the public and private costs.

The specific characteristics of the individual modes are as follows:

Single occupant automobile: Direct door-to-door service is provided by an unpaid owner-driver.

Carpool: Includes collection, line-haul and distribution with detours to collect and discharge the assumed three passengers at the residential end. The driver is the fourth occupant.

Park-and-ride access: Provides access service between the home and line-haul station, where the car is parked to await the traveler's return. Vehicle occupancy is defined to be one.

Kiss-and-ride access: One household member provides this service for another. Two home to line-haul station round trips are required to serve each home to CBD round trip of the traveler. For this service, car purchase is excluded because it is available for other purposes.

Bus-Based Modes

These modes use diesel-powered buses to provide service along fixed routes and with fixed schedules. They operate either in mixed traffic or on reserved or specially built bus lanes for the line-haul portion of the trip. All capital and operating costs are entered in the analysis. In short, costs accrue through vehicle purchase and maintenance, operation, and provision of the roadway. These costs also include those for the driver, who is paid union-scale wages. The modes are defined as conventional bus on arterial roadways and rapid bus on exclusive busways. Individual characteristics are:

Conventional bus: Conventional 50-seat transit buses operating in mixed traffic or on reserved lanes on existing city streets. The route structure is such that one bus route may provide fully integrated service from primary origin to final destination, through serving the access, line-haul, and egress portions of the trip. The bus stops to collect and discharge passengers throughout the trip, i.e., those travelers for whom the bus routes do not match their travel patterns.

Rapid bus on exclusive busways: High standard 50-seat diesel buses operating on exclusive rights-of-way for the line-haul portion of the trip. These buses are capable of serving as collectors and distributors in residential and CBD areas, thus providing fully integrated service. They may also provide partially integrated service, with access facilities and terminals required at the transfer points.

Line-haul only service is also possible under this definition, which requires access and egress facilities and terminals at both ends of the line-haul portion. The required surface and underground busways are built to Interstate standards.

Rail-Based Mode

Conventional heavy rail transit refers to nonautomated systems with conventional vehicle control and signalization systems. Potential top speed of 60 mph is assumed. Higher speeds are feasible with additional capital and operating costs, but with typical station spacings, these higher speeds are infrequently achieved. Improvement in travel times with higher achievable speeds is minimal.

The cost elements appropriate to heavy rail transit include building, operating, and maintaining the rights-of-way, terminals and stations; purchase, operation and maintenance of the vehicles; and labor costs for train crews.

All these modes are matched as needed to provide door-to-door service to the traveler. Some of the permutations are less feasible than others and are omitted from the comparative money and time costs presented in this report. The environment within which these modal combinations are costed in monetary and temporal terms is defined in Chapter 3.

Chapter 3

Generalized City Corridor Description

The comparative costs and times of transportation supply are calculated for an abstract city, which has been designed to approximate the characteristics of a corridor defined by the radius of urbanization surrounding the CBD, the size of the CBD, and the person trip per day volume of travelers originating in the corridor and destined for the CBD. The CBD oriented corridor volumes of most of the higher population cities are given in Table 3-1. The abstract city is defined to have a population ranging from one to two million inhabitants, with varying densities in the study corridor volumes ranging from 50,000 to 200,000 person trips daily. The specific descriptions in this chapter pertain to the abstract city characteristics used to calculate the time and cost values given in Chapter 4. However, the general form of the abstract city is the same for all corridor lengths, CBD sizes, and volume levels. Tables of time and cost values for 25 modal combinations, 9 city configurations, and 3 volume levels are given in Appendix 3.

The study corridor is measured along the radius of urbanization. Its configuration is designed to be pie shaped, one-eighth of the circular abstract city. Line-haul service is provided along the radius which bisects the area of the corridor. The zones in the corridor are 1 mile long, measured along the central radius, and are approximately trapezoidal in shape (Figure 3-1). A 10-mile long corridor will have 20 zones of varying area, depending upon the distance from the CBD, a 5-mile corridor, 10 zones, and a 15-mile corridor, 30 zones.

The CBD is assumed to be square, with a homogenous density. It is assumed to be 1 square mile in area, conforming to the CBD sizes of most U.S. cities. Discharge stops for underground and surface distribution services are spaced such that the maximum walking distance to the final destination is no

TABLE 3-1

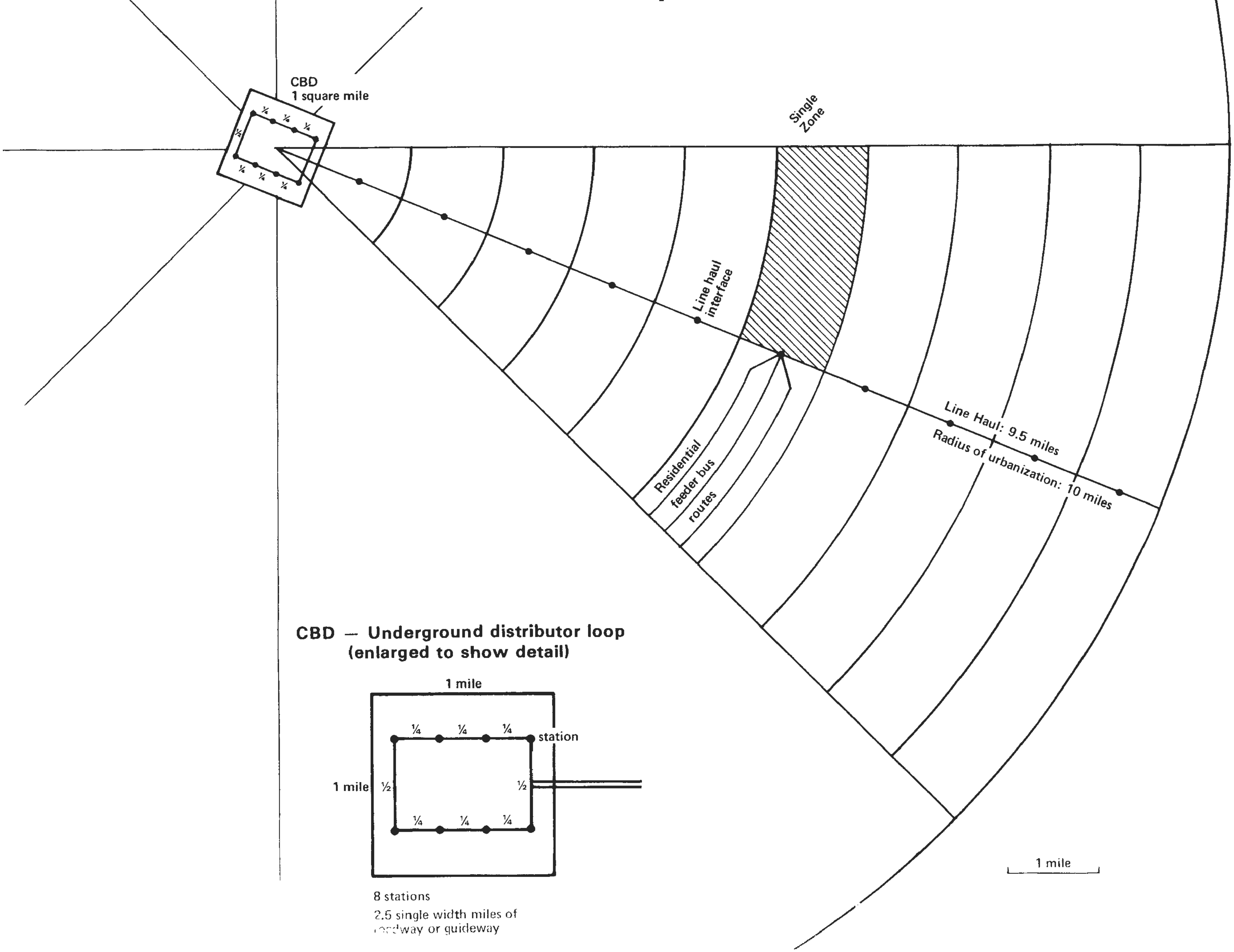
Daily CBD Oriented Corridor Trip Volumes

City	Corridors	Daily Person Trip Volume/Corridor	Peak Hour Person Trip Volume/Corridor
Chicago	4-5	240,000-320,000	30,000-40,000
Boston	7-8	150,000-200,000	20,000-30,000
Philadelphia	7-8	160,000-240,000	20,000-30,000
Washington, D.C.	7-8	160,000-240,000	20,000-30,000
Los Angeles	7-8	100,000-150,000	12,000-20,000
Cleveland	4-5	120,000-160,000	15,000-20,000
Detroit	6	100,000-125,000	12,000-15,000
St. Louis	6	100,000-125,000	12,000-15,000
Baltimore	6	100,000-125,000	12,000-15,000
Atlanta	8	80,000-120,000	10,000-13,000
Pittsburgh	6-8	80,000-120,000	10,000-13,000
Milwaukee	4-5	80,000-120,000	10,000-13,000
Dallas	8	50,000-80,000	6,000-10,000
Minneapolis-St. Paul	8	50,000-80,000	6,000-10,000
Providence	6	50,000-80,000	6,000-10,000
Miami	6	25,000	4,000
Rochester	6	30,000	4,000
Kansas City	8	12,000	2,000

SOURCE: J. R. Meyer, J. F. Kain, and M. Wohl, The Urban Transportation Problem (Cambridge, Massachusetts: Harvard University Press), 1966.

Figure 3-1

Generalized City Corridor



more than three blocks. The location of underground loop stations and stops is given in Figure 3-1 for the 1 square mile CBD. Loop configurations for discharge stations for underground distribution services in 2- and 4-square mile CBD's are given in Appendix 3 for use with the time and money costs of providing such services.

Residential collection services, when provided by feeder buses, are assumed to follow fixed routes, three blocks apart. These routes converge at the single station which serves as a transfer point for the line-haul modes for each contiguous pair of zones (Figure 3-1). The bus stops are located at each cross street. The route design is only pertinent for fixed route buses, since the automobile feeder modes of kiss-and-ride (KAR) and park-and-ride (PAR) are assumed to follow an unassigned minimum time path to the line-haul facility.

Line-haul service, provided along the central radius, is defined to have interface facilities with the residential collection services at 1 mile intervals. This interface point is defined to be the midpoint of the zone boundary. Depending upon the type of line-haul facilities provided, the transfer point is defined to be an expressway interchange, a busway interchange, or a transit station.

The trip volume levels for which the comparative money and time costs are presented are defined to be 50,000, 100,000 and 200,000 person trips per day. A person trip is defined to be the travel from a primary origin to a final destination, e.g., from home to work. The round trip, e.g., from home to work to home, is defined to be two person trips. Table 3-2 presents representative hourly volumes for the given daily volume levels. These hourly volumes are for an 18-hour day, with 4 hours and 60 percent of the volume in the peak and 14 hours and 40 percent of the volume in the off-peak (Figure

3-2). It is assumed that the average volume in each period equals the maximum and the minimum volumes in that period. This assumption requires constant volumes traveling throughout the peak and the off-peak. This is depicted in Figure 3-2 by the flat graph.

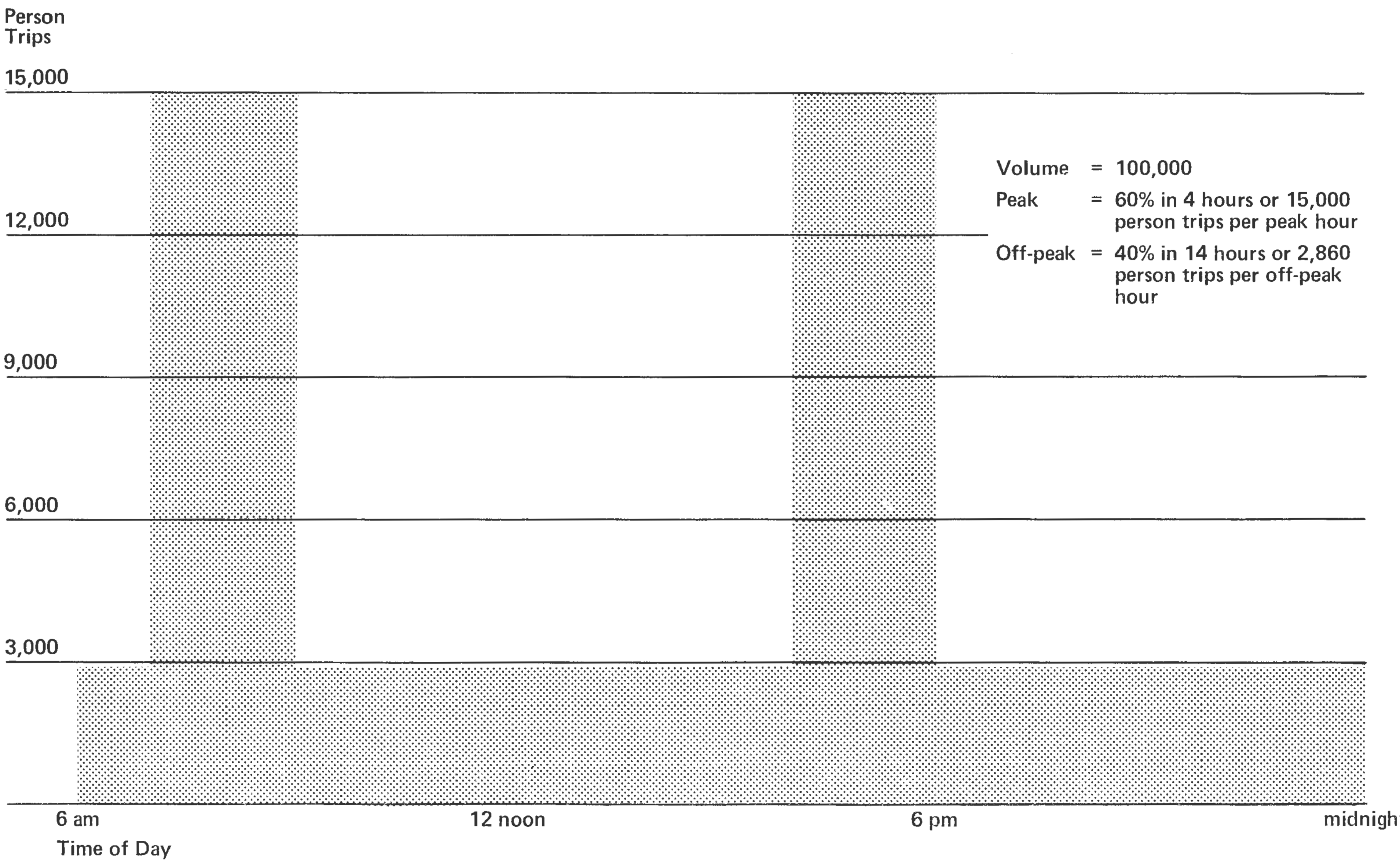
TABLE 3-2

Passenger Trip Volumes

	HOURLY VOLUME	
Daily Volume	Peak	Off-Peak
50,000	7,500	1,430
100,000	15,000	2,860
200,000	30,000	5,720

Figure 3-2

Average Flow Characteristics



Chapter 4

Comparative Money and Time Costs

This chapter presents the comparisons of money and time costs for those modal combinations involving no transfer or one transfer per trip. For the modes which do not provide full door-to-door service, the access or egress mode is mated with the partially integrated line-haul service to carry the traveler the desired distance. This mating is not necessary for the fully integrated services such as carpool, conventional bus, and single occupant automobile. Both money and time costs have been calculated for these mode combinations. The complete set of available modes is given in Table 4-1, with those studied in depth designated.

Money costs per trip are the average cost per trip with maximum defined[1/] seated occupancies per vehicle and 250 operating days per year. The capital costs of mode service provision are amortized at a 10 percent discount rate[2/] over the facility life or vehicle lifespan postulated in the companion report, "Costing Urban Transportation Alternatives." Average operating costs, which are distance dependent, are defined by the average traveler distances as given in Table 4-2 for access, line-haul, and either surface or underground egress.

The specific component costs are derived using the procedures presented in Appendix 1. The comparative money costs have been calculated for all 25 possible modal combinations for three volume levels (50,000, 100,000, and 200,000 person trips per day) for 9 corridor configurations (5-, 10-, and 15-mile radial corridors with 1-, 2-, or 4-square mile CBD's). All of these may be found in Appendix 3 in tabular form.

1/ These are 1 per single occupant automobile, 4 per carpool, 50 per bus, and 110 per rapid rail transit car.

2/ This discount rate is that required by OMB Circular Number A-94, revised March 27, 1972.

Table 4-1

Possible Modal Combinations

	Access	Line-Haul	Egress
** 1.		Single Occupant Automobile	
** 2.		Carpool (4 members)	
** 3.		Conventional Bus on Arterial Streets	
** 4.		Fully Integrated Rapid Bus on Exclusive Busway, Surface Distribution	
** 5.		Fully Integrated Rapid Bus on Exclusive Busway, Underground Distribution	
6.	Park-and-Ride	Partially Integrated Rapid Bus with Surface Distribution	
7.	Kiss-and-Ride	Partially Integrated Rapid Bus with Surface Distribution	
8.	Feeder Bus	Partially Integrated Rapid Bus with Surface Distribution	
* 9.	Park-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
* 10.	Kiss-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
* 11.	Feeder Bus	Partially Integrated Rapid Bus with Underground Distribution	
12.	Park-and-Ride	Line Haul Rapid Bus	Rapid Rail Loop
13.	Kiss-and-Ride	Line Haul Rapid Bus	Rapid Rail Loop
14.	Feeder Bus	Line Haul Rapid Bus	Rapid Rail Loop
15.	Park-and-Ride	Line Haul Rapid Bus	Feeder Bus
16.	Kiss-and-Ride	Line Haul Rapid Bus	Feeder Bus
17.	Feeder Bus	Line Haul Rapid Bus	Feeder Bus
18.	Partially Integrated Rapid Bus with Surface Collection		Feeder Bus
* 19.	Partially Integrated Rapid Bus with Surface Collection		Rapid Rail Loop
**20.	Park-and-Ride	Rail Rapid Transit Line Haul and Underground Distribution Loop	
21.	Kiss-and-Ride	Rail Rapid Transit Line Haul and Underground Distribution Loop	
**22.	Feeder Bus	Rail Rapid Transit Line Haul and Underground Distribution Loop	
23.	Park-and-Ride	Rail Rapid Transit Line Haul	Feeder Bus
24.	Kiss-and-Ride	Rail Rapid Transit Line Haul	Feeder Bus
25.	Feeder Bus	Rail Rapid Transit Line Haul	Feeder Bus

** Designates subset of 7 usual modes and 12 major modes

* Designates subset of 12 major modes only

TABLE 4-2

Average One-Way Traveler Distances
(by trip portion)

Access (residential)	1.35 miles
Line-Haul	5.125
Surface Egress (bus, auto)	0.75
Underground Egress (rail rapid transit, bus)	1.25
Total distance traveled:	
Auto and surface bus	7.225 miles *
Underground bus and rail rapid transit	7.725 miles *

10-mile radial corridor
1 square mile CBD

* These distances differ because underground distribution requires following the set loop configuration, while surface distribution follows the minimum path.

Twelve of these 25 mode combinations have been chosen for detailed presentation in this chapter. This presentation is graphic, and unless otherwise stated, pertains to a 10-mile radial corridor, serving a 1 square mile CBD, with 100,000 person trips daily (15,000 per typical peak hour, 2,860 per typical off-peak hour). The peak period requirements dominate, with excess capacity existing on all modes in the off-peak. This is an approximation of the usual situation with which the user is faced.

