NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **208**

MARKET OPPORTUNITY ANALYSIS FOR SHORT-RANGE PUBLIC TRANSPORTATION PLANNING

PROCEDURES FOR EVALUATING ALTERNATIVE SERVICE CONCEPTS

F. J. WEGMANN, G. E. BYRNE, A. CHATTERJEE,
C. R. BONILLA, AND K. W. HEATHINGTON
The University of Tennessee
Knoxville, Tennessee

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
- PLANNING
- USER NEEDS
- VEHICLE CHARACTERISTICS
- OPERATIONS AND TRAFFIC CONTROL
- TRAFFIC FLOW, CAPACITY, AND MEASUREMENTS
- (PUBLIC TRANSIT)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. OCTOBER 1979

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP Report 208

Project 8-16 FY '76
ISSN 0077-5614
ISBN 0-309-03000-5
L. C. Catalog Card No. 79-67351

Price: $6.80

Notice

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

Each report is reviewed and processed according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering, serving government and other organizations. The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities but also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

FOREWORD

By Staff
Transportation
Research Board

This report will be of special interest to transit planners and engineers responsible for evaluating alternative service concepts in order to satisfy travel needs within available resources. Other professional planners, including marketers and sociologists, will find this report to be of general interest because of its central role in the application of market opportunity analysis to short-range public transportation planning.

Public transportation traditionally has been provided by fixed-route service financially supported through revenues from passengers. Reduced patronage, resulting primarily from increased use of the automobile plus higher operating costs, has caused growing deficits. Public concern about energy, environment, auto dependency, congestion, and the quality of urban living in general has obliged governments to underwrite these deficits in most urban areas. The rising amounts of required public monies plus the successful operation of a wide range of services directed at more specialized market segments have posed questions concerning how much financial support is appropriate, what services are required, and how these services should be provided. Public officials need this information in order to establish appropriate public policies.

Project 8-16 was initiated in order to develop a method to provide public officials with the desired information and direction for local public transportation actions. The initial 12-month period of the project was spent conducting an in-depth analysis of present procedures and practices of the urban mass transit industry. Included in this effort were research team visits to 18 urban areas within the United States. From this research process, a model (Fig. I) was developed depicting the necessary information and procedural steps required for the application of market opportunity analysis to the planning of short-range public transportation. As depicted in the model, the application of market opportunity analysis requires both direction from policy decision areas and data from an engineering data base. A full explanation of this model, its application, and potential value is presented in *NCHRP Report 212,* "Market Opportunity Analysis for Short-Range Public Transportation Planning—Method and Demonstration." Four companion reports are concerned with the application of a market-oriented public transportation planning approach. These constitute a group of reports that bear the main title "Market Opportunity Analysis for Short-Range Public Transportation Planning," and are subtitled as follows: *NCHRP Report 208,* "Procedures for Evaluating Alternative Service Concepts"; *NCHRP Report 209,* "Transportation Services for the Transportation Disadvantaged"; *NCHRP Report 210,* "Economic, Energy, and Environmental Impacts"; and *NCHRP Report 211,* "Goals and Policy Development, Institutional Constraints, and Alternative Organizational Arrangements." Obviously, all elements of the comprehensive planning model could not be addressed in one report. Thus, each report is aimed at one specific segment of the over-all model as shown in Fig. II for this report. Together, the reports provide comprehensive guidelines for public transportation officials covering the three primary

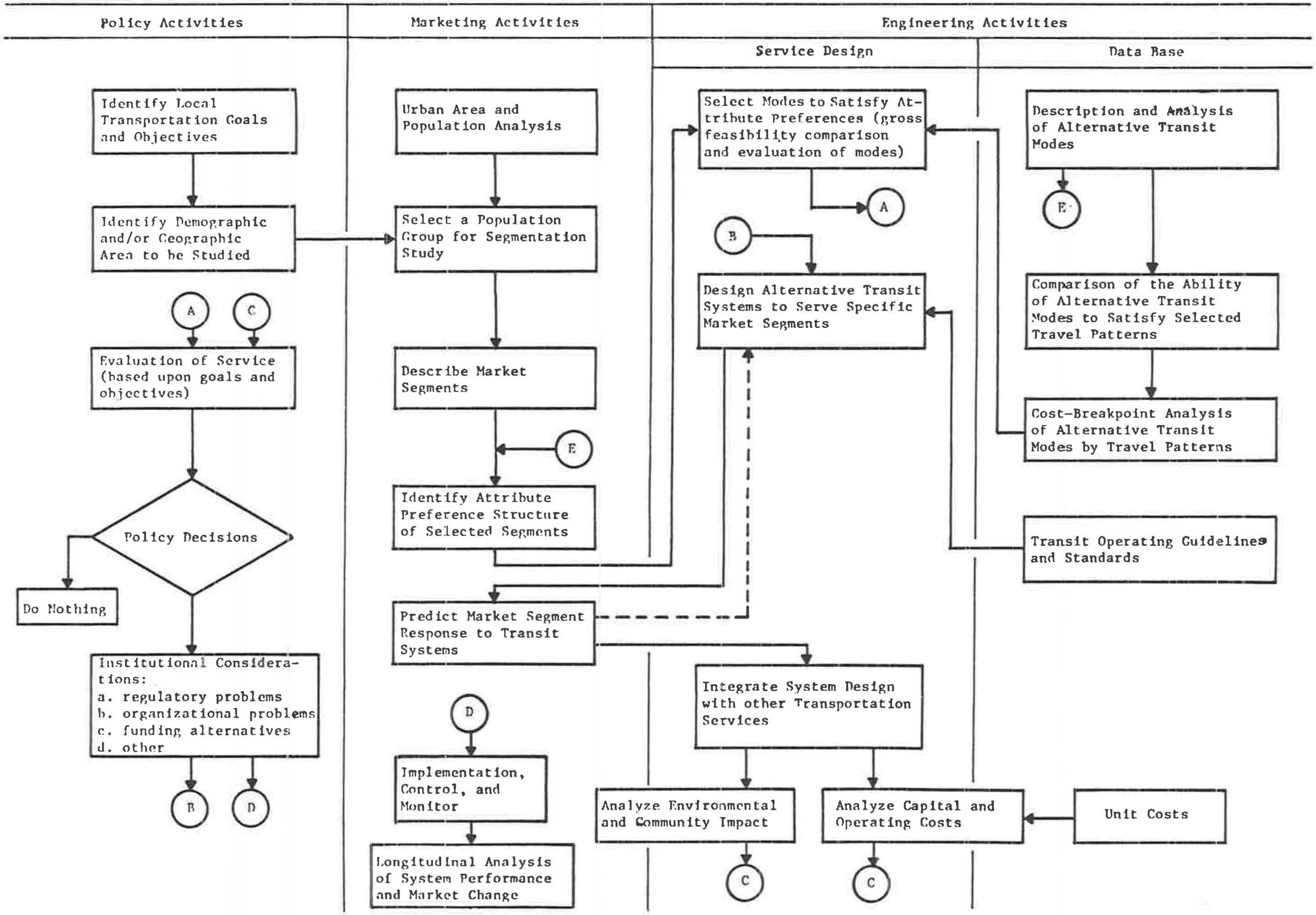


Figure 1. NCHRP Project 8-16 model—a market opportunity analysis approach to short-range public transportation planning.

activities described in the model—policy, marketing, and engineering (Fig. III).

The present report, "Market Opportunity Analysis for Short-Range Public Transportation Planning—Procedures for Evaluating Alternative Service Concepts," contains a general procedure to match desirable service attributes resulting from a market segmentation study with alternative service concepts to determine which alternative services are appropriate for a local area. In addition, key legal, regulatory, and institutional issues of the model involved in the provision of the alternatives are incorporated into the discussion. The purpose of this report is to encourage local planners to consider the full range of alternative public transportation services available to an urban area. "Public transportation," as used herein, includes all forms of intraurban passenger transportation that are available to the public, even if they are not considered common carriers. Public transportation, as defined here, includes private, public, and nonprofit systems. The public transportation system may move masses of people or only one person at a time. Rail systems have been excluded because they are generally beyond the scope of short-term planning considerations.

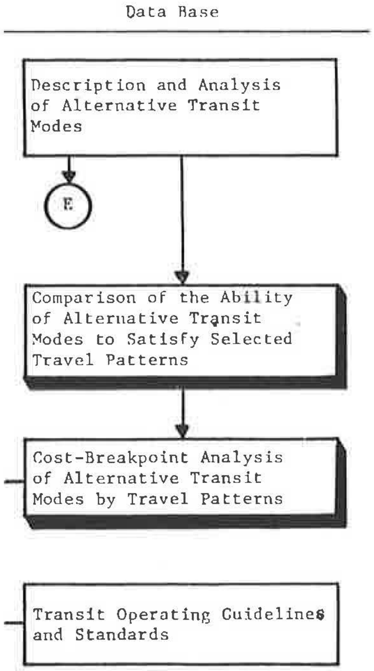


Figure II. Relationship of report to project model.

Policy	Marketing	Engineering
NCHRP Rpt. 211 Short-Range Transportation Goals and Policy Development for Urban Communities Institutional Issues Facing Public Transportation Organization of a Public Transportation Market-Oriented Approach	NCHRP Rpt. 209 Transportation Services for the Transportation Disadvantaged NCHRP Rpt. 212 A Market Opportunity Analysis Approach to Short-Range Public Transportation Planning Methodology and Demonstration of a Market Opportunity Analysis for Short-Range Public Transportation Planning	NCHRP Rpt. 208 Procedures for Local Selection and Cost Evaluation of Alternative Public Transportation Service Concepts NCHRP Rpt. 210 Economic, Energy, and Environmental Impacts of Public Transportation

Figure III. NCHRP Project 8-16 reports.

CONTENTS

PART II

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 8-16 by The University of Tennessee Transportation Center. Drs. Ray A. Mundy and Kenneth W. Heathington were the principal investigators. The authors of this report are Dr. Frederick J. Wegmann, Professor, Department of Civil Engineering; Ms. Grace E. Byrne, Research Assistant, Transportation Center; Dr. Arun Chatterjee, Associate Professor, Department of Civil Engineering; Mr. Carlos R. Bonilla, Research Assistant, Transportation Center, and Dr. Kenneth W. Heathington, Director, Transportation Center.

During the course of this research project many public and private transportation individuals, too numerous to mention, were interviewed concerning their transportation services. Their assistance and cooperation in providing this information are greatly appreciated.

MARKET OPPORTUNITY ANALYSIS FOR SHORT-RANGE PUBLIC TRANSPORTATION PLANNING

PROCEDURES FOR EVALUATING ALTERNATIVE SERVICE CONCEPTS

SUMMARY

This report is part of NCHRP Project 8-16, "Guidelines for Public Transportation Levels of Service and Evaluation," which is directed toward the development of improved methodology for short-range public transportation programs in urban areas. The material presented supports the major contention of the project that public transportation (see "Foreword" for definition of term public transportation) planning should rely on an interactive process of identifying market segments desiring transportation attributes that can be served by one or more service concepts, specifically identifying candidate services possessing these attributes, and determining the feasibility of implementation through cost analysis, field testing, demonstration, evaluation, and refinement. The suggested approach is to institute incremental change to public transportation services that is consistent with the concern for implementing short-range management alternatives.

This report has suggested a general procedure to match desirable service attributes resulting from a market segmentation study with alternative service concepts to determine which alternative services are appropriate for a local area. Alternative service concepts were classified as to vehicle type, degree of right-of-way control, and operational strategy (routing, scheduling, and stop location). This comprehensive classification structure includes many useful service concepts not currently in wide use. Traditional services reflect only a limited spectrum of the full array of service concepts available. The classification chart should suggest opportunities for service that are not being explored currently.

This report also presents typical cost examples and methodologies to aid the planner in assessing the costs of implementing alternatives. Generalized "break-even" curves have been presented for conventional bus, express bus, demand responsive and ridesharing services. Example cost analyses have been developed based on a disaggregate costing procedure. It is felt that the cost of estimation framework should be flexible with respect to cost items and categories to be included, and the estimate should be based on routing, scheduling decisions, recognition of the existing situation in terms of availability of equipment and manpower, and on commitments or investments already made. The costing analysis identified that sizable differences can occur, depending on who is responsible for providing the service (public vs. private), service levels achieved through routing and scheduling, and other operational strategies (work rules, etc.). Rather than provide generalized answers, the planner should refer to the rough feasibility analyses to limit the range of alternatives and then perform a "customized" cost analysis.