Comparative time costs of travel have also been calculated for all modes, all volumes, and all corridor configurations as defined for money costs. These door-to-door times are presented in tabular form in Appendix 3.

The tables and graphs present the objective, easily quantified money and time costs of providing and using the specified mode combination to fulfill a person's travel desires from the residential origin to the CBD destination. These costs are the full economic costs (resource costs) of providing the service. The fare paid by the traveler is not part of the cost of using the service. The fare is payment for services rendered and is thus defined as a transfer cost. To sum the fare with the fixed and variable costs of providing travel services would be double counting the cost of the same facilities. The means by which the money and time costs presented in this research are derived are found in Appendices 1 and 2, respectively.

Comparative Costs and Times

In the graphic presentations of the money and time costs of the 12 mode choices (Figures 4-1 and 4-2), the modes are grouped by common characteristics. As such, the sutomobile modes of single occupant automobile and four-member carpool are given as freestanding bars, as is conventional bus. The rapid bus with underground distribution mode sets are grouped, as are the rapid rail with CBD loop mode sets. Variation among the groups of modes is due to change in the access or egress mode appropriate to the choice.

Figure 4-1
Comparative per Trip Costs

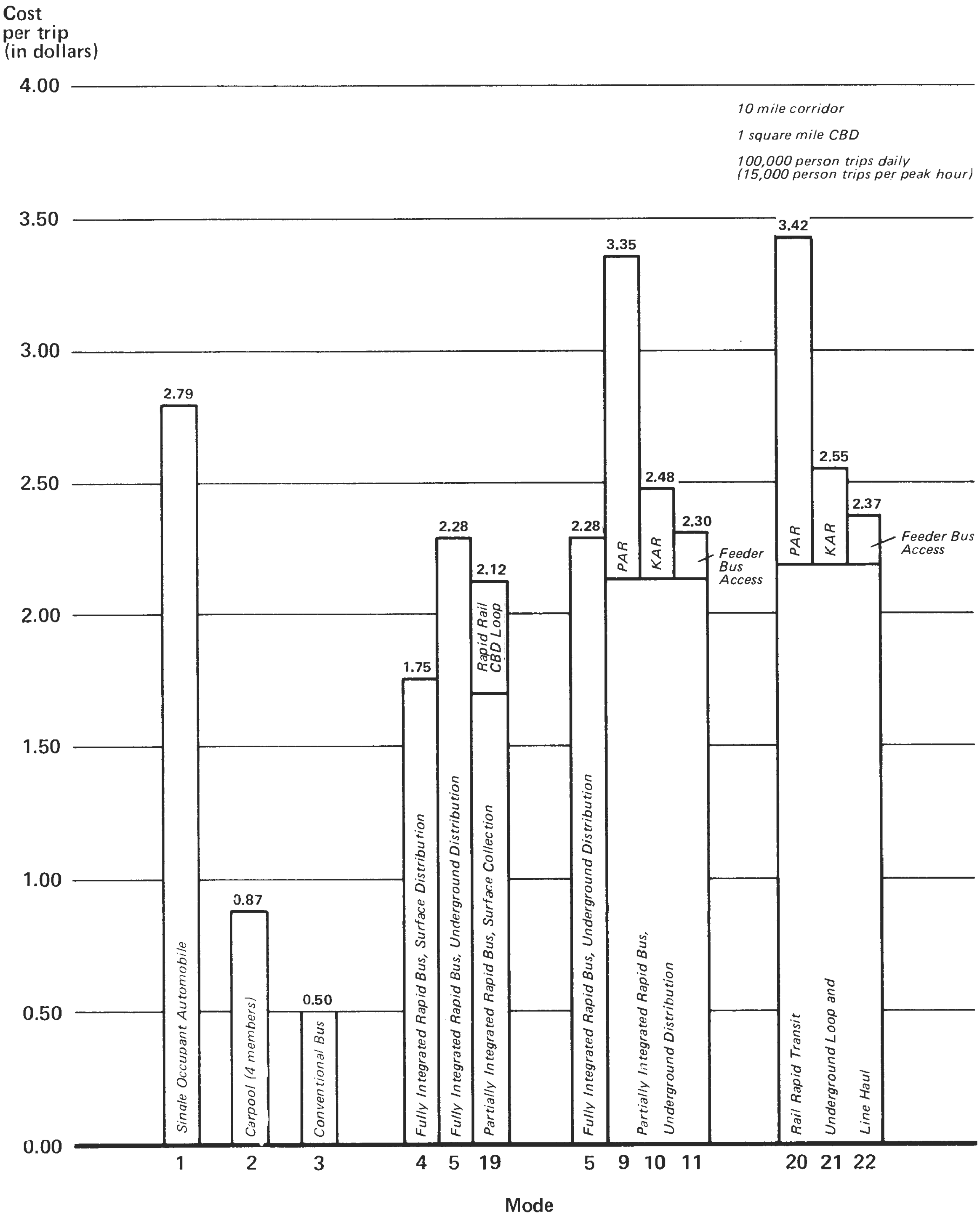
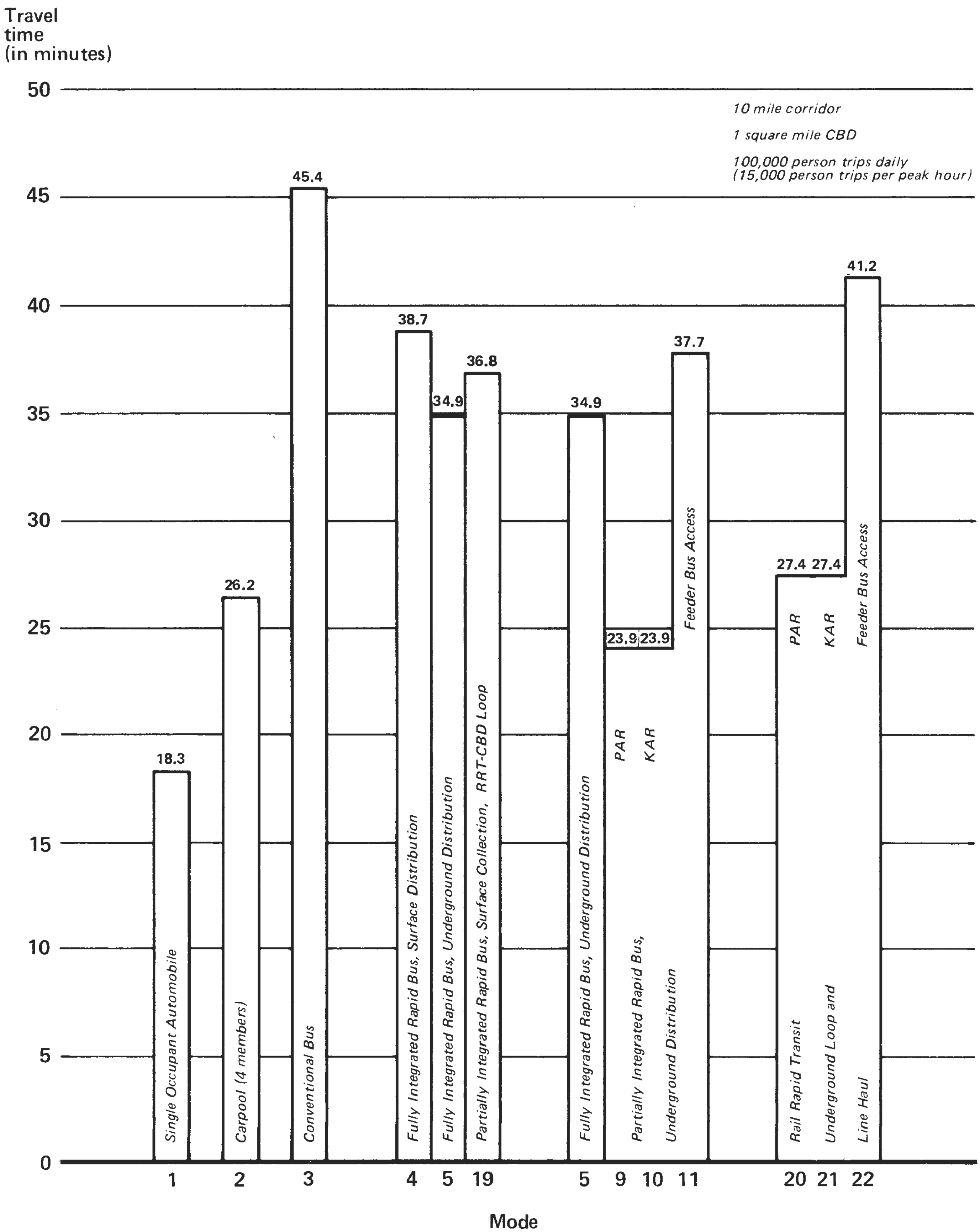


Figure 4-2
Comparative per Trip Times



As is clear from Figure 4-1, the park-and-ride access mode sets will always be more expensive in money terms than will the equivalent modes with feeder bus service. The time cost relationships for these two mode sets will always be the reverse, with park-and-ride mode sets the faster. The trade-off between money and time is left to the user. The user of this report should also remember the unquantified elements of transportation system supply which are appropriate to the given situation. Other elements exist. The user's knowledge of the study area is extremely important to the determination of, and weight ascribed to, the unquantified elements pertinent to the specific corridor and given city. The costs given in this chapter are generalized costs and should be taken as a guide to, but not as, specific transportation supply provision costs.

In Figure 4-3, the money costs of providing transportation services for these 12 modes for three volume levels, (50,000, 100,000, and 200,000 person trips per day) are shown. The impact of increased volume on the cost per trip shows dramatically. Figure 4-4 contains the travel time comparisons across volume levels for these 12 modes. Because of decreased waiting time for higher volumes, the impact of volume is not so dramatic for time costs as it is for money.

Cost Versus Time Comparison

In Figures 4-5, 4-6, and 4-7, the time and money costs per trip are displayed in comparison for the 12 modes. Each figure displays the values for a single volume level. In these figures, the relative positions of the modal values represent the trade-offs of time and money required by each mode. As the person trip volume rises, the cost per trip falls. This is shown as movement from the upper right quadrant (slow and expensive) to the lower left quadrant (fast and inexpensive) as the volume rises.

Figure 4-3
Volume Impact on Money Cost per Trip

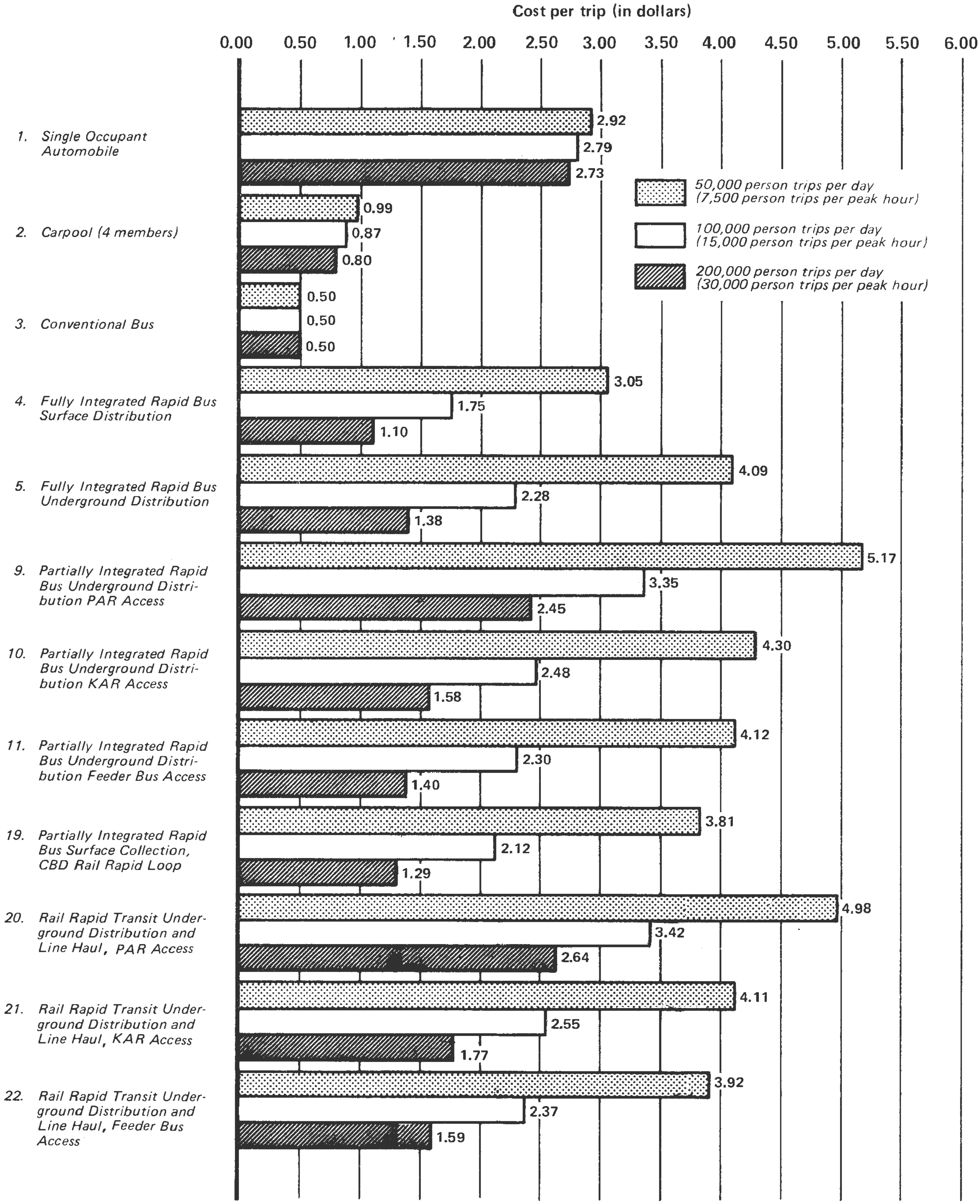


Figure 4-4
Volume Impact on Travel Time per Trip

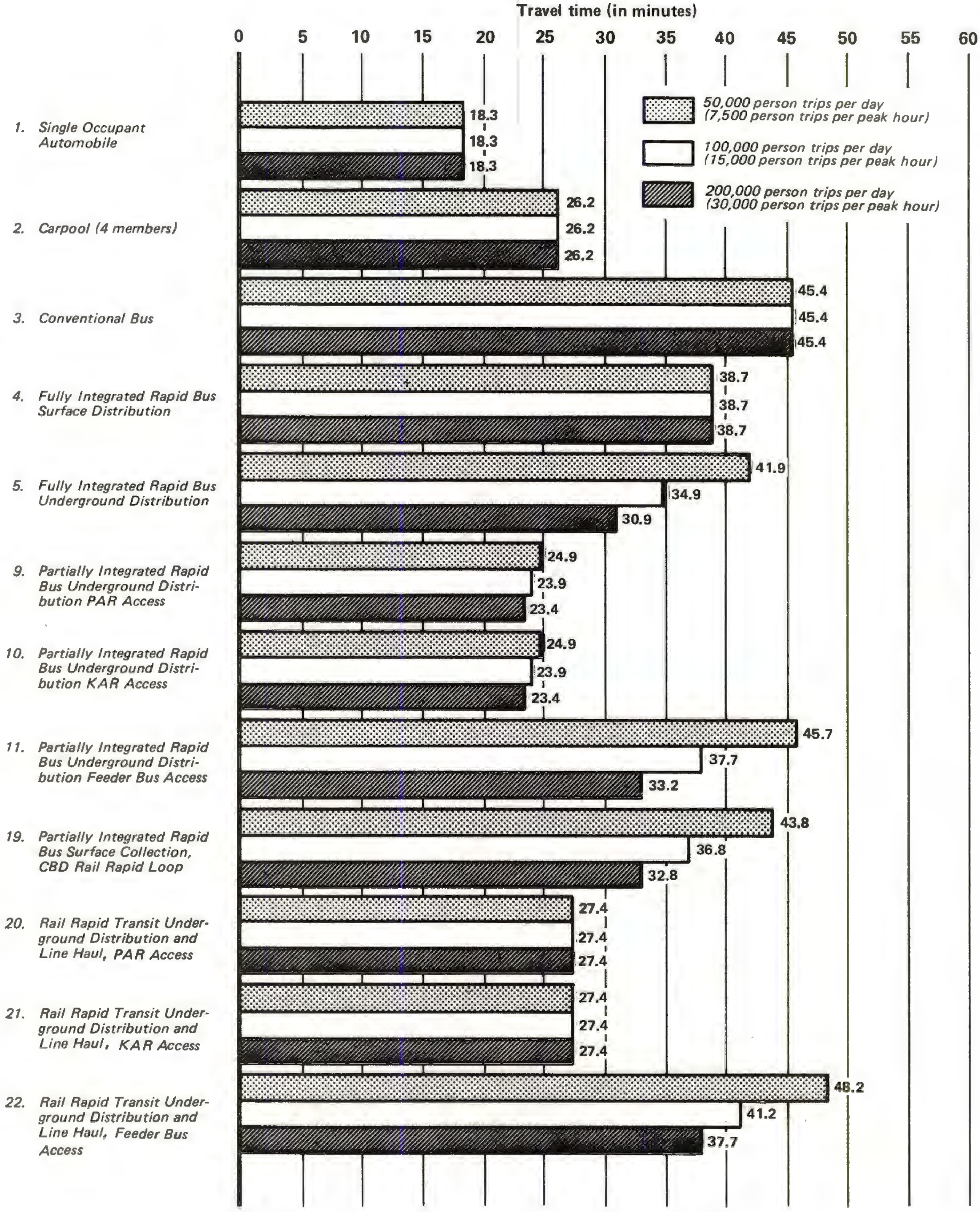
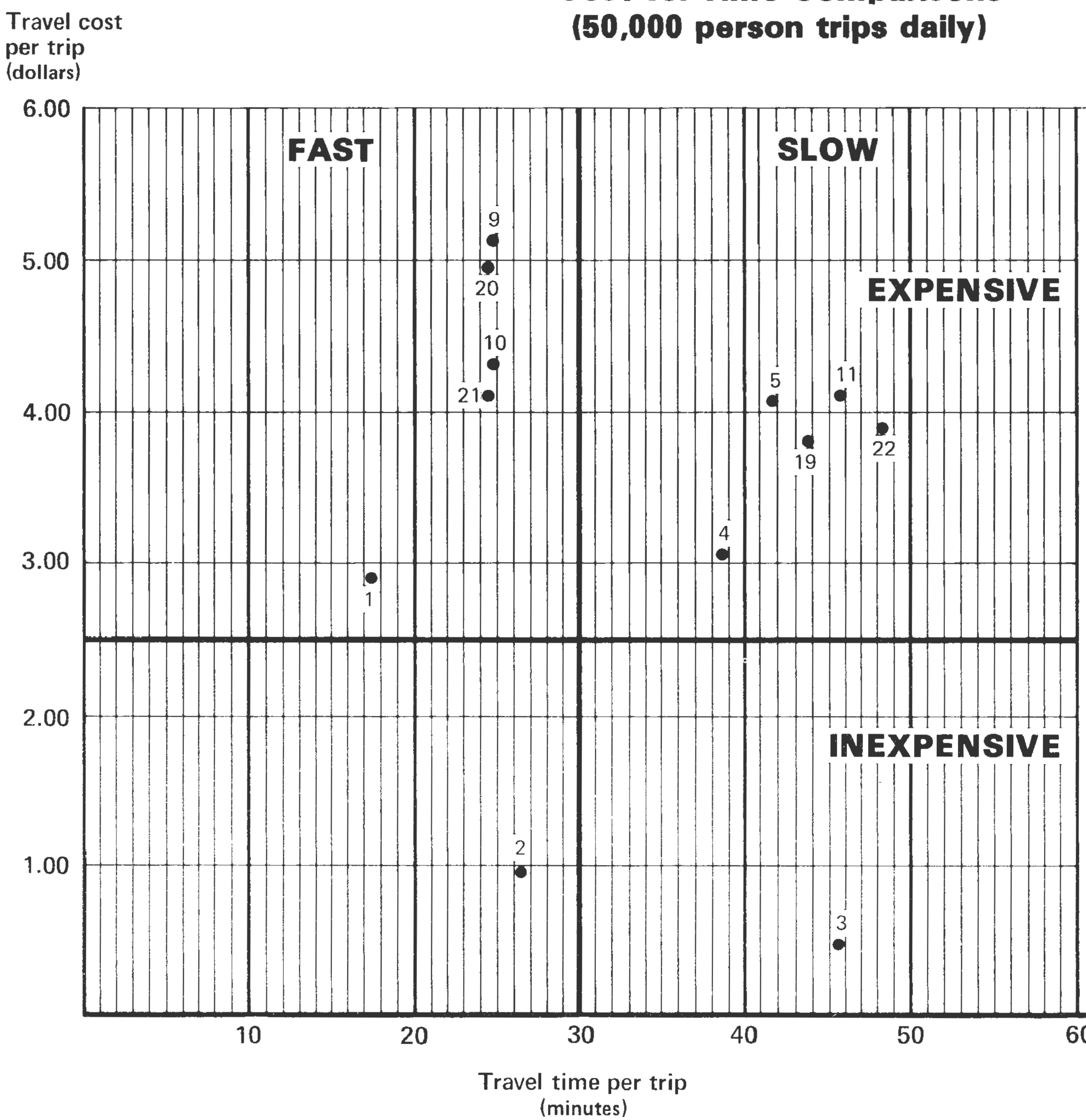