Finally, the application of a service concept to a particular market will depend on factors in addition to cost and service levels. A discussion of key legal, regulatory, and institutional issues is presented to make the planner aware of how these considerations can limit deployment of a particular service concept. In the long-term, many institutional barriers can be overcome if a viable cost-effective concept has been identified.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Transportation planning must change continually if it is to meet the needs of a rapidly changing society. During the 1940s and 1950s, the shortage of high-quality, limited-access urban highways and, in the major cities, the need for improved mass transit rail facilities led the American public to become concerned with the need for providing new and improved transportation facilities. In order to improve urban mobility, reduce travel time, and eliminate congestion, transportation planners became involved in planning the construction of new highway networks. Analytical tools were needed to evaluate objectively and comprehensively large highway networks and mass transit rail facilities with respect to their capabilities to meet future needs. By the late 1950s, the first large-scale transportation planning studies using transportation systems models had been completed in Chicago and Detroit. The chief tool for evaluating these long-range plans involving major construction of new facilities became a complex analytical modeling process that permitted networks of highways or rail facilities to be tested against assumed future needs. During the 1960s, much effort was put into the continual improvement and refinement of the models.

Then, the needs of America changed. By the mid-1960s, most of the major highway corridors and transit facilities had been established or were nearing completion. Many travel needs were being met through these new facilities, but energy and environmental needs had become serious concerns to both the citizenry and the technical community. Periods of recession forced taxpayers to question more seriously all government expenditures and to turn down basic tax levies that previously had been passed almost automatically. Because transportation uses large amounts of energy, contributes to air pollution, and requires large land areas, and because large governmental expenditures had been made on transportation improvements, the transportation objectives of America had to change. The new objectives were to reduce energy consumption, to reduce air pollution, to mitigate the adverse environmental impact, and to reduce governmental expenditures without reducing urban mobility.

These challenging new objectives called for long-range plans that did not, as in the past, involve the large-scale construction of new facilities. Instead, these new objectives called for plans that would meet future travel needs through improved use of existing facilities and the reduction of private auto usage. The long-range plan combined a map showing existing facilities with policies leading to increased capacity on existing facilities. As the long-range plan evolved into a comprehensive statement of policy, the short-range plan became the statement of how long-range policies would be implemented. The transportation planner became involved in transportation systems management. Complex systemwide models were of little assistance in the evaluation of plans that assumed that private auto travel would be increased and that existing facilities would continue to be used. The new transportation systems management elements needed to be evaluated for reduced energy consumption and air pollution, reduced negative land use impact, and reduced governmental expenditures.

Many cities viewed public transportation as the means to achieve these new objectives while possibly increasing mobility. The transportation planner became involved in analyzing the role of public transportation in urban areas of all sizes. The planner found that some privately owned transit systems had become degenerating operations using outdated equipment and underpaid employees. It was felt that transit properties had not been managed effectively and that improvements could be made if they were publicly owned and operated. Some felt that by public ownership of the public transportation system transit operations could become profitable, or at least would break even. Improvements in the financial situation of the transit operations would be made by (1) eliminating taxes, (2) extensive use of federal funds, (3) eliminating the profit incentive, and (4) better management.

Experience proved these assumptions to be false. Because of many factors, costs for transit services increased over 100 percent from 1970 to 1976. Labor wage rates in the transit industry increased faster than in other major industries and were the largest contributor to increased costs besides inflation (*1*). While costs rose, the levels of service provided by many transit systems did not substantially improve. Mobility was not necessarily improved and the public utilization of transit did not increase. Without a shift to public transit, energy consumption and air pollution were not reduced and there was no change in the impact of transportation on the environment.

After taking over transit operations, many cities attempted to create an exclusive franchise for providing public transportation services. These cities felt that by maintaining an exclusive franchise, there would be a greater demand for the publicly owned services. However, the demand for services did not increase, and the number of suppliers that could provide transportation services often decreased. By reducing the number of suppliers, competition was reduced, and along with other factors, including inflation, the result was increased costs for the consumer and/or the city. Many of the largest, most transit-intensive cities have already found the cost of transit service too high despite federal and state assistance, and some have attempted to retrench through service cutbacks and fare increases (*1*).

These service cutbacks and fare increases do not help to meet the nation's transportation needs. Innovative types of services and innovative management of existing services can, in certain situations, assist in reaching the national transportation objectives. Public transportation does not automatically provide levels of service that will attract the ridership necessary to reduce energy consumption or air pollution. Increasing investment in traditional public transportation does not automatically increase mobility. Finally, it has proven difficult to operate traditional public transit without increasing deficits. The planner must now become involved in the analysis and evaluation of all public transportation alternatives both public and private. "What an effective network requires is the largest number of alternative modes of transportation, at varying speeds and volumes, for different functions and purposes" (*2*).

OBJECTIVE

The purpose of this report is to identify alternatives for providing urban public transportation and to assist in determining the feasibility of implementing these alternatives. "Public transportation," as used in this report, includes all forms of intraurban passenger transportation that are available to the public, even if they are not considered common carriers. Public transportation, as defined here, includes private, public, and nonprofit systems. The public transportation system may move masses of people or only one person at a time. Rail systems have been excluded because they are generally beyond the scope of short-term planning considerations.

To assist in determining the feasibility of implementing each alternative, an approach to cost estimation is discussed. The cost to provide a service not only depends on who is responsible for providing the service (public vs. private), but also on how the service is provided (routing, scheduling, work rules, etc.). It is impossible to present cost estimating procedures for the entire spectrum of alternatives. System costs are affected by geographical area, community size, service type, and a variety of other factors that need to be considered. The purpose of this report is to present typical cost examples and methodologies to aid the planner in assessing the costs of implementing alternatives.