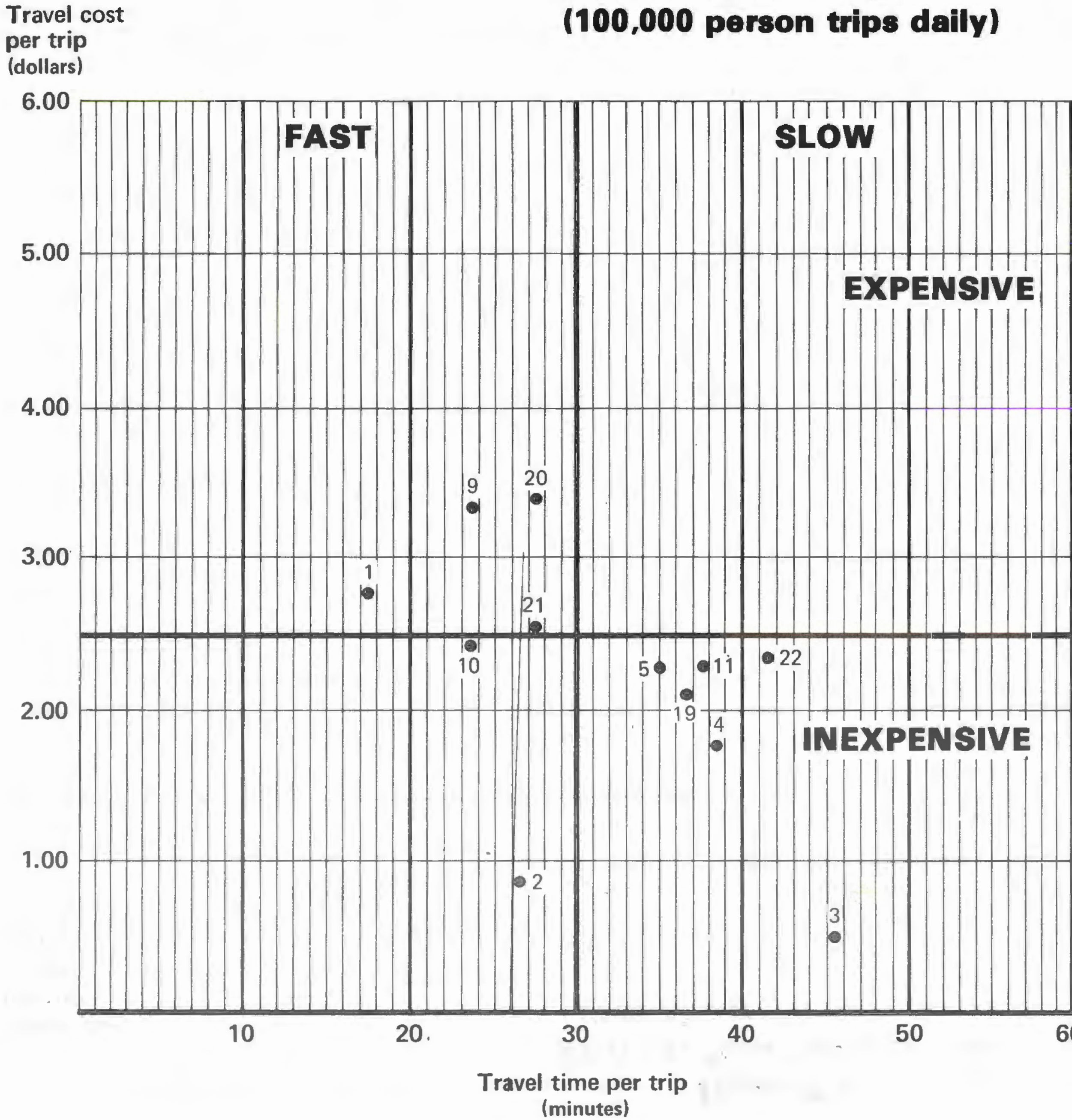
Figure 4-5
Cost vs. Time Comparisons
(50,000 person trips daily)



1. Single Occupant Automobile
2. Carpool (4 members)
3. Conventional Bus
4. Fully Integrated Rapid Bus Surface Distribution
5. Fully Integrated Rapid Bus Underground Distribution
9. Partially Integrated Rapid Bus, Underground Distribution, PAR Access
10. Partially Integrated Rapid Bus, Underground Distribution, KAR Access
11. Partially Integrated Rapid Bus Underground Distribution, Feeder Bus Access
19. Partially Integrated Rapid Bus, Surface Collection, Rail Rapid Distribution
20. Rail Rapid Line Haul and Underground Distribution, PAR Access
21. Rail Rapid Line Haul and Underground Distribution, KAR Access
22. Rail Rapid Line Haul and Underground Distribution, Feeder Bus Access

10 mile corridor
1 square mile CBD
50,000 person trips daily
7,500 per peak hour

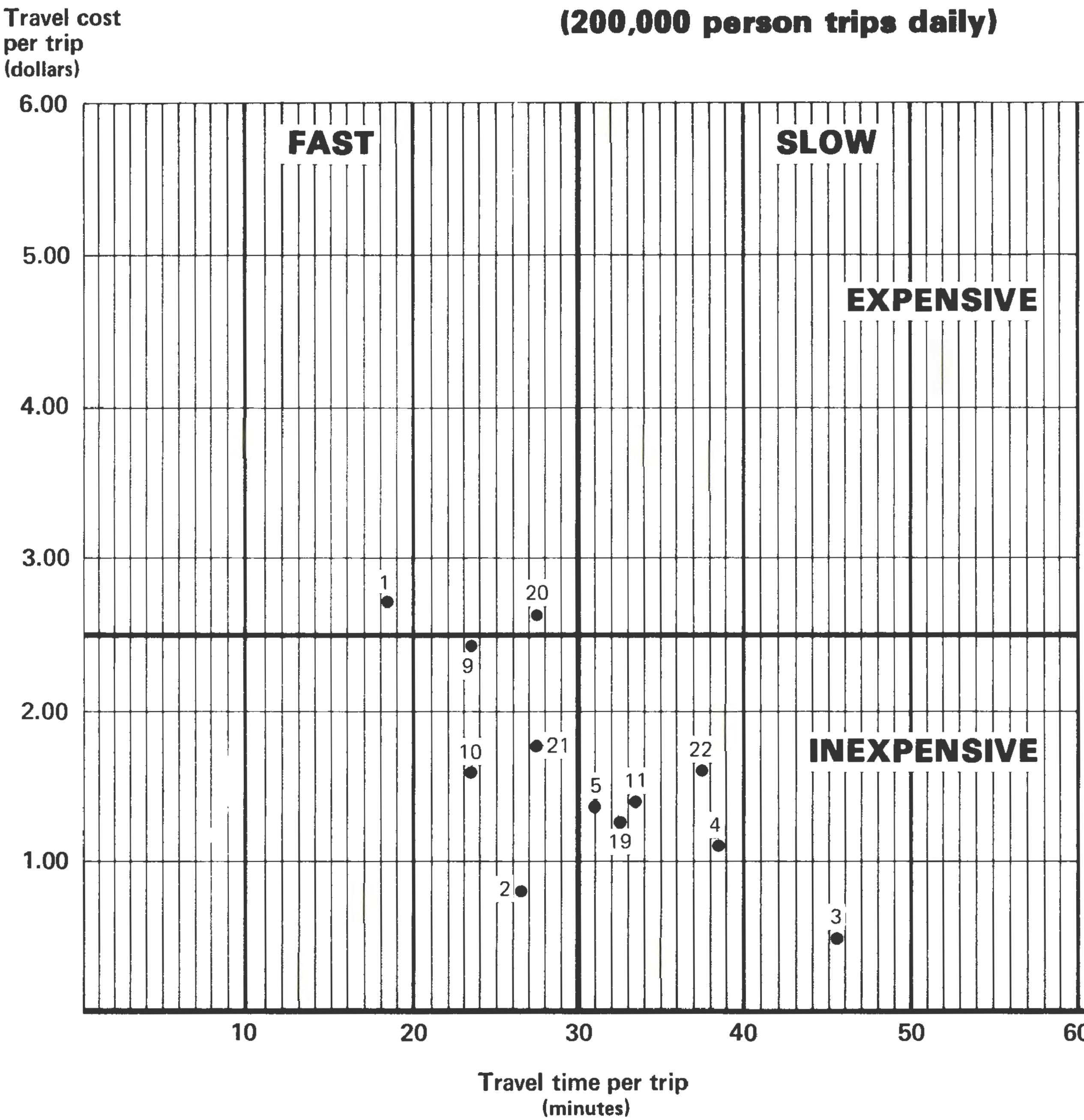
Figure 4-6
Cost vs. Time Comparisons
(100,000 person trips daily)



1. Single Occupant Automobile
2. Carpool (4 members)
3. Conventional Bus
4. Fully Integrated Rapid Bus Surface Distribution
5. Fully Integrated Rapid Bus Underground Distribution
9. Partially Integrated Rapid Bus, Underground Distribution, PAR Access
10. Partially Integrated Rapid Bus, Underground Distribution, KAR Access
11. Partially Integrated Rapid Bus Underground Distribution, Feeder Bus Access
19. Partially Integrated Rapid Bus, Surface Collection, Rail Rapid Distribution
20. Rail Rapid Line Haul and Underground Distribution, PAR Access
21. Rail Rapid Line Haul and Underground Distribution, KAR Access
22. Rail Rapid Line Haul and Underground Distribution, Feeder Bus Access

10 mile corridor
1 square mile CBD
100,000 person trips daily
15,000 person trips per peak hour

Figure 4-7
Cost vs. Time Comparisons
(200,000 person trips daily)



1. Single Occupant Automobile
2. Carpool (4 members)
3. Conventional Bus
4. Fully Integrated Rapid Bus Surface Distribution
5. Fully Integrated Rapid Bus Underground Distribution
9. Partially Integrated Rapid Bus, Underground Distribution, PAR Access
10. Partially Integrated Rapid Bus, Underground Distribution, KAR Access
11. Partially Integrated Rapid Bus Underground Distribution, Feeder Bus Access
19. Partially Integrated Rapid Bus, Surface Collection, Rail Rapid Distribution
20. Rail Rapid Line Haul and Underground Distribution, PAR Access
21. Rail Rapid Line Haul and Underground Distribution, KAR Access
22. Rail Rapid Line Haul and Underground Distribution, Feeder Bus Access

10 mile corridor
1 square mile CBD
200,000 person trips per day
30,000 per peak hour

This shift from slow and expensive to fast and inexpensive as the volume levels increase is due to two very important factors:

1. A large portion of the money costs of providing transportation services for all but automobile modes and conventional bus is for fixed facilities with required minimums (i.e., two tracks for rapid rail transit). This means that these fixed costs are shared by more travelers as volume levels rise.

2. The time element for modes requiring transfers includes intermodal waiting time, which decreases as volume increases. This is due mainly to decreased headways. These modes require less waiting time at the start of the trip and/or during the trip for transit options at higher volumes.

It should be emphasized that underground construction is extremely expensive, especially in downtown areas. Options are provided for comparing the costs and times of underground distribution systems (by bus or rail rapid transit) with those of surface distribution. In part, this cost differential is also due to the use of existing streets for surface distribution, which are excluded from the comparative costs of the affected mode.

The fixed facilities provided for each mode are quantified by the requirements of the peak period. This is peak period dominance and means that the capacity required to provide acceptable service levels in the peak is costed. Excess capacity will exist in the off-peak, especially in such items as rail tracks, lane miles of expressway, and busways. More rolling stock will also be available in the off-peak than is required by the off-peak volume levels.

Component Money Costs

This chapter, to this point, has presented the money costs of providing transportation services as the total money cost per person trip by each of the 12 modal combinations. These total money costs are comprised of individual component costs. These components are for construction (guideway, roadway, and busway; CBD parking; and stations and fringe parking), rolling stock capital (automobile ownership, transit vehicles and yards), and operating and maintenance (automobile maintenance and operation, transit driver or train crew, other transit operating costs).

In Figures 4-8, 4-9, and 4-10, the total per trip money cost of seven common modal combinations are presented for a 10-mile corridor serving a square mile CBD. Each figure gives the per trip cost for a given volume level. The individual component costs are shown as proportions of the total bar. The numeric and percentage values used to define these graphs are given in tabular form in Appendix 3, Tables A3-23 to A3-25.

Operating and maintenance costs and rolling stock capital costs are constant over the three volume levels for each individual mode. The decrease in cost per trip as the volume levels increase is in the construction costs. This is due to a larger volume over which to spread the capital costs. Construction costs are determined by the facilities to be provided and by the requirement to provide entire lanes for busways and freeways and to provide two tracks for rapid rail guideways. At the lower volumes, excess capacity exists. Thus, if the density of the corridor rises, resulting in higher volumes, incremental costs or providing additional transit service will be limited to purchase of rolling stock and operating and maintenance costs for the additional vehicle miles of travel incurred to meet the increased demand.

In this research, average construction costs for freeways, busways, and guideways are used. The money costs for freeways and surface busways are drawn from the Highway Needs Study.[1/] They are for an unspecified mix of construction types and geologic/geographic conditions. The roads are built to Interstate standards. The rapid rail guideway costs are averages of costs incurred in recently built systems and currently operating in the United States.

1/ FHWA Field Study Guide, "National Highway Functional Classification and Needs Study 1970-1990," U.S. Department of Transportation, 1970.

Figure 4-8 Component Money Costs (50,000 person trips per day)

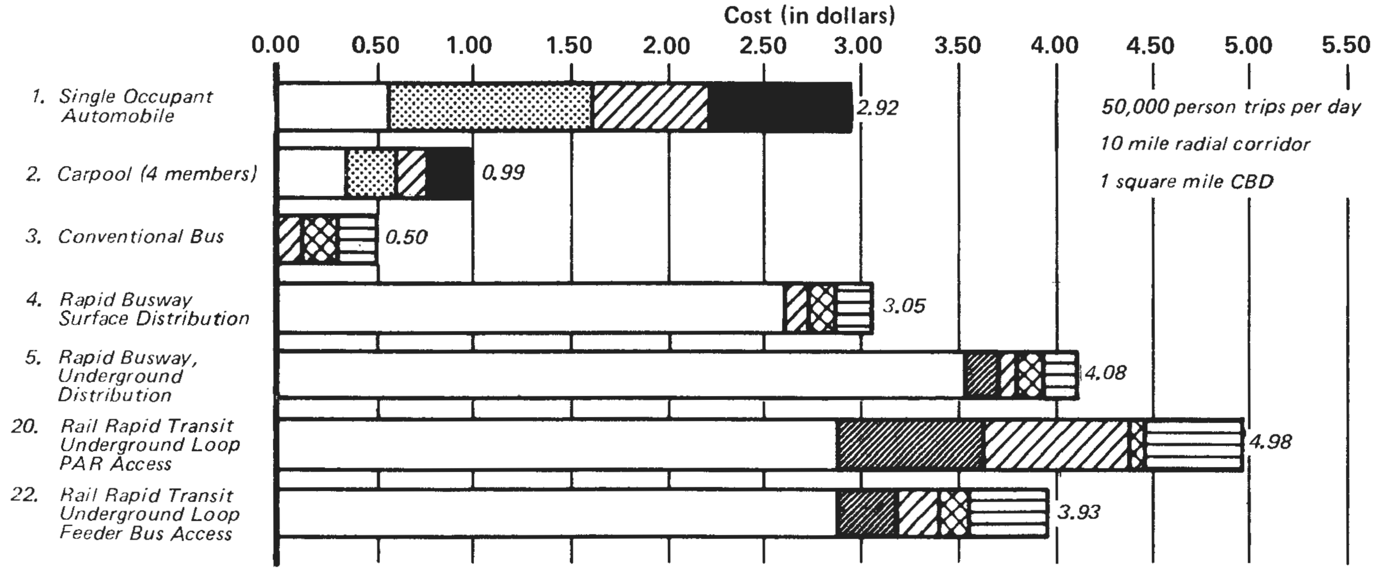


Figure 4-9 Component Money Costs (100,000 person trips daily)