The incremental cost approach is used because an incremental situation is usually what the planner must face when implementing short-range management alternatives. The cost estimation framework in these cases should be flexible with respect to cost items or categories to be included, and the estimates should be based on the existing situation in terms of the availability of equipment and manpower as well as the commitments and/or investments already made by the existing transit company. In order to provide generalized values, a limited sensitivity analysis has been prepared alerting the planner to the range in costs that might be encountered and the impact of selected parameters on total cost. For typical situations, "break-even curves" have been identified to suggest where certain services become more economically advantageous than other competing services. It must be recognized that cost is only one element, however an important one, in evaluating a transit service. The proposed methodology is only one part of an integrated evaluation process. Other elements for evaluation are addressed in companion reports.

CHAPTER TWO

ANALYSIS OF ALTERNATIVE PUBLIC TRANSPORTATION MODES

CLASSIFICATION OF PUBLIC TRANSPORTATION ALTERNATIVES

Public transportation alternatives traditionally are defined and analyzed by "mode." Transportation engineers and planners generally agree that a "mode" should not be solely defined according to the type of vehicle used (*3*). Bus, rail, van, minibus, and so on, are not modes. As noted in Figure 1, a bus can be used to provide a variety of services. For example, buses can be used to provide service on a fixed route and schedule with a stop at every corner, or a bus can be used to pick up commuters at a park-and-ride lot and carry them express nonstop to their place of work. These are two different public transportation alternatives using the same type of vehicle. The way in which the vehicle is used is as important as the type of vehicle. It is the basic contention of this report that the planner must consider the full array of options and not become "locked" into conventional techniques for delivery of public transportation services. To do this, the planner must go beyond traditional definitions of service that categorize service by vehicle type.

To provide a method for considering the full array of public transportation service options available, a classification scheme has been devised to identify and describe alternative public transportation service concepts (*3, 4, 5*). The classification structure involves three factors:

1. Degree of exclusivity of right-of-way: fully shared, partially shared, entirely exclusive.
2. Operational strategy: routing, scheduling, and stop location.
3. Type of vehicle, with emphasis on the vehicle characteristics: that is, vehicle size, access and egress, comfort, etc.

Each of these factors affects the level of transportation service provided. The type of right-of-way can control the speed, reliability, safety, and accessibility of the public transportation service. Operational strategy can determine the service area coverage, service accessibility, frequency of service, service reliability, service demand responsiveness, travel time, waiting time, and walking distance. Finally, vehicle type affects the safety, comfort, accessibility, reliability, and image of the transportation service. There is, of course, some interrelationship between the three classification factors. Some right-of-way decisions affect stop locations; some routing/scheduling decisions affect vehicle size, etc. For example, a decision to use an entirely exclusive right-of-way would necessitate a fixed-route operational strategy.

This classification structure can serve as a guide in showing similarities and differences between alternative service concepts and aid in applying information developed through marketing surveys. Given the desired attributes for service of a market segment, it is possible to suggest a match between the segment and the service concept best able to provide desired attributes. Again, the interest is to ensure that through the classification structure the planner thinks in terms of service concepts and does not restrict the choice of options to a few conventional methods of transit operation.

RIGHT-OF-WAY CLASSIFICATIONS

There are three basic categories of right-of-way alternatives that can be selected for use by a transit service:

1. Fully shared right-of-way; that is, surface streets in mixed traffic.
2. Partially controlled right-of-way; that is, bus lane, signal preemption, toll station bypass.
3. Fully controlled right-of-way; that is, grade-separated—either specially constructed or part of existing freeway.

The type of right-of-way can control the speed, reliability, safety, and accessibility of the public transportation service. It also significantly affects the cost and time frame of implementing the service. For example, construction of an exclusive right-of-way (guideway or busway) can require a major commitment of funds and 5 to 10 years to implement. For these reasons, only in a few instances can a new, fully controlled right-of-way be considered within the time frame of short-range planning.

Fully shared right-of-way refers to a surface street open to mixed traffic. The characteristics of mixed traffic will control many service characteristics of the transit mode (speed, safety, stops, etc.). If automobile traffic movement is slow during rush hour, public transportation service also will be slow. It is possible to apply a variety of treatments to improve speed and schedule dependability of public transportation systems by giving the public transportation vehicle priority over other traffic. The most common example of priority treatment is the exclusive bus lane. If priority treatment is provided along the right-of-way, the right-of-way is categorized as partially controlled.

CLASSIFICATION OF OPERATION STRATEGIES

Operational strategies are those factors that bring the transit vehicle to the customer. These factors, therefore, have great impact on the level of service provided the customer. Although an unlimited number of possible operational strategies exists, three major categories have been identified: (1) routing, (2) scheduling, and (3) stop location.