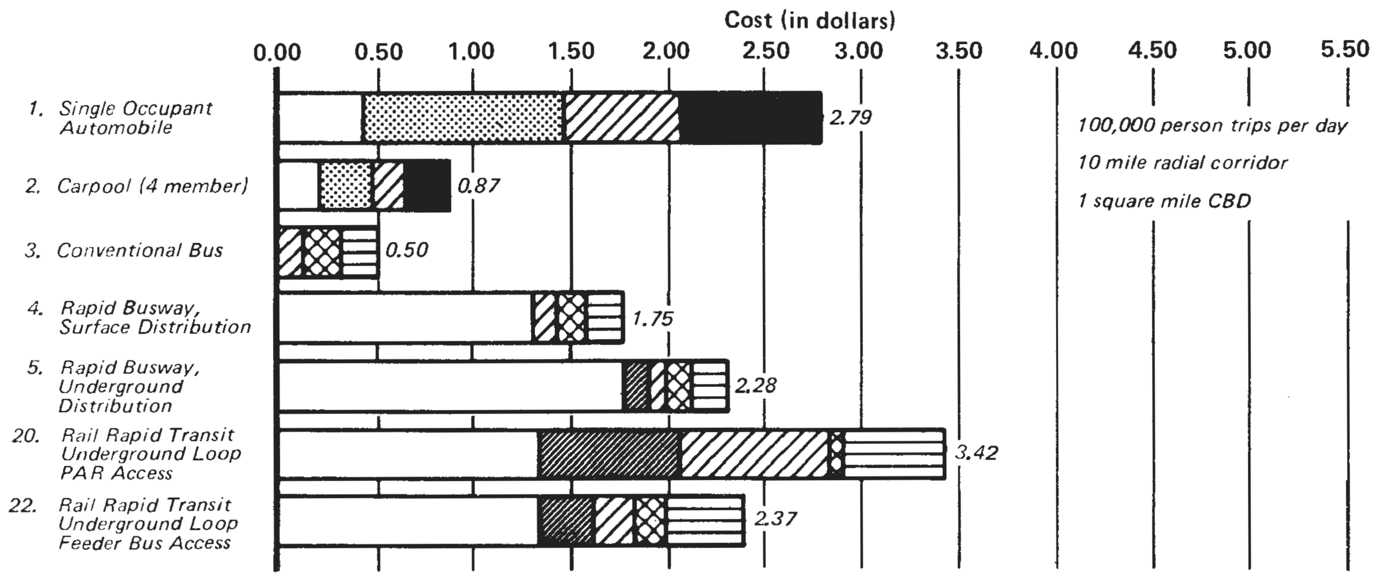
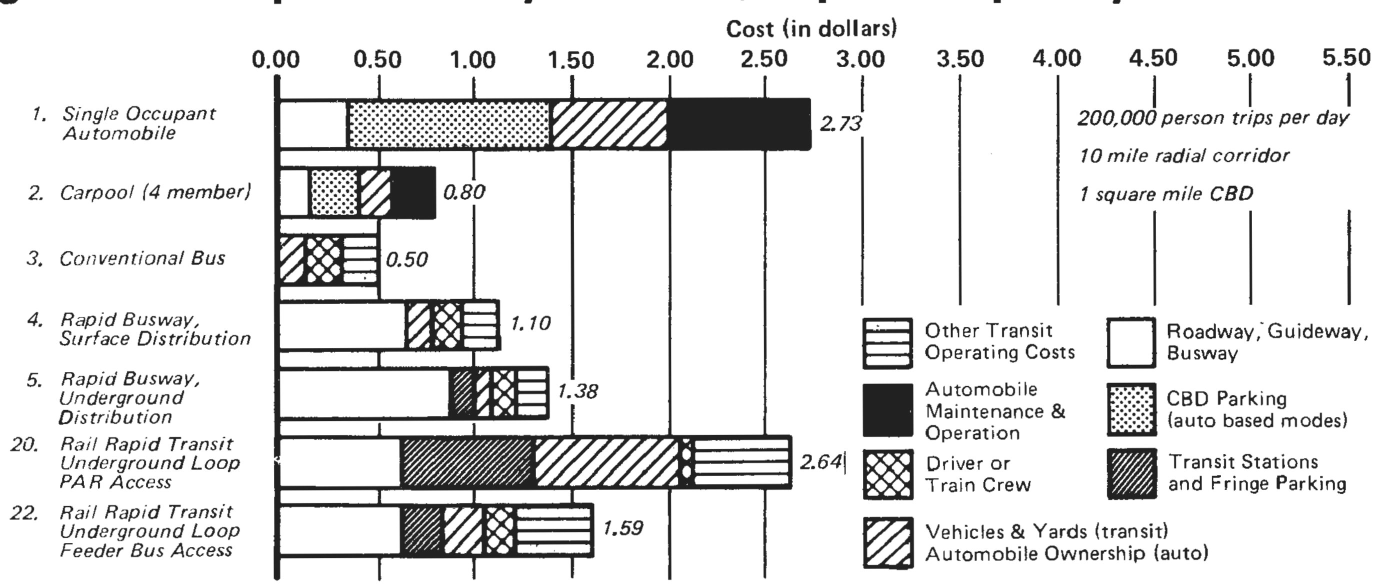


Figure 4-10 Component Money Costs (200,000 person trips daily)



The underground distribution loop provided for the rapid bus service and the 5 miles of line-haul underground busway that feed it are costed through extrapolation from rapid rail underground construction costs, with additional costs for ventilation and bigger tunnels included. The construction costs are amortized over a facility life of 35 years (surface busways and freeways) or 50 years (other capital facilities), assuming a 10 percent discount rate and 250 operating days per year.

Automobile-based modes in this research are not subject to minimum facility requirements as are the transit modes. Freeway lanes are added incrementally, based on predetermined volume to capacity ratios, as the number of automobiles traveling at a given time rises. The number of parking spaces provided is also a direct result of the number of cars, whether CBD spaces for the single occupant automobile and carpool or line-haul station lot spaces in the corridor for park-and-ride travelers.

The land requirements of automobile-based modes are great. Purchase of land in the appropriate locations is included in the comparative money costs presented in this report. For example, these land requirements are for a 100,000 person trip volume in a 10-mile corridor with a 1 square mile CBD:

a. Single occupant automobile: 53.625 lane miles of reversible freeway, requiring 131.21 acres of right-of-way. 2.73 of these acres are in the CBD, 87.27 acres are in the inner 5 miles, and 41.21 in the outer 5 miles of the corridor.

   Six city blocks of 7-level parking facilities are also required to park those cars all day arriving in the a.m. peak and to provide parking for the cars arriving in 2 midday, off-peak hours.

b. Park-and-ride lots are provided in the corridor. To park these cars, 270 acres of land must be made into surface lots. Since there are 10 line-haul stations, 27 acres of parking lots surround each station.

c. Carpool: 25.5 lane miles of reversible dedicated freeway, requiring [illegible] acres of right-of-way, 2.4 acres in the CBD, 37.6 acres in the inner 5 miles, and 23 acres in the outer 5 miles of the corridor.

Freeway interchanges are included in these land requirements.

The high-capital transit modes require 24 acres of right-of-way in the outer 5 miles of the corridor. This is because the rapid busway and rapid rail transit modes are costed as underground facilities for the inner 5 miles and elevated for the outer 4.5 miles of line-haul. Right-of-way is needed for only the above ground portion of the facility. Stations, but not PAR facilities, are included in this land requirement. Park-and-ride facilities are needed only if PAR is the chosen access mode. Feeder bus and kiss-and-ride facilities are provided as part of the station land needs if these modes are chosen as access to the line-haul.

Conventional bus is the only mode costed in this research which does not require fixed capital investment. The highways used by conventional buses are assumed to exist as a sunk cost.

If the underground distribution loop (for rail rapid transit or rapid bus with underground distribution) is used to serve additional travelers from other corridors or as a downtown distributor system, the fixed capital costs of that loop are spread over a larger number of trips. This fixed capital cost ranges from 91 percent (or $0.77 for the 1 square mile CBD) of the egress mode costs for 50,000 person trips daily through 84 percent ($0.39) of the per trip egress cost for 100,000 person trips to 73 percent ($0.21) of the cost for 200,000 person trips daily. Rolling stock capital costs (for rail transit cars or buses) and operating and maintenance costs are directly related to the projected demand, and, therefore, these per trip costs will remain the same for all volume levels.

An implication of the individual component costs that comprise the total costs per mode has to do with automation. Rail rapid transit modes are the only ones which can be automated, and for those modes, the train crews that would be replaced are a miniscule portion of the total costs. In order to automate the fixed guideway system, more capital must be invested in the fixed facilities. Maintenance costs also increase. Automated rail rapid transit systems are thus cost ineffective when compared to rail systems using normal train crews.

The fixed capital costs of providing the transportation system are a substantial portion of the total costs. Alteration of the costs of construction would thereby substantially alter the costs of service provision and, therefore, cannot be ignored.

Construction Cost Sensitivities

Due to data limitations, the impacts of variations in construction costs on transportation service provision can only be approximated. This is done by raising or lowering construction costs by 20 percent from the average. (Figure 4-11, 4-12, and 4-13 for 50,000, 100,000, and 200,000 person trips daily.) It is in this way that the impact of geological conditions (e.g., percentage grades, rock versus earth tunneling, elevation of roadbed,,and climatic conditions) on construction costs is included. The variation from the average costs which would be appropriate for the given area must be obtained from individual sources. The change in per trip costs would be the specific percentage of the construction capital component cost due to the deviation from the average. All other trip money cost components (rolling stock and operating costs) are constant. The application of this money cost sensitivity discussion presumes that the user is able to obtain an approximation of the deviation from the average construction costs required by the user's circumstances. The actual money values upon which this discussion is based are found in the companion report, "Costing Urban Transportation Alternatives: A Handbook for Transportation Planners."

Since underground busway construction costs are extrapolated from underground rail construction costs, both components are likely to move in concert, ~~where they do change~~.

Figure 4-11
Construction Cost Sensitivities
(50,000 Person Trips Daily)

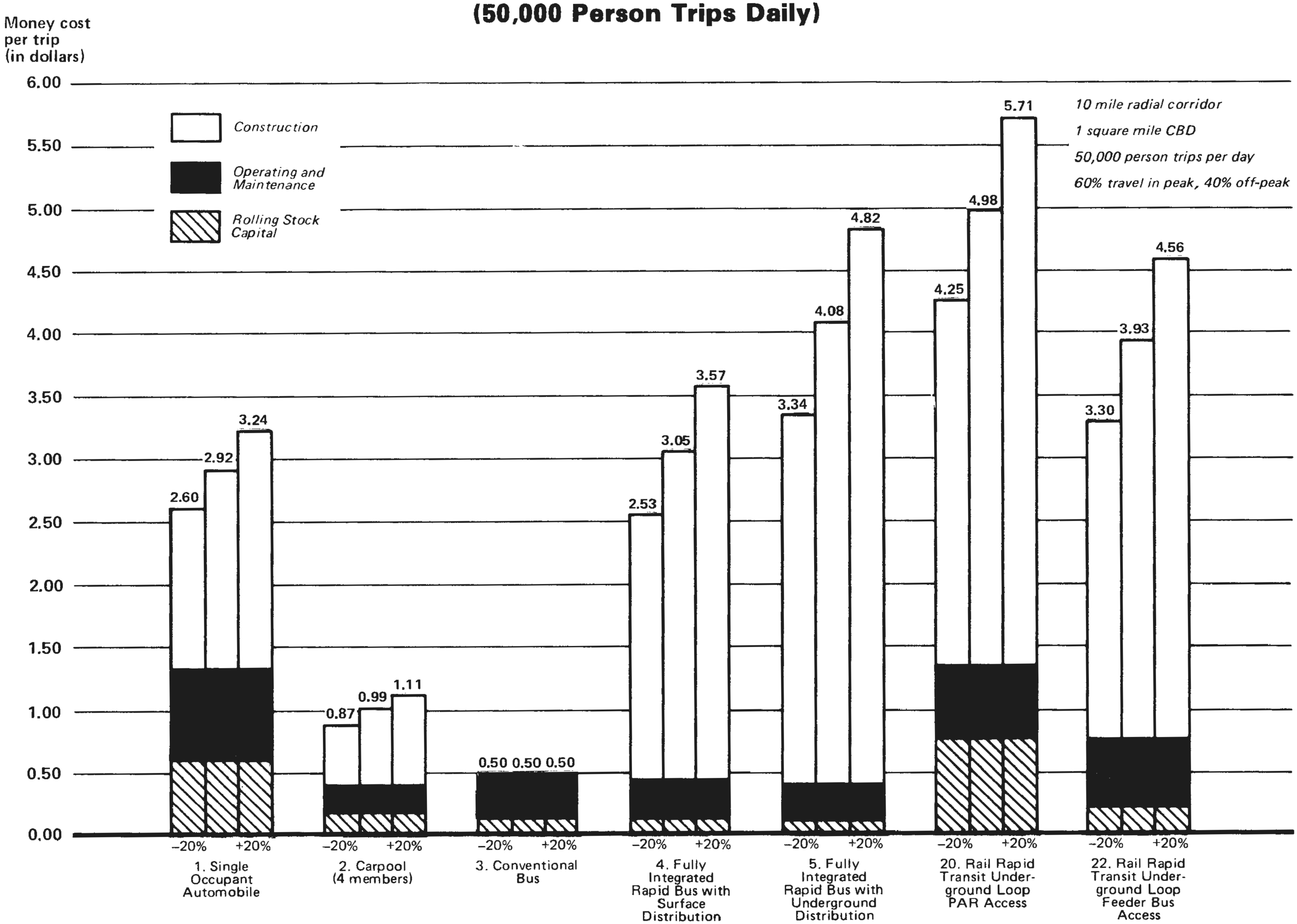


Figure 4-12
Contruction Cost Sensitivities
(100,000 Person Trips Daily)

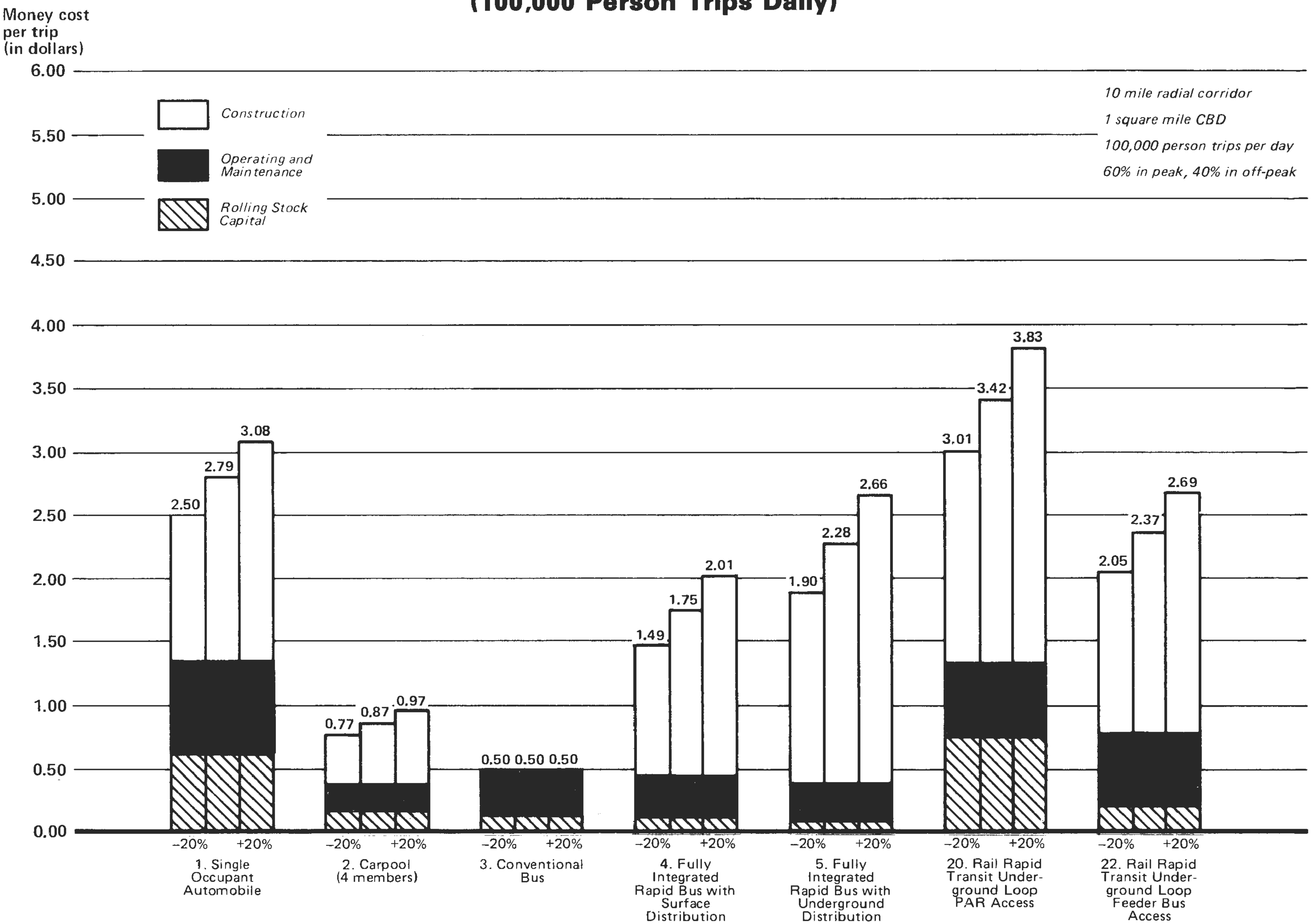
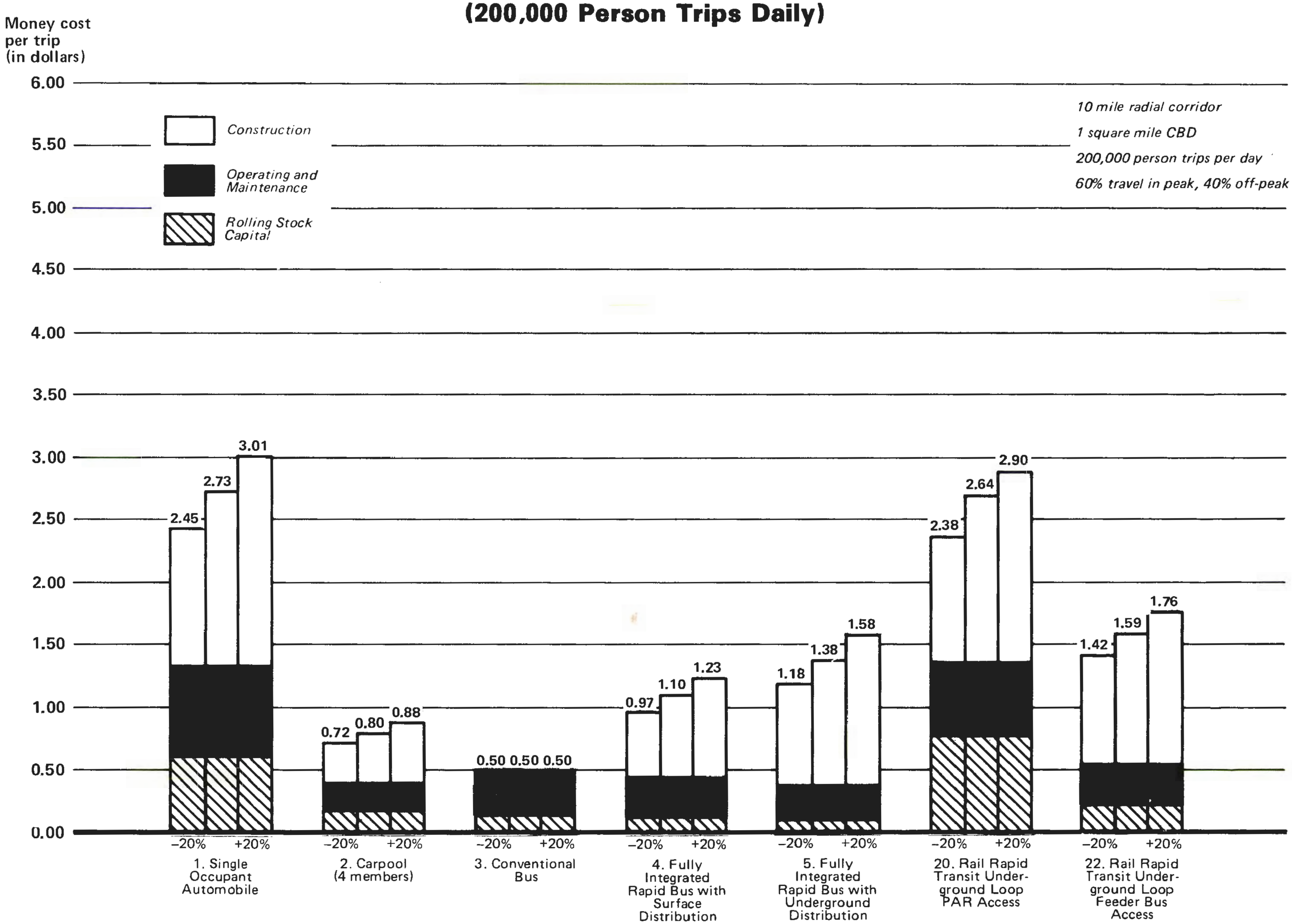


Figure 4-13
Construction Cost Sensitivities
(200,000 Person Trips Daily)



Those modes with park-and-ride access include auto ownership in the rolling stock capital segment. The center bar in each group of three is the average cost per trip at the given volume level. The left-hand bar is the cost, assuming construction costs are reduced by 20 percent of the base case, while the right-hand bar assumes a 20 percent rise in construction costs. The numeric values upon which these figures are based are found in Appendix 3, Tables A3-26 to A3-28.

Chapter 5

Conclusions

The comparative costs presented in this report are designed as guides for the decision maker and planner facing the problem of providing transportation services. These comparative costs are intended to aid in determining potentially viable alternative choices of transportation systems in a long-range sketch planning context. The resource costs and the time requirements are mean values for a generalized context. The users' knowledge of the specific area for which transportation services are to be provided is invaluable and would be preferred, if available. However, such information is rarely available for all technologically feasible modal combinations for the specific area.

For simplicity, this research is constrained to the question of the costs of supplying transportation services. Demand for those services is the other, equally important side of this coin. Information on both supply and demand are integral inputs to the decision making process. Demand information should be obtained from other sources.

These comparative costs are designed to provide the user with information needed to narrow the field of feasible transportation systems to those that are potentially viable in the study corridor. They are not intended to lead the user to a single modal choice. This is further supported by the finding that no single system is optimal over all possible conditions. Trade-offs are required among the various components to determine the best systems for the study area. Such trade-offs include speed (i.e., time) and money (i.e., resource costs). Other criteria, which are important inputs to the selection process, are the societal costs of congestion, pollution, and disruption, the desire for urban rejuvenation, the desire to improve the quality of life for special population groups, and the individual traveler's perceptions of the separate modes. These traveler perceptions are not completely defined, much less quantified, and include schedule flexibility, privacy, reliability, personal safety, and convenience. These personal, nonmonetary components affect the mode choice decisions of the travelers, and for these reasons, a single mode (such as conventional bus) cannot be prescribed as the only transportation service available for the corridor.

While mixed mode corridors are needed to meet the varying needs of the travelers, this research has provided comparative costs based on a single mode meeting those needs. This was done to avoid the intractable analysis problems inherent in costing mixed mode corridors composed of several different modal combinations and various proportions of each mode. However, it is possible to view a corridor with 100,000 or 200,000 daily person trips, for comparison purposes, as two corridors each having an appropriate volume to represent modal usage. As such, a 100,000-person-trip corridor might be thought of as two 50,000-person-trip corridors. The resulting comparison uses the time and cost values for the smaller corridor. It is more expensive per trip to provide several mode choices than to provide a single one.

Volume levels defining the expected demand for transportation services also greatly affect the choices of modes available to the decision maker and planner. Because fixed facilities (guideways, stations, roadways, etc.) are the largest component of the supply cost, and because, for most modes, they cannot be built in fractional quantities, the number of trips over which these costs can be spread is extremely important. This is especially true of line-haul rapid rail transit, where no fewer than two tracks are built. Automobile-based modes are not subject to such minimum requirements. The number of freeway lanes provided is a function of the number of automobiles, determined by given volume to capacity ratios, rounded to the next highest integer value. The parking spaces built to store the automobiles is also a direct function of the number of automobiles to be stored in a given location.

The impact of volume level projections on possible mode choices cannot be over emphasized. The volume level projections are, however, constrained by the population of the study area and by the modal service proposed. Only New York and Chicago have corridor volumes exceeding 200,000 daily person trips, and these volumes are influenced both by population and by geographic configuration. Users of this research planning for smaller cities are very unlikely to have corridor volumes exceeding 100,000 daily person trips on each of several modes in a mixed mode corridor. It is more likely that they will have corridor volumes of approximately 50,000 daily person trips on each mode in the corridor. This serves to limit the economically feasible options to those with lower minimum fixed capital requirements, meaning lower per trip construction costs. In Figures 4-3 and 4-4 the impact of lower volume levels shows in higher per trip costs. High-volume corridors have all modal combinations as potentially viable options.

The user is cautioned that the costs presented in this report are for providing service for a single corridor. This means that the costs of the underground loops required by rail rapid transit and by rapid busways with underground distribution are assigned only to the trips from that corridor. The cost per person trip may be lowered for the underground loop modes by assigning the use of these underground facilities to other users, for example, as a downtown distributor and/or as a distributor for other corridors. The impact of spreading the construction cost load over a larger population is not defined in this report.[1/] This cost is affected by the volume added to the downtown segment of the trip. More tracks are not needed until the passenger volume exceeds 350,000 daily person trips on the downtown loop. Additional rolling stock and operation and maintenance costs will accrue in direct proportion to the added traffic.

1/ For a 1 square mile CBD, these per trip capital costs are $0.77 for 50,000 person trips, $0.39 for 100,000 person trips, and $0.21 for 200,000 person trips.

Another aspect of the component costs, which comprise the money costs of providing transportation service, affects automation of the rail-based systems. Train crews are a small portion of the costs. Automation raises the construction costs. Maintenance and operating personnel costs also rise for automated trains.

Except for conventional bus, the transit modes for which comparative costs are derived have substantial fixed capital components. Transit modes do not have substantial investments in land. Within the dense urban core, for the most part, the guideways and busways are built underground, thus requiring no rights-of-way except for the surface entrances to the stations. Automobile-based modes, on the other hand, have substantially greater land requirements than transit modes. For the 10-mile radial corridor, serving a 1 square mile CBD, with 100,000 person trips daily, .25 square miles, or 3 percent, of the corridor's area is dedicated to freeways and parking spaces for single occupant automobiles. This is the additional increment needed to build the new facilities and is over and above the land used to provide the other streets required by the corridor. The major portion of this additional increment of land is required in the CBD and in the inner 5 miles of the corridor. The transit modes, by comparison, require 0.038 square miles, or 0.4 percent of the corridor's area. Further, the incremental land requirements are needed in the outer 5 miles of the corridor for stations and to provide yards and shops.

For the 12 major modal combinations, the time versus cost per trip tradeoffs have been plotted (Figures 4-5, 4-6, and 4-7). The individual points show the relative positions of the separate modal combinations to each other and their characterization as fast or slow and expensive or inexpensive. Four modal combinations are found to minimize time and/or cost. These are single occupant automobile (fastest, expensive), carpool (fast, inexpensive), fully integrated rapid bus with surface distribution (slow, inexpensive), and conventional bus (slowest, most inexpensive). Rail rapid modes are expensive, but fast. Any mode falling in the slow, expensive quadrant (cost over $2.50 per person trip, travel time exceeding 30 minutes) is an inefficient choice. Conversely, those modes falling into the fast, inexpensive quadrant would be efficient choices. The modes which are either fast and expensive or slow and inexpensive require further scrutiny.

From the findings of this research into the comparative costs of transportation systems, it may be concluded that the decisions as to choice of modes not only include the usual money and time costs of a mode to the society it serves, but also the individual perceptions of the mode characteristics held by the users.

This report uses the costs of the separate modes to society, including the costs borne by private individuals and various governmental units. Benefits ascribed to each mode, such as pollution control, urban rejuvenation, and quality of life considerations, should be included in the final decision making process, but should not supercede the resource costs and travel times associated with providing those modes. In short, the societal costs of transportation cannot and should not be overlooked in the process of determining which transportation services to provide. This report is one step in this direction.

APPENDIX 1

Component Cost Derivation

The comparative costs presented in Chapter 4 for the various modes in combination are derived using the procedures described in the companion report "Costing Urban Transportation Alternatives: A Handbook for Transportation Planners." These procedures use the quantification of the components necessary to provide the given transportation service (e.g., vehicles, fixed capital facilities, and operating and maintenance requirements) for a given level of demand to determine the comparative cost of that mode for a given trip segment (e.g., access, egress, line-haul, or the various permutations thereof). The components thus quantified are multiplied by the individual unit cost of each and the products summed to obtain the total daily vehicle cost per trip. The per person trip comparative cost is the quotient of the total cost divided by the given daily passenger load.

Seven assumptions are made which greatly influence the comparative costs. These are:

1. The flow of travel is undirectional in the peak periods, meaning that all traffic is CBD bound in the a.m. peak, residence bound in the p.m. peak. All fixed facilities are costed as though only one direction of travel is possible. Expressways have reversible lanes. Transit services collect (or discharge) along the line, deadheading on return. Off-peak travel is assumed to be equal in both directions.

2. All travel is defined to be CBD oriented - meaning that either the origin or destination is in the CBD. Travel between points in the corridor is excluded.

3. Each mode or modal combination providing door-to-door service in turn is defined to carry either the entire trip load or none of it. Partial loads on several mode options are excluded because of intractable analysis problems.

4. Each service is assumed to operate for 250 days each year.

5. The corridor for which these quantities apply is 10 miles long, with 20 zones, each 1 mile long along the radial, and half of the corridor's width. Each of these 20 zones is assumed to generate an average number of trips (e.g., 750 per peak hour and 286 per off-peak hour with 100,000 trips per day).

6. The trip segments are assumed to be separable so that each segment may be costed separately and then summed to obtain door-to-door trip cost.

7. The operating day is assumed to be 6 a.m. to 12 midnight. Peak hours are 7 to 9 a.m. and 4 to 6 p.m. For a total corridor volume of 100,000, there are 15,000 trips per peak hour. Off-peak periods are 6 to 7 a.m., 9 a.m. to 4 p.m., and 6 to 12 midnight. For 100,000 trips per corridor, 2,860 will be made in each off-peak hour. These trip flows are assumed to be constant.

In addition to these assumptions, general information is needed, describing the environment within which the comparative costs were derived. This is best given in the following manner:

1. All capital components (freeways, parking facilities, busways, tracks, stations, terminals, and vehicles) are amortized over a given lifespan at a 10 percent discount rate. The specific lifespans are given in Table A1-1.

2. Transit line-haul facilities are assumed to be two tracks for rail transit and 44-foot wide busways for rapid buses.

3. All underground CBD distributor loops (RRT or busway) are single width, i.e., one track for RRT and 20-foot wide busway (12-foot lane plus 8-foot paved shoulder). Underground CBD stations are one sided. The costs of these are not half of full width costs, but are 40 percent of the cost of the length plus 60 percent of the remaining cost.

4. All underground construction, whether line-haul or CBD distribution, is built as 75 percent cut and coverr, 12 1/2 percent rock tunnel, and 12 1/2 percent earth tunnel.

5. Line-haul facilities are provided for 9.5 linear miles in the 10-mile corridor due to the positions of stations and interchanges at the midpoint of the shared radial per zone pair. The inner 5 transit miles of facilities are underground in average development, the outer 4.5 miles elevated in sparse development. Freeways are the mix of facilities defined in the Highway Needs Report. The inner 5 miles are in fringe densities, the outer 4.5 miles in residential densities.

6. All line-haul facilities are assumed to have an additional 1/8 linear mile into the CBD to serve as a connector to the appropriate CBD distribution system.

7. Maintenance of fixed capital facilities is a function of the number of units of each, except for maintaining CBD and residential streets, which is a function of vehicle miles of travel.

8. Operation and maintenance of the rolling stock (automobiles, buses, and trains) are a function of the vehicle miles of travel plus, for buses only,

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1/ FHWA Field Study Guide, "National Highway Functional Classification and Needs Study 1970-1990," U.S. Department of Transportation, 1970.

TABLE A1-1

Average Life of Facilities & Vehicles
(in Years)

	Life	Capital Recovery Factor (CRF) @ 10%
Land	Infinity	0.10
Rail Line & Stations	50	0.10085
Underground Busways	50	0.10085
Busway Terminals	50	0.10085
Surface Busways	35	0.1037
Expressways	35	0.1037
Rail & Bus Yards	50	0.10085
Parking Lots	50	0.10085
Bus Shelters	10	0.162
Rail Car	30	0.1037
Busway Rapid Rus	12	0.1468
Conventional Bus	15	0.1313
Auto	10	0.162
Carpool Vehicle	10	0.162

the vehicle hours of travel. These expenses are all variable costs of providing the service and include fuel, labor, tires, oil, insurance, vehicle maintenance, administrative and general, and miscellaneous expenses as appropriate to the modes.

9. The per person trip variable cost is the quotient obtained from dividing the operating and maintenance costs per vehicle trip by the occupancy. Rolling stock capital and person trip is the quotient of dividing the cost is the amortized daily cost over the facility lifetime divided by daily person trips. The total person trip comparative cost is the sum of these components: variable, rolling stock, and fixed capital costs per person trip.

For convenience, the quantity of each component required in each modal type is presented in tabular form. The additional information specific to each mode type is given in the supporting text.

Automobile-Based Modes

The automobile-based modes defined in this report provide either door-to-door service through single occupant automobiles and four passenger carpools or access to the line-haul mode through single passenger park-and-ride and kiss-and-ride services. Each of these four modes is costed separately. Although the costing procedures are the same, the component quantities required differ by mode. For each mode, the components required in each category (fixed capital, rolling stock, and operating costs) of the service are given in Table A1-2.

Sufficient freeway capacity is provided to maintain an average of at least 45 mph at all times. No reverse commutation is allowed, since all travel is defined to be CBD oriented. The lanes are reversible, with inbound traffic in the a.m. peak, outbound in the p.m. peak, and equal in- and outbound traffic in off-peak periods.[1/]

All day parking is provided for all automobiles arriving in the a.m. peak. Parking is also provided for automobiles arriving in 2 midday off-peak

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1/ Freeway lanes to provide reverse flow commuting are not costed in this report. Provision of additional lanes to accommodate reverse flow traffic in the peak periods entails additional costs for right-of-way, construction, and maintenance. This would be offset by the additional travel served.

Table A1-2
Automobile-Based Mode Component Requirements

		Vehicle Trips	Automobiles	Lane Miles of Freeway	CBD Spaces	PAR Spaces	VMT per Trip	VMT: Freeway	VMT: CBD + Residential
1.	Single Occupant Automobile	100,000	50,000	53.625	35,720	------	7.225	5.125	2.10
2.	Carpool	25,000	12,500	25.5	8,930	------	8.725	5.125	3.60
3.	Park & Ride	100,000	50,000	------	------	41,440	1.35	------	1.35
4.	Kiss & Ride	100,000	na	------	------	------	2.70	------	2.70

hours for 2 hours stay (for the CBD) or 3 midday off-peak hours for 3 hours stay (for PAR lots).

CBD parking is defined to be in 7 levels: 5-story structures and 2 underground levels. PAR parking is in surface lots at the line-haul stations.

Bus-Based Modes

In this research, the bus-based modes are defined as conventional, rapid, and feeder bus services providing the full gamut of transportation services. Given the appropriate bus service type, these range from access, egress, and line-haul only through the partially integrated services (line-haul with either access or egress in the same vehicle) to fully integrated door-to-door service.

Vehicle loads are defined to be 50 passengers for each round trip. This means that in the a.m. peak periods, the buses collect 50 passengers, then travel nonstop to the CBD, where they discharge their passengers before dead-heading back to pick up another load. The reverse occurs in the p.m. peaks. In off-peak periods, 25 passengers are carried both ways. Twenty-five passengers are carried into the CBD, whereup, another 25 are collected to carry back to the residential area. Along-the-line service is not provided within the confines of these comparative costs.

In Table A1-3, the quantities of each of the components required to provide the separate services are given. The maintenance requirements for the fixed capital facilities are a set amount per unit per year with the exception of residential and CBD street maintenance which is based on the amount of travel in these areas. Yards and shops are also required.

The underground distribution required by two of these services is a one-way loop with 2.5 miles of single width (20 feet) busway and 8 stations with 3 loading bays in each. If the service includes surface distribution, the existing CBD streets are assumed to have sufficient capacity to provide 12 mph running speeds (approximately 4 mph with stops for collection and distribution). The

Table A1-3
Bus-Based Mode Component Requirements
10-mile corridor, 1 square mile CBD, 100,000 volume

	Line Haul Busway	Underground Busway	Line Haul Stations	Underground Stations	Terminals	Rapid Buses	Conventional Buses	Yards and Shops	Busway Trip VMT	Arterial Trip VMT	CBD + Residential Trip VMT	Busway Trip VHT	Arterial Trip VHT	CBD + Residential Trip VHT	# Vehicle Trips Peak	# Vehicle Trips Off-peak	Total Vehicle Trips
Conventional Bus	na	na	na	na	na	na	315	As required for the appropriate fleet.	na	10.25	7.4	na	0.36	0.69	1,200	800	2,000
Line-Haul Rapid Bus	9.625	---	10	--	1	72	na		10.25	na	na	.230	na	na	1,200	800	2,000
Line-Haul + Surface Distribution Rapid Bus	9.625	---	10	--	0	148	na		10.25	na	2.5	.200	na	0.295	1,200	800	2,000
Line-Haul + Surface Collection Rapid Bus	9.625	---	--	--	1	190	na		10.25	na	4.9	.200	na	0.41	1,200	800	2,000
Line-Haul + Underground Distribution Rapid Bus	9.625	2.5	10	8	0	98	na		12.75	na	---	0.20	na	0.11	1,200	800	2,000
Fully Integrated Rapid Bus-Surface Collection + Distribution	9.625	---	--	---	0	266	na		10.25	na	7.4	0.17	na	0.69	1,200	800	2,000
Fully Integrated Rapid Bus Surface Collection, Underground Distribution	9.625	2.5	--	8	0	216	na		12.75	na	4.9	0.17	na	0.58	1,200	800	2,000
Feeder Bus Collection	na	na	na	na	0	na	136		na	na	4.9	na	na	0.45	1,200	800	2,000
Feeder Bus Distribution	na	na	na	na	0	na	104		na	na	2.5	na	na	0.33	1,200	800	2,000

residential streets used for residential collection are assumed to have 15 mph running speeds.

Line-haul stations, required by those services without residential collection, are on the surface. The line-haul busways are underground for the inner 5 miles, elevated for the outer 4.5 miles. Station access and egress from the busway is by ramp surface.

An underground terminal is needed for interface between line-haul and CBD distribution when these trip segments are not in the same vehicle. This is not identical to the stations since turn-around facilities are required in terminals. This underground terminal consists of five bus loading bays and 0.1 mile of 20-foot wide turn-around loop.

Bus operating and maintenance costs are defined both by bus miles and bus hours of travel. Both are needed to determine the variable costs of bus-based transportation services.

<u>Rail-Based Modes</u>

In the comparative costs, the rail-based modes are confined to rail rapid transit. Rail rapid transit (RRT) in this research is defined to provide line-haul only, line-haul with CBD distribution, or CBD distribution only service.

Each rail rapid car is defined to carry a 110-passenger load on each round trip. In peak periods, this load is in the peak direction only. The train deadheads the return trip after discharging the passengers. Off-peak loads are 55 passenger loads in both directions, collected as CBD-bound passengers and discharged as residence-bound travelers. No along-the-line service is provided in this costing process.