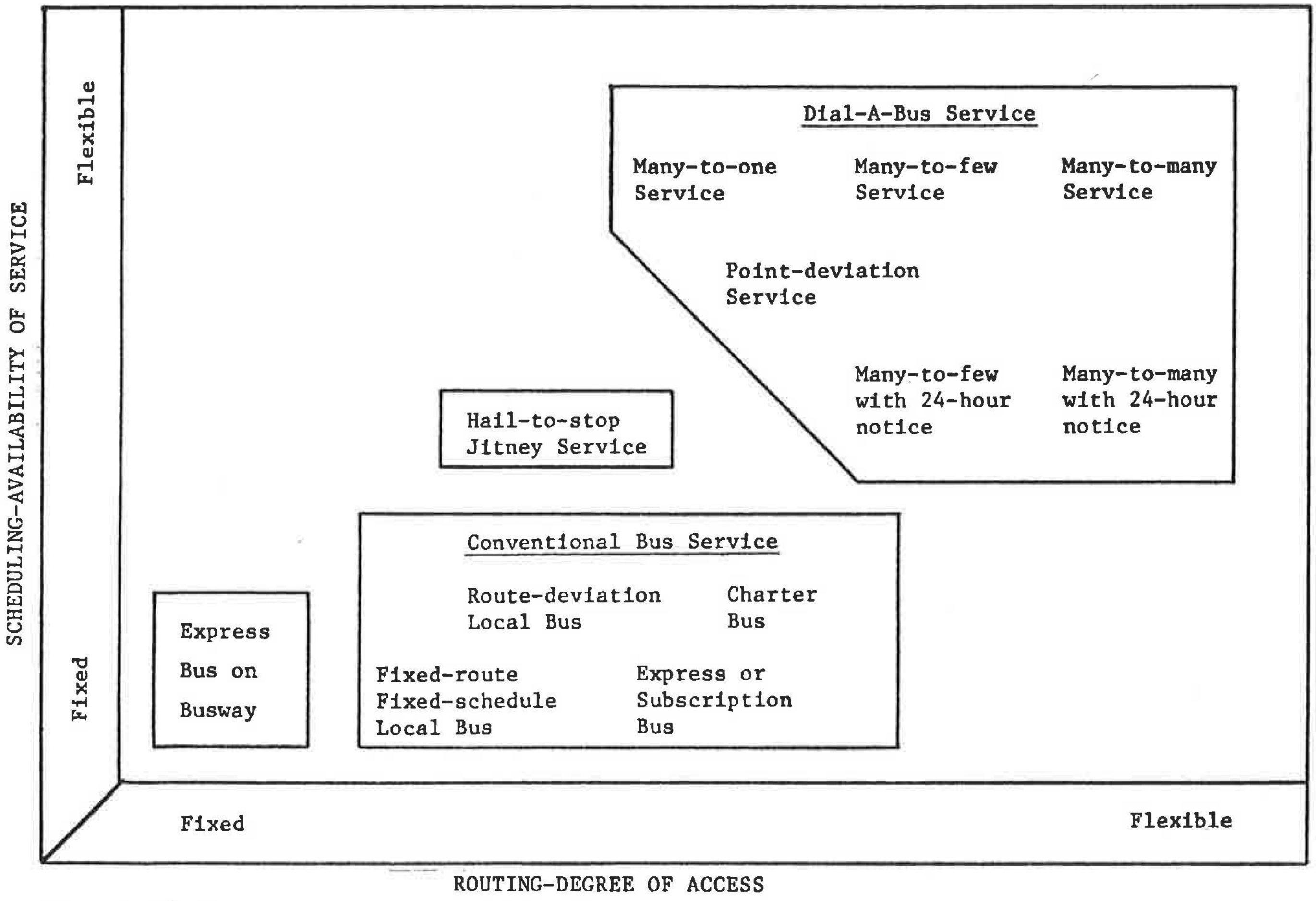


Figure 1. Broad spectrum of services provided by a bus.

Routing

Routing can be defined as the assignment of the course to be followed by the transit vehicle. Routing can be a predetermined path or a real time decision made to service different origin–destination demands in the minimum amount of time. The route structure directly determines the accessibility of the transit system to the potential customer and the degree to which desired destinations are serviced. If routing alone is considered, the closer the routing corresponds to the local pattern of origins and destinations, the more accessible the service will be. Basic routing strategies are defined as follows:

1. *Fixed-Route Service.* Transit vehicle travels a pre-established route. Passengers are picked up or dropped off at designated locations along the route (see Fig. 2). Stops may be designated by markers (signs, benches, etc.) or by policy (at the near side of an intersection).

2. *Route Deviation Service.* A vehicle travels a basic fixed route, picking up or dropping off people anywhere along the route. On request, and, perhaps, with additional charge the vehicle will deviate a few blocks from the fixed route to pick up or deliver a passenger (see Fig. 3).

3. *Point Deviation Service.* A vehicle stops at specified checkpoints (shopping centers, industrial parks, etc.) at specified times, but travels a flexible route between these points to service specific customer requests for doorstep pickup or delivery (see Fig. 4).

4. *Many-to-Few Service.* Although origin points may be anywhere in a defined service area, destinations are limited to a few activity centers. Conversely, for a return trip, origins are limited whereas destinations are areawide. The vehicle travels a flexible route between origin and destination points to service specific customer requests (see Fig. 5). Activity centers are not served unless a request for service to or from the center is received.

5. *Many-to-Many Service.* All inclusive service is provided throughout a defined service area. Service is not provided outside the service area. All origins and destinations within the service area are served. The vehicle travels a flexible route between the origin and destination points to service specific customer requests for doorstep pickup and delivery (see Fig. 6) (*6*).

Scheduling

Scheduling can be defined as the assignment of the time that the transit vehicle will be available to specific customers for transportation service. Schedules can be predetermined or fixed, or they can be responsive to personal requirements of customers. Scheduling options fall along a continuum from fixed to responsive (see Fig. 7). A fixed schedule remains the same from day to day; a responsive schedule varies from day to day, depending on customer demands.

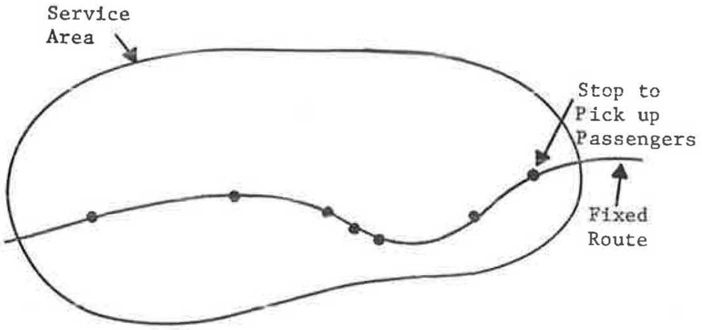


Figure 2. Fixed-route service.

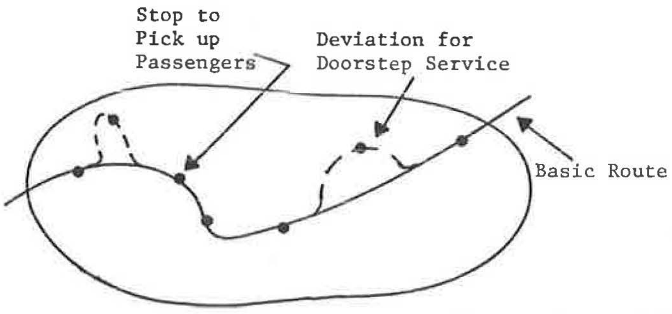


Figure 3. Route deviation service.