Table A1-4 describes the quantities of each component required to provide each type of service. Operation and maintenance costs are a function of car miles of travel.

Table A1-4
Rail Rapid-Based Mode Component Requirements

	Line-Haul Double Track Miles	CBD Single Track Miles	Line-Haul Stations	CBD Stations	Terminals	Rail Rapid Cars	Yards & Shops	Line-Haul VMT (Trip)	Distributor VMT (Trip)	Total Trip VMT	Line-Haul VHT (Trip)	Distributor VHT (Trip)	Total Trip VHT	# Peak Hour (car loads) Vehicle Trips	# Off-Peak (car loads) Vehicle Trips	Total Vehicle Trips
Rail Rapid Line-Haul	9.625	na	9	na	2	86		19.25	na	19.25	0.64	na	0.64	544 4 cars per train	364 1 car per train	908
Rail Rapid With Loop	9.625	2.5	9	8	1	92	As required	19.25	2.5	21.75	0.56	0.11	0.67	544	364	908
Distributor	na	2.5	na	8	1	26		na	2.5	2.5	na	0.19	0.19	544	364	908

NOTE:

1. Line-haul track distance = total mileage - station mileage.
2. Stub required in terminals to turn around, therefore, greater than line-haul distance.
3. Operating & maintenance are f (VMT) only.
4. Proportion as surface, elevated, CBD must be defined, as well as density (for costs).
5. CBD components are f(CBD size). These are for a 1 square mile CBD.

Rail rapid transit, as a fixed guideway system, uses tracks and stations to provide the service. The total linear distance to be built is the sum of the line-haul track length and the station length. The stations are 400 feet long. For 10 stations, 0.76 linear miles will be within stations, 8.865 miles will be the line-haul.

The line-haul is split into the inner 5 miles of underground track and the outer 4.5 miles of elevated track.

Terminals are different from stations in that they have turn around facilities for the trains. They must be provided at the ends of each rail rapid line, the outermost point of service, and if no underground CBD loop is provided, at the interface point between the corridor and the CBD distribution system.

Yards and shops are also provided. When RRT serves the line-haul travelers in the corridor, these yards and shops are located at the outermost terminus of the line. They are in fringe areas and are built on the surface. Access is by a spur track from the last passenger boarding point. The size of the facility is determined by the number of cars.

The CBD distributor loop is a one-way, single track facility with eight single-sided, 400-foot stations. Yards and shops are provided as surface facilities built in fringe areas. Minimal access to these facilities is assumed to be included in the construction costs. This probably underestimates the true costs of providing an access spur to a (distant) fringe facility or building the yards and shops in the downtown area nearer the RRT distributor loop.

The vehicle miles of travel per trip of RRT is double the one-way distance. Unlike bus service, RRT service is required to travel the full distance in order to turn around. Each train also stops at each station.

RRT operating and maintenance costs are determined by the car miles of travel.

In summary, the modal combinations presented in Chapter 4 are costed by using the component quantities given in this appendix in conjunction with the unit costs obtained from the companion report "Costing Urban Transportation Alternatives." Those fully integrated modes defined in this research are, thus, costed for comparison in per trip terms. Partially integrated and line-haul only modes must be matched with access and/or egress modes as required to provide door-to-door service. The per trip cost of each mode must be summed with its complementary mode(s) to obtain the comparative per trip cost of the combination. The quantities given here are for a 10-mile radial corridor feeding a 1 square mile CBD, with 100,000 person trips per day. The other corridor lengths, CBD sizes, and trip volumes given in Appendix 3 are costed through the same process.

APPENDIX 2

Comparative Times Derivation

Chapter 4 and Appendix 3 present the travel times required by each of the modes and modal combinations. These travel times are based upon the clock time required for an average traveler to make the door-to-door journey by each mode or modal combination. The values presented in this appendix, as well as in Chapter 4 and Appendix 3, are for a traveler making a morning peak period trip from a residential origin to a CBD destination. The average line-haul distance traveled is approximately half the length of the corridor. The average traveler in a 5-mile corridor travels 4.225 miles, in a 10-mile corridor, 7.225 miles, and in a 15-mile corridor, 10.225 miles. This door-to-door distance is broken down into line-haul, residential access, and CBD egress portions of the trip.

This appendix presents the context, method, and assumptions appropriate to the derivation of the individual time components. The component time values are presented in Tables A2-1 through A2-9. They are divided by modal type (automobile-based, bus-based, or rapid rail-based) and by corridor length (5, 10, or 15 miles). Within each table, the components affected by volume levels are given separate columns to show the different times appropriate to those volumes. Also within each table, the CBD in-vehicle times for the egress modes or portion of the trip are given for a 1 square mile CBD.

The values given in these tables are average times defined to be required by the average traveler to traverse the given distance by the specified mode. No weights have been assigned to the separate components of these total travel times in an attempt to reflect the behavioral perceptions of travel time components.

It is apparent from the tables that certain time components do not change despite corridor length, CBD size, or volume level. These are transfer time and walking time. Transfer time is defined to be 1 minute per transfer, and is required only when a change in vehicle is required by the modal combination being timed. The transfer time is in addition to waiting time and is assigned to the vehicle being boarded throughout the analysis. Walking time is defined as not to exceed 3 blocks at both ends of the trip, with a walking speed of 3 minutes per block postulated. Bus routes and rail rapid transit distributor loops are designed to fit this requirement so that the change in CBD sizes and in corridor zone sizes due to differing geographic characteristics do not affect the walking time component of the door-to-door trip travel time.

The line-haul travel times given in these tables are based upon free flowing traffic. A line-haul average speed of 45 mph is postulated for the auto-based modes. Bus and rail transit times include loading and unloading times and acceleration and deceleration times for intermediate stops. CBD running speeds of approximately 12 mph are assumed for all surface modes. Residential speeds are assumed to be 15 mph for all modes.

Waiting time is defined to be half of the transit mode headway, not to exceed 15 minutes. The waiting time required for a transfer between vehicles is in addition to the transfer time of 1 minute postulated above. Lower volumes require longer waits for both initial boarding and transfers involving transit vehicles because of the greater headways at the lower volumes.

The tables in this appendix are presented without totals for each of the permutations of mode type or combination, corridor length and volume, and CBD size. The total times are those presented in Tables A3-12 through A3-20 in Appendix 3. This appendix is meant as a presentation of the components used to compile these total time values, both as to what the components are and as which values are assigned to each of the appropriate components in a door-to-door trip.

TABLE A2-1

Automobile-Based Mode Component Times

5-mile corridor, 1 square mile CBD, 100,000 trips per day

	Walk	In-vehicle residential	In-vehicle line-haul	In-vehicle CBD	Walk
Single Occupant Auto*	1.0	3.4	3.4	3.7	1.5
Carpool*	1.0	11.4	3.4	3.7	1.5
Park-and-Ride	1.0	3.4	na	na	na
Kiss-and-Ride	1.0	3.4	na	na	na

* For these modes, transfer and waiting times are zero. Walking time is independent of the corridor length and of the CBD size.

TABLE A2-2

Automobile-Based Mode Component Times

10-mile corridor, 1 square mile CBD, 100,000 trips per day

	Walk	In-vehicle residential	In-vehicle line-haul	In-vehicle CBD	Walk
Single Occupant Auto*	1.0	5.4	6.7	3.7	1.5
Carpool*	1.0	13.4	6.7	3.7	1.5
Park-and-Ride	1.0	5.4	na	na	na
Kiss-and-Ride	1.0	5.4	na	na	na

* For these modes, transfer and waiting times are zero. Walking time is independent of the corridor length and of the CBD size.

TABLE A2-3

Automobile-Based Mode Component Times

15-mile corridor, 1 square mile CBD, 100,000 trips per day

	Walk	In-vehicle residential	In-vehicle line-haul	In-vehicle CBD	Walk
Single Occupant Auto*	1.0	7.4	10.0	3.7	1.5
Carpool*	1.0	15.4	10.0	3.7	1.5
Park-and-Ride	1.0	7.4	na	na	na
Kiss-and-Ride	1.0	7.4	na	na	na

* For these modes, transfer and waiting times are zero. Walking time is independent of the corridor length and of the CBD size.

A2-4
Bus-Based Mode Component Times
5-mile corridor, 1 square mile CBD

	Walk	Wait – Daily Corridor Volume 50,000	Wait – Daily Corridor Volume 100,000	Wait – Daily Corridor Volume 200,000	Residential In-vehicle	Transfer to Line-Haul	Wait – Daily Corridor Volume 50,000	Wait – Daily Corridor Volume 100,000	Wait – Daily Corridor Volume 200,000	Line-Haul In-vehicle	Transfer to Egress	Wait	CBD Egress In-vehicle	Walk
Conventional Bus	2.5	15.0	15.0	8.0	5.9	0	0	0	0	6.0	0	0	4.3	3.0
Line-Haul Rapid Bus	na		na		na	1.0	1.0	0.5	0.25	2.7	na	na	na	na
Line-Haul + Surface Distribution Rapid Bus	na		na		na	1.0	4.0	2.0	1.0	2.6	0	0	4.3	3.0
Line-Haul + Surface Collection Rapid Bus	2.5	8.0	4.0	2.0	5.9	0	0	0	0	2.6	na	na	na	na
Line-Haul + Underground Distribution Rapid Bus	na		na		na	1.0	1.0	0.5	0.25	2.6	0	0	3.2	3.0
Fully Integrated Rapid Bus-Surface Collection + Distribution	2.5	15.0	15.0	8.0	5.9	0	0	0	0	2.5	0	0	4.3	3.0
Fully Integrated Rapid Bus-Surface Collection, Underground Distribution	2.5	8.0	4.0	2.0	5.9	0	0	0	0	2.5	0	0	3.2	3.0
Feeder Bus Collection	2.5	8.0	4.0	2.0	6.7	na	na	na	na	na	na	na	na	na
Feeder Bus Distribution	na	na	na	na	na	na	na	na	1.0	0.8	0.4	0.2	6.8	3.0

Table A2-5
Bus-Based Mode Component Times
10-mile corridor, 1 square mile CBD

	Walk	Wait: Daily Corridor Volume 50,000	Wait: Daily Corridor Volume 100,000	Wait: Daily Corridor Volume 200,000	Residential In-vehicle	Transfer to Line-Haul	Wait: Daily Corridor Volume 50,000	Wait: Daily Corridor Volume 100,000	Wait: Daily Corridor Volume 200,000	Line-Haul In-vehicle	Transfer to Egress	Wait	CBD Egress In-vehicle	Walk
Conventional Bus	2.50	15.0	15.0	15.0	8.9	0	0	0	0	11.7	0	0	4.3	3.0
Line-Haul Rapid Bus	na		na		na	1.0	2.0	1.0	0.5	5.2	na	na	na	na
Line-Haul + Surface Distribution Rapid Bus	na		na		na	1.0	8.0	4.0	2.0	5.1	0	0	4.3	3.0
Line-Haul + Surface Collection Rapid Bus	2.50	1.50	8.0	4.0	8.9	0	0	0	0	5.1	na	na	na	na
Line-Haul + Underground Distribution Rapid Bus	na		na		na	1.0	2.0	1.0	0.5	5.1	0	0	3.2	7.20
Fully Integrated Rapid Bus-Surface Collection and Distribution	2.50	15.0	15.0	15.0	8.9	0		0		5.0	0	0	4.3	3.0
Fully Integrated Rapid Bus-Surface Collection, Underground Distribution	2.50	15.0	8.0	4.0	8.9	0		0		5.0	0	0	3.2	7.20
Feeder Bus Collection	2.50	15.0	8.0	4.0	9.7	na	na	na	na	na	na	na	na	na
Feeder Bus Distribution	na		na		na	na	na	na	na	na	1	0.2	6.8	3.0

Table A2-6
Bus-Based Mode Component Times
15-mile corridor, 1 square mile CBD

	Walk Access	Wait			Residential In-vehicle	Transfer to Line-Haul	Wait			Line-Haul In-vehicle	Transfer to Egress	Wait	CBD Egress In-vehicle	Walk
		Daily Corridor Volume					Daily Corridor Volume							
		50,000	100,000	200,000			50,000	100,000	200,000					
Conventional Bus	2.5	15.0	15.0	15.0	11.9	0	0	0	0	7.4	0	0	4.3	3.0
Line-Haul Rapid Bus	na		na		na	1.0	3.0	1.5	0.75	7.7	na	na	na	na
Line-Haul + Surface Distribution Rapid Bus	na		na		na	1.0	12.0	6.0	3.0	7.6	0	0	4.3	3.0
Line-Haul + Surface Collection Rapid Bus	2.5	15.0	12.0	6.0	11.9	0	0	0	0	7.6	na	na	na	na
Line-Haul + Underground Distribution Rapid Bus	na		na		na	1.0	3.0	1.5	0.75	7.6	0	0	3.2	3.0
Fully Integrated Rapid Bus-Surface Collection + Distribution	2.5	15.0	15.0	15.0	11.9	0	0	0	0	7.5	0	0	4.3	3.0
Fully Integrated Rapid Bus-Surface Collection + Underground Distribution	2.5	15.0	15.0	6.0	11.9	0	0	0	0	7.5	0	0	3.2	3.0
Feeder Bus Collection	2.5	15.0	12.0	6.0	12.7	na	na	na	na	na	na	na	na	na
Feeder Bus Distribution	na		na		na	na	na	na	1.0	0.8	0.4	0.2	6.8	3.0

Table A2-7
Rail Rapid Transit Component Times
5-mile corridor, 1 square mile CBD

	Transfer to Line-Haul	Wait: Daily Corridor Volume			Line-Haul In-vehicle	Transfer to Egress	Wait: Daily Corridor Volume			CBD Egress In-vehicle	Walk
		50,000	100,000	200,000			50,000	100,000	200,000		
Rail Rapid Line-Haul	1.0	0.9	0.9	0.9	4.1	na		na		na	na
Rail Rapid with CBD Loop	1.0	0.9	0.9	0.9	4.1	0		0		3.2	7.2
RRT Distributor Loop	na	na	na	na	na	1.0	0.9	0.9	0.9	3.3	7.2

Table A2-8
Rail Rapid Transit Component Times
10-mile corridor, 1 square mile CBD

	Transfer to Line-Haul	Wait: Daily Corridor Volume 50,000	Wait: Daily Corridor Volume 100,000	Wait: Daily Corridor Volume 200,000	Line-Haul In-vehicle	Transfer to Egress Mode	Wait	CBD Egress In-vehicle	Walk
Rail Rapid Line-Haul	1.0	0.9	0.9	0.9	8.7	na	na	na	na
Rail Rapid with CBD Loop	1.0	0.9	0.9	0.9	8.7	0	0	3.2	7.2
Distributor Loop (RRT)	na	na	na	na	na	1.0	0.9	3.3	7.2

Table A2-9
Rail Rapid Transit Component Times
15-mile corridor, 1 square mile CBD

	Transfer to Line-Haul	Wait (Daily Corridor Volume) 50,000	100,000	200,000	Line-Haul In-vehicle	Transfer to Egress	Wait (Daily Corridor Volume) 50,000	100,000	200,000	CBD Egress In-vehicle	Walk
RRT Line-Haul	1.0	0.9	0.9	0.9	13.1	na		na		na	na
RRT with CBD Loop	1.0	0.9	0.9	0.9	13.1	0		0		3.2	7.2
RRT Distributor Loop	na	na	na	na	na	1.0	0.9	0.9	0.9	3.3	7.2

APPENDIX 3

Specific Values for Comparative Money and Time Costs

This appendix augments and supports the comparative money and time costs presented graphically in Chapter 4. In this appendix, the per trip costs (both money and time) of travel by all mode combinations (Table A3-1) are defined for 5-, 10-, and 15-mile radial corridors serving 1-, 2-, and 4-square mile CBD's. The average one-way distances traveled by persons in the varying corridor lengths and CBD sizes are given in Table A3-2. The CBD underground loop, needed by rail rapid transit and by rapid busway with underground distribution, follows the configurations of Figure A3-1. This conforms to the requirement that no point in the CBD be more than 3 blocks from a station. The loop is a single line, with one-sided stations.

The per trip money and time costs are a function of the distance traveled, as well as of the corridor volumes. Time and money costs are determined for all 25 modal combinations for corridor volumes of 50,000, 100,000, and 200,000 person trips daily. The values for money costs are presented in Tables A3-3 to A3-11, grouped by corridor length. The time cost values are given in Tables A3-12 through A3-20, also grouped by corridor length.

This appendix also incudes the tables that support Figures 4-8 to 4-10, which present, graphically, the components that comprise each comparative money cost for a 10-mile corridor serving a 1 square mile CBD. The daily trip volumes are 50,000, 100,000, and 200,000 person trips. These components are defined for the seven more common modes in Tables A3-23 to A3-25.

Further, this appendix contains the tables that show the approximations of construction cost fluctuations on the per trip money costs. These approximations are calculated for a 10-mile corridor, 1 square mile CBD, and 100,000 person trips daily. ~~The seven modes~~ chosen to show the impact of these construction cost fluctuations are the more common ones. Tables A3-26 to A3-28 support Figures 4-11 to 4-13.

Corridors with volumes ranging upwards from 200,000 to 400,000 person trips daily may exist. For the user faced with such situations, the following sensitivities of money and time costs to increased corridor densities are presented. The context is the same, i.e., a 10-mile corridor with a 1 square mile CBD. The modes for which values are derived are confined to the seven more common choices-single occupant automobile, carpool, conventional bus, integrated rapid bus with surface collection and distribution, integrated rapid bus with surface collection and underground distribution, and rapid rail with an underground distributor loop, and either park-and-ride or feeder bus access. For these seven modes, money and time costs per person trip at the greater volume levels are presented in Tables A3-21 and A3-22.