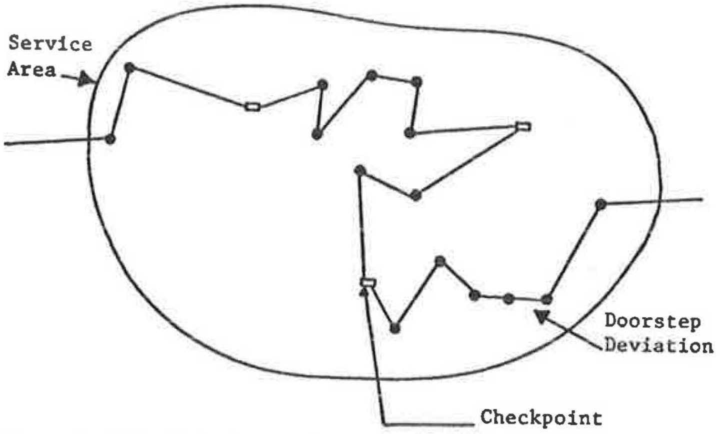
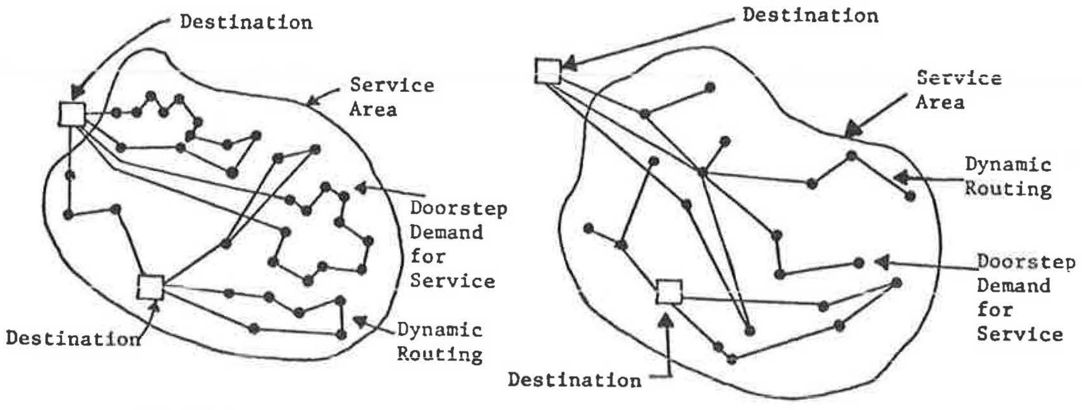


Figure 4. Point deviation service.



With 24-hour notice

Immediate Request

Figure 5. Many-to-few service.

Scheduling affects the ability of a system to meet demands for service both on a continuous time scale and in a reliable or responsive fashion. Scheduling also affects the customer's wait and trip times. Fixed-schedule options generally provide more reliable service and shorter trip and wait times. Variable schedule options give the customer more flexibility in determining the time the trip is to be made. Basic scheduling options are defined as follows:

1. *Fixed Schedule.* Customers board a vehicle at specified times. Schedule is established by transportation operating agency.

2. *Flexible Fixed Schedule.* Customers board a vehicle at a specified time established in advance by the customers. Schedule changes are permitted with short notice—perhaps weekly, daily, or hourly. For example, carpooling traditionally relies on a pickup time negotiated between driver and rider. The times continually are adjusted to reflect changing circumstances. A flexible fixed schedule is more responsive to personal customer requirements than a fixed schedule, but the degree of responsiveness is constrained by the requirements of other riders and the driver.

3. *Vehicle Hail.* A customer desiring service hails (waves or calls) a passing public transportation vehicle to obtain a ride. In some cases, the person must be standing at a designated vehicle stop in order to legally hail the passing vehicle. If public transportation vehicles frequently

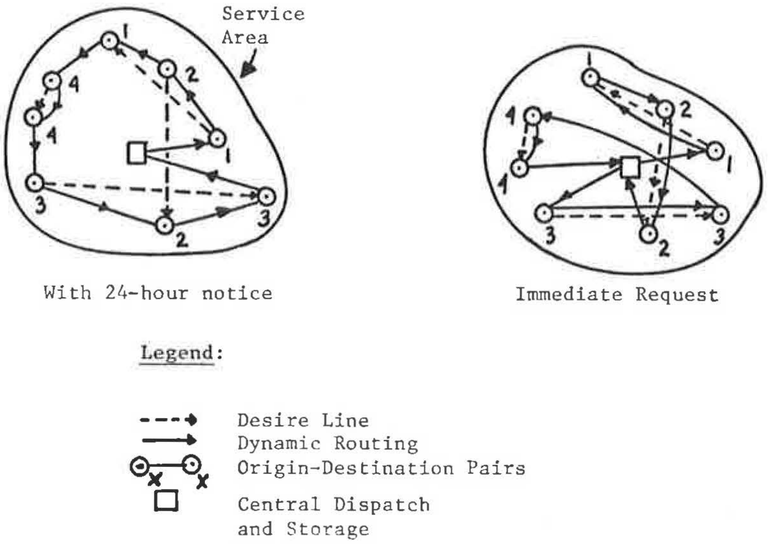


Figure 6. Many-to-many service.

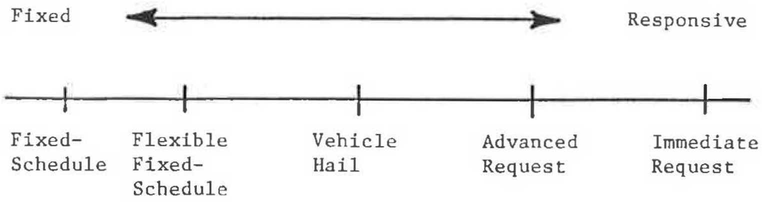


Figure 7. Continuum of scheduling options.

pass the place or stop where the customer is waiting, the customer will receive almost instantaneous service. In this case, the vehicle hail scheduling option is responsive to the customer's personal requirements. If, however, there are few vehicles and infrequent passings, the customer may have to wait a long time and may not receive service. To receive prompt service responsive to personal requirements, the customer must be aware of the hours when frequent service is available. This constraint affects the responsiveness of this service.

4. *Advance Request.* Service is requested for a single trip to occur at some time, perhaps 24 to 48 hours later. Request is made through a control center. The customer has control of the pickup time with the advance request option, but must know complete trip details in advance. As this is not always possible, this requirement constrains the responsiveness of the service.

5. *Immediate Request.* Service is requested through a central control or dispatcher for a single trip to be made as soon as possible. Request generally is made by telephone. The constraints affecting the responsiveness of this option are the availability of a telephone, the availability of a vehicle to make the trip, and the availability of space in the vehicle. This is the most responsive service possible except for the personal automobile (*6*).

Stop Location

Stop location can be defined as an assigned geographical location where the transit vehicle may pick up or deliver passengers. Stop locations affect vehicle travel time, waiting time, walking distance, and general accessibility of the service. Basically, there are three ways to classify locations of transit stops along a fixed route: local, express, and skip-stop (*3*). These are shown in Figure 8. Stop location is also a basic consideration in point deviation or many-to-few service as convenient, safe locations must be determined to facilitate the congregation of patrons. These stop locations also must be desired destinations. Stop location decisions also must be made in implementing a many-to-many service. Consideration must be given to the kinds of places at which the transportation vehicle will stop, the number of stops, and the spacing of stops within the service area.

CLASSIFICATION OF VEHICLE TYPES

Traditionally, planners have described public transportation services by type of vehicle. As stated previously, it is the way in which the vehicle is used that primarily determines the level of service provided. However, vehicle type is important because it helps determine the customer image of the transportation service, right-of-way type, and operating strategy.

There are many different types of vehicles available for public transportation services. The four basic classes considered in this report are bus, small bus (including converted motor homes), van, and automobile (including stretched limousines). In most cases, a number of different vehicle types could be used for a particular service. Selection of vehicle class should be based on four factors:

seating capacity, maneuverability, operational reliability, and customer acceptability. Table 1 lists the seating capacity of selected vehicle types.

CURRENT HIGHWAY-BASED PUBLIC TRANSPORTATION SERVICES

Using the classification structure described, Table 2 gives the range of available public transportation services that operate on highways. Common terminology—such as dial-a-ride, express bus, and subscription bus—is used to describe transportation services with different characteristics. Some options, such as dial-a-ride, appear in various locations on the table. The term dial-a-ride has been used in the literature to refer to almost any service in which the customer uses the telephone to request pickup. However, the operating characteristics and levels of service of various dial-a-ride services may differ. Some services require an advance request (perhaps 24 to 48 hours), whereas other services respond immediately. Some services follow fixed routes; some only go to a few destinations and some go to any destination. Different levels of service could meet the requirements of different market segments, illustrating the importance of defining transportation services by operating characteristics and not by vehicle type.

In Table 2, selected routing/stop location and scheduling combinations have been blocked because the combinations are unworkable. Other combinations serve as possible service concepts, but insufficient data are available to document successes or failures. However, it is the intent of this material to encourage planners to ponder these combinations before rejecting them, not *a priori*, but based on characteristics of the travel market.

TRADITIONAL SERVICES PROVIDED BY VEHICLE TYPE

The type of vehicle and the degree of exclusivity of right-of-way must be considered along with the operational strategy to describe completely a transportation service

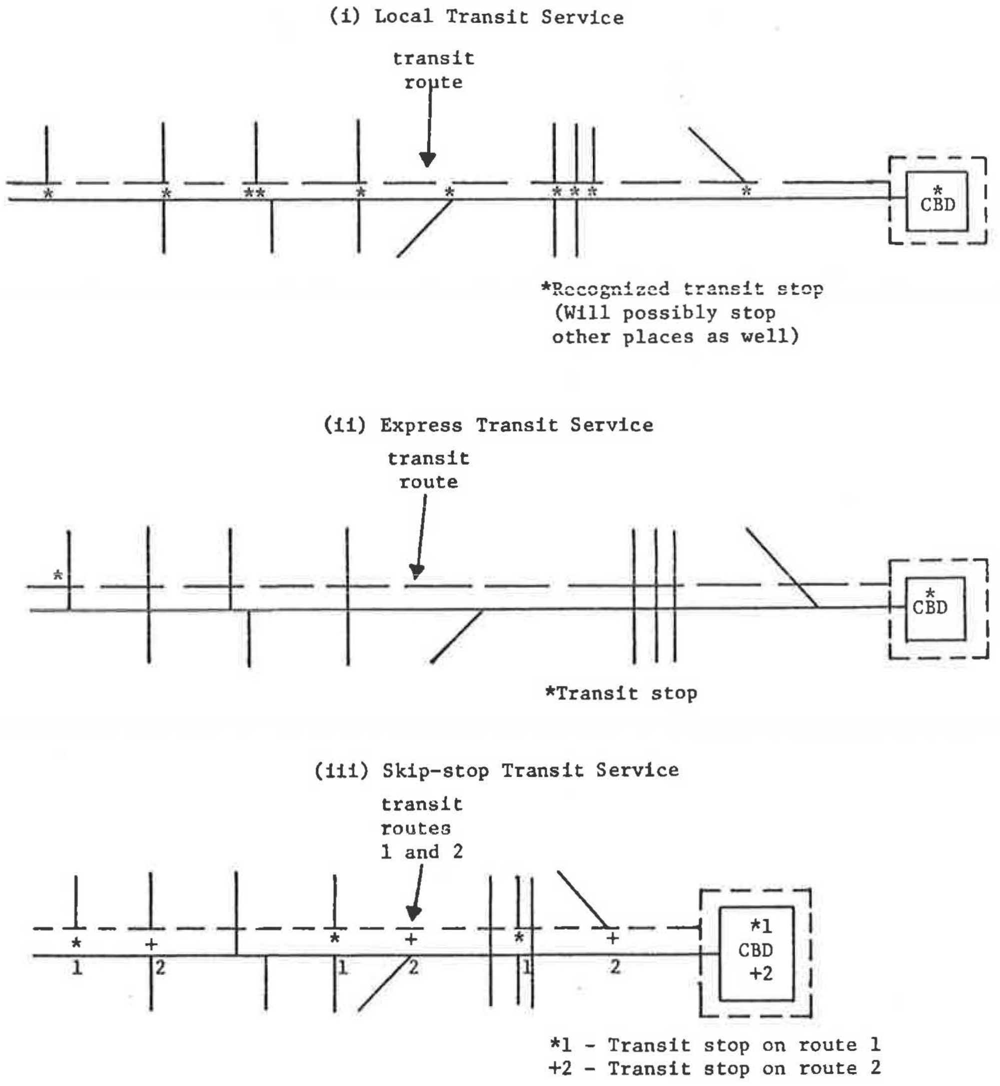


Figure 8. Classification of stop spacing fixed route or route deviation service.

alternative. Any of the vehicles listed in Table 1 could provide the current services identified in Table 2. Traditionally this has not occurred. Tables 3 through 6 give the services that currently are being provided by each of the four vehicle type categories.