Table A3-1

Possible Modal Combinations

	Access	Line-Haul	Egress
** 1.		Single Occupant Automobile	
** 2.		Carpool (4 members)	
** 3.		Conventional Bus on Arterial Streets	
** 4.		Fully Integrated Rapid Bus on Exclusive Busway, Surface Distribution	
** 5.		Fully Integrated Rapid Bus on Exclusive Busway, Underground Distribution	
6.	Park-and-Ride	Partially Integrated Rapid Bus with Surface Distribution	
7.	Kiss-and-Ride	Partially Integrated Rapid Bus with Surface Distribution	
8.	Feeder Bus	Partially Integrated Rapid Bus with Surface Distribution	
* 9.	Park-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
* 10.	Kiss-and-Ride	Partially Integrated Rapid Bus with Underground Distribution	
* 11.	Feeder Bus	Partially Integrated Rapid Bus with Underground Distribution	
12.	Park-and-Ride	Line Haul Rapid Bus	Rapid Rail Loop
13.	Kiss-and-Ride	Line Haul Rapid Bus	Rapid Rail Loop
14.	Feeder Bus	Line Haul Rapid Bus	Rapid Rail Loop
15.	Park-and-Ride	Line Haul Rapid Bus	Feeder Bus
16.	Kiss-and-Ride	Line Haul Rapid Bus	Feeder Bus
17.	Feeder Bus	Line Haul Rapid Bus	Feeder Bus
18.	Partially Integrated Rapid Bus with Surface Collection		Feeder Bus
* 19.	Partially Integrated Rapid Bus with Surface Collection		Rapid Rail Loop
**20.	Park-and-Ride	Rail Rapid Transit Line Haul and Underground Distribution Loop	
21.	Kiss-and-Ride	Rail Rapid Transit Line Haul and Underground Distribution Loop	
**22.	Feeder Bus	Rail Rapid Transit Line Haul and Underground Distribution Loop	
23.	Park-and-Ride	Rail Rapid Transit Line Haul	Feeder Bus
24.	Kiss-and-Ride	Rail Rapid Transit Line Haul	Feeder Bus
25.	Feeder Bus	Rail Rapid Transit Line Haul	Feeder Bus

** Designates subset of 7 usual modes and 12 major modes

* Designates subset of 12 major modes only

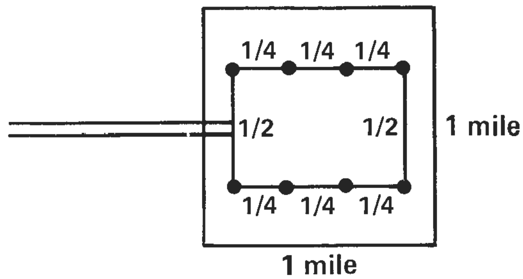
Table A3-2

Average One-Way Traveler Distances
(by trip portion)

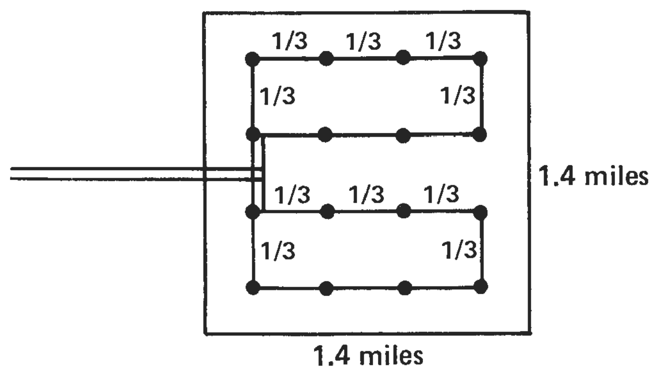
Corridor length (miles)-CBD Size (mi)	5-1	5-2	5-4	10-1	10-2	10-4	15-1	15-2	15-4
Access (residential)	0.85	0.85	0.85	1.35	1.35	1.35	1.85	1.85	1.85
Line-Haul	2.625	2.625	2.625	5.125	5.125	5.125	7.625	7.725	7.625
Surface Egress (bus, auto)	0.75	1.05	1.50	0.75	1.05	1.50	0.75	1.05	1.50
Underground Egress (rail rapid transit, bus)	1.25	1.35	2.30	1.25	1.35	2.30	1.25	1.35	2.30
Total Distance Traveled in Miles:									
Auto and Surface Bus	4.225	4.525	4.975	7.225	7.525	7.975	10.225	10.525	10.975
Underground Bus and Rail Rapid Transit	4.725	4.825	5.775	7.725	7.825	8.775	10.725	10.825	11.775

Figure A3-1

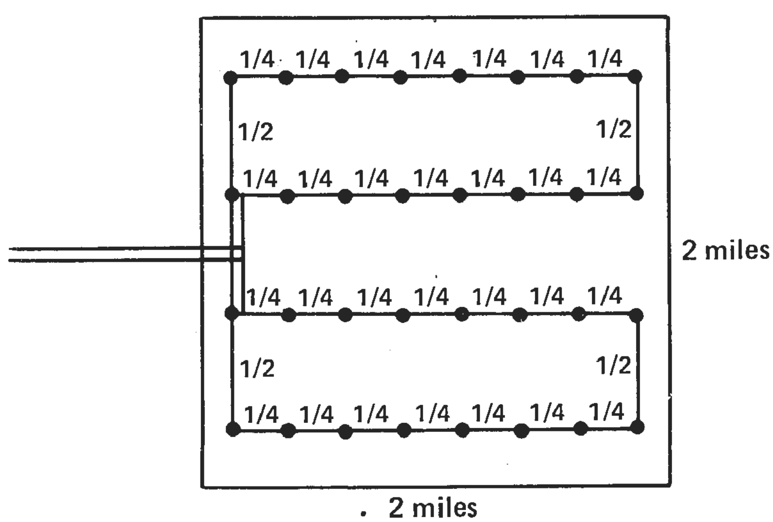
CBD Distribution Loop (RRT and Busway)



CBD: 1 square mile
8 stations
2.5 miles of single width roadbed



CBD: 2 square miles
16 stations
6 miles of single width roadbed



CBD: 4 square miles
32 stations
10 miles of single width roadbed

Table A3-3

Money Cost per Person Trip
5 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume		
		50,000	100,000	200,000
1.	Single Occupant Automobile	$2.34	$2.28	$2.26
2.	Carpool (4 members)	0.74	0.69	0.66
3.	Conventional Bus	0.34	0.34	0.34
4.	Fully Integrated Rapid Bus with Surface Distribution	2.63	1.47	0.89
5.	Fully Integrated Rapid Bus with Underground Distribution	3.67	2.00	1.17
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	3.70	2.54	1.96
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	2.77	1.60	1.02
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	2.65	1.49	0.91
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	4.74	3.07	2.24
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	3.80	2.13	1.30
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	3.69	2.02	1.19
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	4.47	2.91	2.15
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	3.53	1.98	1.22
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	3.42	1.87	1.11
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	3.75	2.58	2.00
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	2.81	1.64	1.06
17.	Line Haul Busway, Feeder Bus Distribution and Access	2.70	1.53	0.95
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	2.68	1.51	0.93
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	3.40	1.85	1.09
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	4.36	2.94	2.24
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	3.43	2.01	1.31
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	3.32	1.90	1.20
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	3.80	2.70	2.14
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	2.87	1.76	1.20
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	2.75	1.65	1.09

Table A3-4

Money Cost per Person Trip
5 mile corridor, 2 square mile CBD

MODE	Daily Corridor Volume 50,000	100,000	200,000
1. Single Occupant Automobile	$2.38	$2.33	$2.30
2. Carpool (4 members)	0.76	0.70	0.67
3. Conventional Bus	0.38	0.38	0.38
4. Fully Integrated Rapid Bus with Surface Distribution	2.66	1.51	0.93
5. Fully Integrated Rapid Bus with Underground Distribution	4.95	2.70	1.53
6. Partially Integrated Rapid Bus with Surface Distribution, PAR Access	3.73	2.57	1.99
7. Partially Integrated Rapid Bus with Surface Distribution, KAR Access	2.80	1.63	1.05
8. Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	2.67	1.52	0.94
9. Partially Integrated Rapid Bus with Underground Distribution, PAR Access	6.02	3.76	2.59
10. Partially Integrated Rapid Bus with Underground Distribution, KAR Access	5.08	2.83	1.66
11. Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	4.97	2.72	1.54
12. Line Haul Busway, Rapid Rail Loop, PAR Access	5.55	3.49	2.44
13. Line Haul Busway, Rapid Rail Loop, KAR Access	4.61	2.56	1.51
14. Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	4.50	2.44	1.40
15. Line Haul Busway, Feeder Bus Distribution, PAR Access	3.78	2.61	2.03
16. Line Haul Busway, Feeder Bus Distribution, KAR Access	2.85	1.68	1.10
17. Line Haul Busway, Feeder Bus Distribution and Access	2.74	1.57	0.98
18. Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	2.71	1.55	0.96
19. Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	4.48	2.42	1.38
20. Rail Rapid Line Haul and Underground Loop, PAR Access	5.45	3.52	2.54
21. Rail Rapid Line Haul and Underground Loop, KAR Access	4.51	2.58	1.60
22. Rail Rapid Line Haul and Underground Loop, Feeder Access	4.40	2.47	1.49
23. Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	3.83	2.73	2.17
24. Rapid Rail Line, Surface Bus Distribution, KAR Access	2.90	1.80	1.24
25. Rapid Rail Line Haul, Surface Bus Distribution and Collection	2.79	1.69	1.13

Table A3-5

Money Cost per Person Trip
5 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume		
		50,000	100,000	200,000
1.	Single Occupant Automobile	$2.44	$2.39	$2.36
2.	Carpool (4 members)	0.77	0.71	0.69
3.	Conventional Bus	0.42	0.42	0.42
4.	Fully Integrated Rapid Bus with Surface Distribution	2.72	1.56	0.98
5.	Fully Integrated Rapid Bus with Underground Distribution	6.65	3.48	1.99
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	3.79	2.62	2.04
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	2.85	1.69	1.11
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	2.74	1.58	0.99
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	7.72	4.55	3.05
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	6.79	3.62	2.12
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	6.67	3.50	2.00
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	6.86	4.16	2.85
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	5.93	3.22	1.91
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	5.82	3.11	1.80
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	3.83	2.66	2.08
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	2.89	1.72	1.14
17.	Line Haul Busway, Feeder Bus Distribution and Access	2.78	1.61	1.03
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	2.76	1.59	1.01
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	5.79	3.09	1.78
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	6.76	4.18	2.94
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	5.82	3.25	2.00
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	5.71	3.14	1.89
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	3.88	2.78	2.22
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	2.94	1.84	1.28
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	2.83	1.73	1.17

Table A3-6

Money Cost per Person Trip
10 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$2.92	$2.79	$2.73
2.	Carpool (4 members)	0.99	0.87	0.80
3.	Conventional Bus	0.50	0.50	0.50
4.	Fully Integrated Rapid Bus with Surface Distribution	3.05	1.75	1.10
5.	Fully Integrated Rapid Bus with Underground Distribution	4.09	2.28	1.38
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.13	2.82	2.17
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	3.26	1.95	1.30
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.08	1.77	1.12
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	5.17	3.35	2.45
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	4.30	2.48	1.58
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	4.12	2.30	1.40
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	4.90	3.20	2.36
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	4.03	2.33	1.49
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	3.85	2.15	1.31
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.18	2.87	2.21
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.31	2.00	1.34
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.13	1.82	1.16
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.10	1.79	1.14
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	3.81	2.12	1.29
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	4.98	3.42	2.64
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	4.11	2.55	1.77
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	3.92	2.37	1.59
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	4.41	3.17	2.54
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	3.54	2.30	1.67
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.36	2.12	1.49

Table A3-7

Money Cost per Person Trip
10 mile corridor, 2 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$2.96	$2.84	$2.77
2.	Carpool (4 members)	1.00	0.88	0.81
3.	Conventional Bus	0.53	0.53	0.53
4.	Fully Integrated Rapid Bus with Surface Distribution	3.08	1.78	1.13
5.	Fully Integrated Rapid Bus with Underground Distribution	5.37	2.96	1.73
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.17	2.86	2.20
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	3.30	1.99	1.33
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.12	1.81	1.15
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	6.45	4.05	2.81
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	5.58	3.18	1.94
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	5.40	3.00	1.76
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	5.98	3.78	2.66
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	5.11	2.91	1.79
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	4.93	2.73	1.61
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.21	2.90	2.24
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.34	2.03	1.37
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.16	1.85	1.19
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.13	1.82	1.17
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	4.90	2.70	1.58
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	6.06	3.99	2.93
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	5.19	3.12	2.06
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	5.01	2.94	1.88
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	4.44	3.21	2.57
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	3.57	2.34	1.70
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.39	2.16	1.52

Table A3-8

Money Cost per Person Trip
10 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$3.02	$2.90	$2.83
2.	Carpool (4 members)	1.02	0.90	0.83
3.	Conventional Bus	0.58	0.58	0.58
4.	Fully Integrated Rapid Bus with Surface Distribution	3.13	1.83	1.18
5.	Fully Integrated Rapid Bus with Underground Distribution	7.07	3.76	2.19
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.22	2.91	2.26
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	3.35	2.04	1.39
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.17	1.86	1.21
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	8.15	4.84	3.26
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	7.28	3.97	2.39
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	7.10	3.78	2.21
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	7.29	4.44	3.06
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	6.42	3.57	2.19
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	6.24	3.39	2.01
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.26	2.94	2.29
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.39	2.07	1.42
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.21	1.89	1.24
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.17	1.87	1.22
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	6.21	3.36	1.99
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	7.37	4.66	3.34
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	6.50	3.79	2.47
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	6.32	3.61	2.29
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	4.49	3.25	2.62
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	3.62	2.38	1.75
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.44	2.20	1.57

Table A3-9

Money Cost per Person Trip
15 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$3.48	$3.30	$3.19
2.	Carpool (4 members)	1.24	0.99	0.95
3.	Conventional Bus	0.68	0.68	0.68
4.	Fully Integrated Rapid Bus with Surface Distribution	3.51	2.05	1.32
5.	Fully Integrated Rapid Bus with Underground Distribution	4.54	2.58	1.60
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.41	2.95	2.22
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	3.79	2.32	1.59
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.54	2.08	1.34
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	5.45	3.48	2.50
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	4.83	2.85	1.87
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	4.58	2.61	1.62
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	5.18	3.33	2.41
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	4.55	2.70	1.78
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	4.31	2.45	1.54
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.46	2.99	2.56
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.83	2.36	1.63
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.59	2.12	1.38
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.55	2.09	1.36
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	4.27	2.43	1.52
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	5.31	3.66	2.84
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	4.69	3.04	2.21
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	4.44	2.79	1.97
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	4.75	3.42	2.73
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	4.12	2.79	2.11
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.88	2.55	1.86

Table A3-10

Money Cost per Person Trip
15 mile corridor, 2 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$3.52	$3.34	$3.23
2.	Carpool (4 members)	1.25	1.00	0.96
3.	Conventional Bus	0.71	0.71	0.71
4.	Fully Integrated Rapid Bus with Surface Distribution	3.54	2.09	1.36
5.	Fully Integrated Rapid Bus with Underground Distribution	5.81	2.28	1.96
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.63	3.16	2.43
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	2.82	2.36	1.62
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.57	2.11	1.38
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	6.91	4.35	3.03
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	6.11	3.55	2.23
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	5.86	3.30	1.98
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	6.44	4.08	2.85
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	5.64	3.27	2.05
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	5.39	3.03	1.80
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.67	3.20	2.47
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.87	2.40	1.66
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.62	2.15	1.42
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.59	2.13	1.40
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	5.36	3.00	1.81
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	6.57	4.42	3.31
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	5.77	3.61	2.50
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	5.52	3.11	2.26
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	4.96	3.63	2.95
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	4.15	2.83	2.14
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.91	2.58	1.89

Table A3-11

Money Cost per Person Trip
15 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	$3.58	$3.40	$3.29
2.	Carpool (4 members)	1.27	1.02	0.97
3.	Conventional Bus	0.76	0.76	0.76
4.	Fully Integrated Rapid Bus with Surface Distribution	3.59	2.14	1.41
5.	Fully Integrated Rapid Bus with Underground Distribution	7.53	4.06	2.42
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	4.68	3.21	2.48
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	3.87	2.41	1.68
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	3.63	2.17	1.43
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	8.61	5.14	3.49
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	7.81	4.34	2.69
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	7.56	4.09	2.44
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	7.75	4.74	3.28
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	6.95	3.94	2.48
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	6.70	3.69	2.23
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	4.72	3.25	2.51
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	3.91	2.44	1.71
17.	Line Haul Busway, Feeder Bus Distribution and Access	3.67	2.20	1.46
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	3.63	2.17	1.44
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	6.67	3.67	2.21
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	7.88	5.08	3.71
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	7.08	4.28	2.91
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	6.83	4.03	2.66
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	5.00	3.68	2.99
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	4.20	2.87	2.19
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	3.95	2.62	1.94

Table A3-12

Travel Time per Person Trip
5 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	13.7	13.7	13.7
2.	Carpool (4 members)	21.2	21.2	21.2
3.	Conventional Bus	36.5	36.5	29.5
4.	Fully Integrated Rapid Bus with Surface Distribution	33.2	33.2	26.2
5.	Fully Integrated Rapid Bus with Underground Distribution	29.4	25.4	23.4
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	19.2	17.2	16.2
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	19.2	17.2	16.2
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	32.0	26.0	23.0
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	19.4	18.9	18.6
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	19.4	18.9	18.6
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	32.2	27.7	25.4
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	21.6	20.9	20.6
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	21.6	20.9	20.6
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	34.4	29.7	27.4
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	20.9	19.8	19.8
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	20.9	19.8	19.8
17.	Line Haul Busway, Feeder Bus Distribution and Access	33.7	28.6	26.1
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	30.9	26.3	24.0
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	31.3	27.3	25.3
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	20.9	20.9	20.9
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	20.9	20.9	20.9
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	33.7	29.7	27.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	22.2	21.7	21.5
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	22.2	21.7	21.5
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	35.0	30.5	28.3

Table A3-13

Travel Time per Person Trip
5 mile corridor, 2 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	15.2	15.2	15.2
2.	Carpool (4 members)	22.7	22.7	22.7
3.	Conventional Bus	38.5	38.5	35.5
4.	Fully Integrated Rapid Bus with Surface Distribution	35.2	35.2	32.2
5.	Fully Integrated Rapid Bus with Underground Distribution	36.8	29.8	25.8
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	23.2	20.2	18.7
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	23.2	20.2	18.7
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	36.0	29.0	25.5
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	20.8	19.8	19.3
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	20.8	19.8	19.3
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	33.6	28.6	26.1
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	22.5	22.0	21.8
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	22.5	22.0	21.8
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	35.3	30.8	28.6
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	22.9	21.8	21.3
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	22.9	21.8	21.3
17.	Line Haul Busway, Feeder Bus Distribution and Access	35.7	30.6	28.1
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	32.9	28.3	26.0
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	32.6	28.6	26.6
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	22.2	22.2	22.2
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	22.2	22.2	22.2
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	35.0	28.2	26.2
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	24.0	23.5	23.3
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	24.0	23.5	23.3
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	36.8	32.3	30.1

Table A3-14

Travel Time per Person Trip
5 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	17.4	17.4	17.4
2.	Carpool (4 members)	24.9	24.9	24.9
3.	Conventional Bus	40.8	40.8	40.8
4.	Fully Integrated Rapid Bus with Surface Distribution	37.5	37.5	37.5
5.	Fully Integrated Rapid Bus with Underground Distribution	39.0	32.0	28.0
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	28.5	23.5	21.5
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	28.5	23.5	21.5
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	40.3	32.3	28.3
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	23.0	22.0	21.5
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	23.0	22.0	21.5
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	35.8	30.8	28.3
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	24.3	24.0	23.9
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	24.3	24.0	23.9
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	37.1	32.8	30.7
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	25.2	24.1	23.6
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	25.2	24.1	23.6
17.	Line Haul Busway, Feeder Bus Distribution and Access	38.0	32.9	30.4
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	35.2	30.6	28.3
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	34.8	30.8	28.8
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	23.9	23.9	23.9
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	23.9	23.9	23.9
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	36.7	32.7	30.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	26.8	26.3	26.1
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	26.8	26.3	26.1
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	39.6	35.1	32.9

Table A3-15

Travel Time per Person Trip
10 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	18.3	18.3	18.3
2.	Carpool (4 members)	26.2	26.2	26.2
3.	Conventional Bus	45.4	45.4	45.4
4.	Fully Integrated Rapid Bus with Surface Distribution	38.7	38.7	38.7
5.	Fully Integrated Rapid Bus with Underground Distribution	41.9	34.9	30.9
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	27.7	23.7	21.7
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	27.7	23.7	21.7
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	48.5	37.5	31.5
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	24.9	23.9	23.4
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	24.9	23.9	23.4
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	45.7	37.7	33.2
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	27.1	25.9	25.3
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	27.1	25.9	25.3
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	47.9	39.7	35.1
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	26.4	24.8	24.0
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	26.4	24.8	24.0
17.	Line Haul Busway, Feeder Bus Distribution and Access	47.2	38.6	33.8
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	43.4	35.8	31.5
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	43.8	36.8	32.8
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	27.4	27.4	27.4
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	27.4	27.4	27.4
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	48.2	41.2	37.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	28.7	28.2	28.0
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	28.7	28.2	28.0
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	49.5	42.0	37.8

Table A3-16

Travel Time per Person Trip
10 mile corridor, 2 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	19.8	19.8	19.8
2.	Carpool (4 members)	27.7	27.7	27.7
3.	Conventional Bus	47.4	47.4	47.4
4.	Fully Integrated Rapid Bus with Surface Distribution	40.7	40.7	40.7
5.	Fully Integrated Rapid Bus with Underground Distribution	42.3	42.3	35.3
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	33.7	27.7	24.7
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	33.7	27.7	24.7
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	54.5	41.5	34.5
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	27.3	25.3	24.3
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	27.3	25.3	24.3
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	48.1	39.1	34.1
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	28.0	27.0	26.5
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	28.0	27.0	26.5
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	48.8	40.9	36.3
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	28.4	26.8	26.0
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	28.4	26.8	26.0
17.	Line Haul Busway, Feeder Bus Distribution and Access	49.2	40.7	35.8
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	45.4	37.8	33.5
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	45.1	38.1	34.1
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	29.7	29.7	29.7
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	29.7	29.7	29.7
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	49.5	42.5	39.5
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	30.5	30.0	29.8
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	30.5	30.0	29.8
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	51.3	43.8	39.6

Table A3-17

Travel Time per Person Trip

10 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	22.0	22.0	22.0
2.	Carpool (4 members)	29.9	29.9	29.9
3.	Conventional Bus	52.7	52.7	52.7
4.	Fully Integrated Rapid Bus with Surface Distribution	46.0	46.0	46.0
5.	Fully Integrated Rapid Bus with Underground Distribution	44.5	44.5	37.5
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	41.0	34.0	30.0
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	41.0	34.0	30.0
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	61.8	47.8	39.8
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	29.5	27.5	26.5
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	29.5	27.5	26.5
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	50.3	41.3	36.3
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	29.8	29.0	28.6
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	29.8	29.0	28.6
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	50.6	42.9	38.4
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	30.7	29.1	28.3
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	30.7	29.1	28.3
17.	Line Haul Busway, Feeder Bus Distribution and Access	51.5	43.0	38.1
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	47.7	40.1	35.8
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	47.3	40.3	36.3
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	30.4	30.4	30.4
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	30.4	30.4	30.4
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	51.2	44.2	40.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	33.3	32.8	32.6
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	33.3	33.8	32.6
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	54.1	46.6	42.4

Table A3-18
Travel Time per Person Trip
15 mile corridor, 1 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	23.6	23.6	23.6
2.	Carpool (4 members)	32.3	32.3	32.3
3.	Conventional Bus	54.2	54.2	54.2
4.	Fully Integrated Rapid Bus with Surface Distribution	44.2	44.2	44.2
5.	Fully Integrated Rapid Bus with Underground Distribution	47.4	44.4	38.4
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	36.2	30.2	27.2
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	36.2	30.2	27.2
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	58.0	49.0	40.0
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	30.4	28.9	28.1
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	30.4	28.9	28.1
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	52.2	47.7	40.2
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	32.6	31.0	30.2
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	32.6	31.0	30.2
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	54.4	49.8	43.0
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	31.9	29.9	28.9
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	31.9	29.9	28.9
17.	Line Haul Busway, Feeder Bus Distribution and Access	53.7	48.7	41.7
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	48.9	44.8	38.6
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	49.3	46.3	40.3
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	31.9	31.9	31.9
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	31.9	31.9	31.9
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	53.7	50.7	44.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	33.2	32.7	32.5
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	33.2	32.7	32.5
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	55.0	51.5	45.3

Table A3-19

Travel Time per Person Trip
15 mile corridor, 2 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	25.1	25.1	25.1
2.	Carpool (4 members)	32.8	32.8	32.8
3.	Conventional Bus	56.2	56.2	56.2
4.	Fully Integrated Rapid Bus with Surface Distribution	46.2	46.2	46.2
5.	Fully Integrated Rapid Bus with Underground Distribution	47.8	47.8	44.8
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	42.2	35.2	30.7
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	42.2	35.2	30.7
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	63.0	54.0	43.5
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	33.8	30.8	29.3
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	33.8	30.8	29.3
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	55.6	49.6	42.1
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	33.4	32.0	31.3
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	33.4	32.0	31.3
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	57.6	50.8	44.1
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	33.8	31.8	30.8
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	33.8	31.8	30.8
17.	Line Haul Busway, Feeder Bus Distribution and Access	55.6	50.6	43.6
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	50.9	46.9	40.6
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	50.6	47.6	41.6
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	33.2	33.2	33.2
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	33.2	33.2	33.2
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	55.0	52.0	46.0
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	35.0	34.5	34.3
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	35.0	34.5	34.3
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	56.8	53.3	47.1

Table A3-20
Travel Time per Person Trip
15 mile corridor, 4 square mile CBD

	MODE	Daily Corridor Volume 50,000	100,000	200,000
1.	Single Occupant Automobile	27.3	27.3	27.3
2.	Carpool (4 members)	35.0	35.0	35.0
3.	Conventional Bus	58.5	58.5	58.5
4.	Fully Integrated Rapid Bus with Surface Distribution	48.5	48.5	48.5
5.	Fully Integrated Rapid Bus with Underground Distribution	50.0	50.0	47.0
6.	Partially Integrated Rapid Bus with Surface Distribution, PAR Access	43.5	40.5	34.5
7.	Partially Integrated Rapid Bus with Surface Distribution, KAR Access	43.5	40.5	34.5
8.	Partially Integrated Rapid Bus with Surface Distribution, Feeder Bus Access	65.3	59.3	47.3
9.	Partially Integrated Rapid Bus with Underground Distribution, PAR Access	36.0	33.0	31.5
10.	Partially Integrated Rapid Bus with Underground Distribution, KAR Access	36.0	33.0	31.5
11.	Partially Integrated Rapid Bus with Underground Distribution, Feeder Bus Access	57.8	51.8	44.3
12.	Line Haul Busway, Rapid Rail Loop, PAR Access	35.3	34.1	33.5
13.	Line Haul Busway, Rapid Rail Loop, KAR Access	35.3	34.1	33.5
14.	Line Haul Busway, Rapid Rail Loop, Feeder Bus Access	57.1	52.9	46.3
15.	Line Haul Busway, Feeder Bus Distribution, PAR Access	36.2	34.2	33.2
16.	Line Haul Busway, Feeder Bus Distribution, KAR Access	36.2	34.2	33.2
17.	Line Haul Busway, Feeder Bus Distribution and Access	58.0	53.0	46.0
18.	Partially Integrated Rapid Bus with Surface Collection, Feeder Bus Distribution	53.2	49.2	42.9
19.	Partially Integrated Rapid Bus with Surface Collection, Rapid Rail Loop Distribution	52.8	49.8	43.8
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	34.9	34.9	34.9
21.	Rail Rapid Line Haul and Underground Loop, KAR Access	34.9	34.9	34.9
22.	Rail Rapid Line Haul and Underground Loop, Feeder Access	56.7	53.7	47.7
23.	Rail Rapid Line Haul, Surface Feeder Distribtion, PAR Access	37.8	37.3	37.1
24.	Rapid Rail Line, Surface Bus Distribution, KAR Access	37.8	37.3	37.1
25.	Rapid Rail Line Haul, Surface Bus Distribution and Collection	59.6	56.0	49.9

TABLE A3-21

Travel Cost per Person Trip
10-mile corridor, 1 square mile CBD

Mode	Daily Corridor Volume 200,000	300,000	400,000
1. Single Occupant Automobile	$2.73	$2.72	$2.71
2. Carpool (4 members)	0.80	0.76	0.75
3. Conventional Bus	0.50	0.50	0.50
4. Fully Integrated Rapid Bus with Surface Distribution	1.10	0.88	0.78
5. Fully Integrated Rapid Bus with Underground Distribution	1.38	1.08	0.93
20. Rail Rapid Line-Haul and Underground Loop, PAR Access	2.64	2.37	2.38*
22. Rail Rapid Line-Haul and Underground Loop, Feeder Access	1.59	1.32	1.33*

* At this volume level, the number of trains required to meet the demands of travelers exceeds the capacity of the usual number of tracks. For CBD distribution purposes, two tracks are required, as opposed to one for all smaller volumes.

TABLE A3-22

Travel Time per Person Trip
10-mile corridor, 1 square mile CBD

	Mode	Daily Corridor Volume 200,000	300,000	400,000
1.	Single Occupant Automobile	18.3	18.3	18.3
2.	Carpool (4 members)	26.2	26.2	26.2
3.	Conventional Bus	45.4	41.0	39.6
4.	Fully Integrated Rapid Bus with Surface Distribution	38.7	34.3	32.9
5.	Fully Integrated Rapid Bus with Underground Distribution	30.9	29.6	28.9
20.	Rail Rapid Line Haul and Underground Loop, PAR Access	27.4	27.4	27.4
22.	Rail Rapid Line-Haul and Underground Loop, Feeder Access	37.7	36.2	35.2

Table A3-23
Component Money Costs per Trip
50,000 person trips per day

	COMPONENTS	Guideway Roadway Busway		CBD Parking		Stations & Fringe Parking		Ownership		Vehicles & Yards		Driver or Train Crew		Maintenance & Operation		Other Operating		TOTALS	
	MODE			$	%	$	%	$	%	$	%	$	%	$	%	$	%	$	%
1.	Single Occupant Automobile	$0.56	19%	$1.03	35%	na	na	$0.60	21%	na	na	na	na	$0.73	25%	na	na	$2.92	100%
2.	Carpool (4 members)	$0.34	35%	$0.26	26%	na	na	$0.16	16%	na	na	na	na	$0.23	23%	na	na	$0.99	100%
3.	Conventional Bus	$0.00	0%	na	na	na	na	na	na	$0.12	25%	$0.19	37.5%	na	na	$0.19	37.5%	$0.50	100%
5.	Fully Integrated Busway with Underground Distribution	$3.52	86%	na	na	$0.17	4%	na	na	$0.09	2%	$0.12	3%	na	na	$0.18	5%	$4.08	100%
4.	Fully Integrated Busway with Surface Distribution	$2.60	85%	na	na	$0.00	0%	na	na	$0.11	4%	$0.15	5%	na	na	$0.19	6%	$3.05	100%
20.	Rail Rapid Transit with Underground Loop, PAR Access	$2.88	58%	na	na	$0.75	15%	na	na	$0.76	15%	$0.07	2%	na	na	$0.52	10%	$4.98	100%
22.	Rail Rapid Transit with Underground Loop, Feeder Bus Access	$2.88	73%	na	na	$0.29	8%	na	na	$0.21	5%	$0.15	4%	na	na	$0.40	10%	$3.93	100%

10-mile radial corridor
1 square mile CBD
60% peak, 40% off-peak

Table A3-24
Component Money Costs per Trip
100,000 person trips per day

MODE / COMPONENTS	Guideway, Roadway, Busway $	Guideway, Roadway, Busway %	CBD Parking $	CBD Parking %	Stations & Fringe Parking $	Stations & Fringe Parking %	Ownership $	Ownership %	Vehicles & Yards $	Vehicles & Yards %	Driver or Train Crew $	Driver or Train Crew %	Maintenance & Operation $	Maintenance & Operation %	Other Operating $	Other Operating %	TOTALS $	TOTALS %
1. Single Occupant Automobile	$0.43	15%	$1.03	37%	na	na	$0.60	22%	na	na	na	na	$0.73	26%	na	na	$2.79	100%
2. Carpool (4 members)	$0.22	25%	$0.26	30%	na	na	$0.16	18%	na	na	na	na	$0.23	27%	na	na	$0.87	100%
3. Conventional Bus	$0.00	0%	na	na	$0.00	0%	na	na	$0.12	25%	$0.19	37.5%	na	na	$0.19	37.5%	$0.50	100%
5. Fully Integrated Busway, Underground Distribution	$1.76	77%	na	na	$0.13	6%	na	na	$0.09	4%	$0.12	5%	na	na	$0.18	8%	$2.28	100%
4. Fully Integrated Busway, Surface Distribution	$1.30	74%	na	na	$0.00	0%	na	na	$0.11	6%	$0.15	9%	na	na	$0.19	11%	$1.75	100%
20. Rail Rapid Transit Underground Loop, PAR Access	$1.33	39%	na	na	$0.74	22%	na	na	$0.76	22%	$0.07	2%	na	na	$0.52	15%	$3.42	100%
22. Rail Rapid Transit Underground Loop, Feeder Bus Access	$1.33	56%	na	na	$0.28	12%	na	na	$0.21	9%	$0.15	6%	na	na	$0.40	17%	$2.37	100%

10-mile radial corridor
1 square mile CBD
60% peak, 40% off-peak

Table A3-25
Component Money Costs per Trip
200,000 person trips per day

MODE \ COMPONENTS	Guideway, Busway, Roadway $	%	CBD Parking $	%	Stations & Fringe Parking $	%	Ownership $	%	Vehicles & Yards $	%	Driver or Train Crew $	%	Maintenance & Operation $	%	Other Operating $	%	TOTALS $	%
1. Single Occupant Automobile	$0.37	13%	$1.03	38%	na	na	$0.60	22%	na	na	na	na	$0.73	27%	na	na	$2.73	100%
2. Carpool (4 members)	$0.15	19%	$0.26	32%	na	na	$0.16	20%	na	na	na	na	$0.23	29%	na	na	$0.80	100%
3. Conventional Bus	$0.00	0%	na	na	$0.00	0%	na	na	$0.12	25%	$0.19	37.5%	na	na	$0.19	37.5%	$0.50	100%
5. Fully Integrated Busway, Underground Distribution	$0.88	64%	na	na	$0.11	8%	na	na	$0.09	7%	$0.12	8%	na	na	$0.18	13%	$1.38	100%
4. Fully Integrated Busway, Surface Distribution	$0.65	59%	na	na	$0.00	0%	na	na	$0.11	10%	$0.15	14%	na	na	$0.19	17%	$1.10	100%
20. Rail Rapid Transit, Underground Loop, PAR Access	$0.62	23%	na	na	$0.67	25%	na	na	$0.76	29%	$0.07	3%	na	na	$0.52	20%	$2.64	100%
22. Rail Rapid Transit Underground Loop, Feeder Bus Access	$0.62	39%	na	na	$0.21	13%	na	na	$0.21	13%	$0.15	10%	na	na	$0.40	25%	$1.59	100%

10-mile radial corridor
1 square mile CBD
60% peak, 40% off-peak

Table A3-26
Construction Cost Sensitivities
50,000 person trips per day

		Guideway, Roadway, Busway	CBD Parking	Stations & Fringe Parking	Subtotal (construction)	-20%	+20%	Other Capital	Operating & Maintenance	Subtotal (other)	TOTAL	TOTAL - 20%	TOTAL + 20%
1.	Single Occupant Automobile	0.56	1.03	na	1.59	1.27	1.91	0.60	0.73	1.33	2.92	2.60	3.24
2.	Carpool	0.34	0.26	na	0.60	0.48	0.72	0.16	0.23	0.39	0.99	0.87	1.11
3.	Conventional Bus	0.00	na	na	0.00	0.00	0.00	0.12	0.38	0.50	0.50	0.50	0.50
5.	Fully Integrated Bus, Underground Distribution	3.52	na	0.17	3.69	2.95	4.43	0.09	0.30	0.39	4.08	3.34	4.82
4.	Fully Integrated Bus, Surface Distribution	2.60	na	0.00	2.60	2.08	3.12	0.11	0.34	0.45	3.05	2.53	3.57
20.	Rail Rapid Transit, Underground Loop, PAR Access	2.88	na	0.75	3.63	2.90	4.36	0.76	0.59	1.35	4.98	4.25	5.71
22.	Rail Rapid Transit, Underground Loop, KAR Access	2.88	na	0.29	3.17	2.54	3.80	0.21	0.55	0.76	3.93	3.30	4.56

10-mile radial corridor
1 square mile CBD
60% travel in peak, 40% off-peak

Table A3-27
Construction Cost Sensitivities
100,000 person trips per day

		Guideway, Roadway, Busway	CBD Parking	Stations & Fringe Parking	Subtotal (construction)	-20%	+20%	Other Capital	Operating & Maintenance	Subtotal (other)	TOTAL	TOTAL - 20%	TOTAL + 20%
1.	Single Occupant Automobile	0.43	1.03	na	1.46	1.17	1.75	.60	0.73	1.33	2.79	2.50	3.08
2.	Carpool	0.22	0.26	na	0.48	0.38	0.58	0.16	0.23	0.39	0.87	0.77	0.97
3.	Conventional Bus	0.00	na	na	0.00	0.00	0.00	0.12	0.38	0.50	0.50	0.50	0.50
5.	Fully Integrated Bus, Underground Distribution	1.76	na	0.13	1.89	1.51	2.27	0.09	0.30	0.39	2.28	1.90	2.66
4.	Fully Integrated Bus, Surface Distribution	1.30	na	0.00	1.30	1.04	1.56	0.11	0.34	0.45	1.75	1.49	2.01
20.	Rail Rapid Transit, Underground Loop, PAR Access	1.33	na	0.74	2.07	1.66	2.48	0.76	0.59	1.35	3.42	3.01	3.83
22.	Rail Rapid Transit, Underground Loop, KAR Access	1.33	na	0.28	1.61	1.29	1.93	0.21	0.55	0.76	2.37	2.05	2.69

10-mile radial corridor
1 square mile CBD
60% travel in peak, 40% in off-peak

Table A3-28
Construction Cost Sensitivities
200,000 person trips per day

		Guideway, Roadway, Busway	CBD Parking	Stations & Fringe Parking	Subtotal (construction)	-20%	+20%	Other Capital	Operating & Maintenance	Subtotal (other)	TOTAL	TOTAL - 20%	TOTAL + 20%
1.	Single Occupant Automobile	0.37	1.03	na	1.40	1.12	1.68	0.60	0.73	1.33	2.73	2.45	3.01
2.	Carpool	0.15	0.26	na	0.41	0.33	0.49	0.16	0.23	0.39	0.80	0.72	0.88
3.	Conventional Bus	0.00	na	0.00	0.00	0.00	0.00	0.12	0.38	0.50	0.50	0.50	0.50
5.	Fully Integrated Bus, Underground Distribution	0.88	na	0.11	0.99	0.79	1.19	0.09	0.30	0.39	1.38	1.18	1.58
4.	Fully Integrated Bus, Surface Distribution	0.65	na	0.00	0.65	0.52	0.78	0.11	0.34	0.45	1.10	0.97	1.23
20.	Rail Rapid Transit, Underground Loop PAR Access	0.62	na	0.67	1.29	1.03	1.55	0.76	0.59	1.35	2.64	2.38	2.90
22.	Rail Rapid Transit, Underground Loop KAR Access	0.62	na	0.21	0.83	.66	1.00	0.21	0.55	0.76	1.59	1.42	1.76

10 mile radial corridor
1 square mile CBD
60% travel in peak, 40% in off-peak

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