There are a few technical considerations that limit the use of some vehicle types. Large capacity vehicles, such as the standard size bus, generally are not chosen to provide flexible route, flexible schedule service. If the bus is used to capacity, most of the passengers will experience excessive travel time because of the route deviations necessary to pick up other passengers. Some increased operating costs (in the magnitude of 10 to 20 percent) and maneuverability problems are incurred with operating large-size vehicles

TABLE 1

EXISTING PUBLIC TRANSPORTATION VEHICLES *(6, 7)*

VEHICLE	TYPE	CAPACITY
Bus	Full-size Bus	30-50
	Small Bus	15-30
Van	Converted Motor Home	10-30
	Passenger Van, Van Conversion	8-16
Automobile	Stretched "Airport" Limousine	8-16
	Spec. Checker Cab	4-7
	London Cab	4-7
	Standard Passenger Car	4-7
	Mini-Cab	2-3

TABLE 2

RANGE OF POSSIBLE PUBLIC TRANSPORTATION SERVICE ALTERNATIVES CATEGORIZED BY OPERATIONAL STRATEGY

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Transit	Subscription Bus		▨	▨
Express	Express Bus	Subscription Bus	▨	▨	▨
Skip-stop	Express Bus		▨	▨	▨
Rt. Deviat. Local	Traditional Transit Airport Limousine		Dial-a-Ride Jitney		Dial-a-Ride Jitney
Express			▨		
Skip-stop			Jitney		
Rt. Deviat.	Rt. Deviat.			Seasonal Charters	Dial-a-Ride
Many-to-Few	Vanpools	Vanpools Carpools Taxipools	Dial-a-Ride Taxi	Subscription Dial-a-Ride	Dial-a-Ride Taxi
Many-to-Many	▨	Subscription Dial-a-Ride	Taxi	Dial-a-Ride Jitney Limousine Taxi	Dial-a-Ride Taxi Shared-Ride Taxi

Traditional Transit, etc. — Public Transportation Alternative Reported in the Literature[1]

▨ — Not a Possible Public Transportation Alternative

☐ — Possible Public Transportation Alternative (Not Reported in the Literature)

---

[1] A listing of cities where examples of each of the transportation alternatives were reported is included in Appendix A.

TABLE 3

RANGE OF PUBLIC TRANSPORTATION SERVICES THAT COULD BE PROVIDED BY A FULL-SIZE BUS

Capacity 30 to 60 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Transit			▨	▨
Express	Express Bus	Subscription Bus	▨	▨	▨
Skip-stop	Express Bus		▨	▨	▨
Rt. Deviat. Local					
Express			▨		
Skip-stop					
Rt. Deviat.					
Many-to-Few					Dial-a-Ride
Many-to-Many	▨	Subscription Bus		Jitney	Dial-a-Ride

Traditional Transit, etc.	Public Transportation Alternative Reported in the Literature[1]
☐	Possible Public Transportation Alternative (Not Reported in the Literature)
▨	Not a Possible Public Transportation Alternative

---

[1] A listing of cities where examples of each of the transportation alternatives were reported is included in Appendix A.

that are not used to capacity. Small capacity vehicles, such as a standard automobile, generally are not chosen to provide fixed route, fixed schedule service because this service is usually only financially viable where there are fairly large demands for service. There are, however, many unique situations. A small, but consistent, demand for service could lend itself to fixed route, fixed schedule automobile service. The planner should not choose the vehicle solely on the basis of tradition.

Most of the service concepts defined by Table 2 and restated in Tables 3 through 6 could be used in conjunction with right-of-way priority treatments to improve speed and schedule reliability. Generally, these treatments are justified when there is a concentration of public transportation vehicles on selected routes. For this reason, most of the experience with partially controlled right-of-way public transportation alternatives has been with the fixed-route, fixed-schedule buses providing either express or local service.

TABLE 4

RANGE OF PUBLIC TRANSPORTATION SERVICES THAT COULD BE PROVIDED BY A SMALL BUS

Capacity 10 to 30 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Transit	Subscription Bus		▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local			Dial-a-Ride Jitney		Dial-a-Ride Jitney
Express			▨		
Skip-stop			Jitney		
Rt. Deviat.	Pt. Deviat.			Seasonal Charters	
Many-to-Few			Dial-a-Ride	Subscription Dial-a-Ride	Dial-a-Ride
Many-to-Many	▨	Subscription Dial-a-Ride		Dial-a-Ride Jitney	Dial-a-Ride

Traditional Transit, etc.	Transportation Alternative Reported in the Literature[1]
	Possible Public Transportation Alternative (Not Reported in the Literature)
▨	Not a Possible Public Transportation Alternative

[1] A listing of cities where examples of each of the transportation alternatives were reported is included in Appendix A.

In order to highlight the importance of defining transportation services by operating characteristics, currently existing services were categorized using the classification scheme developed earlier. The classification table can be used, in conjunction with market segmentation, to differentiate and select between alternative service concepts for implementation in a local area. Use of the classification scheme should allow the local planner to consider all alternatives. In order to match service concepts with customer needs and desires, user sensitive attributes of the alternative service concepts need to be defined.

USER SENSITIVE ATTRIBUTES OF ALTERNATIVE PUBLIC TRANSPORTATION SERVICE CONCEPTS

All service concepts are not appropriate for use in every community. Also, it is impractical to evaluate in detail every alternative mode for any one community. For these reasons, the local transportation planner must select the two or three most likely alternative service concepts for detailed evaluation early in the planning process. In effect, the planner should customize the service to meet the needs of the customer. Therefore, the selection process must include information about the potential customers' needs and wants—the user's evaluation criteria. Evaluation criteria are those characteristics or attributes of the transportation service that potential customers have indicated are desired before they will probably use the service (*8*).

Several researchers have compiled lists of criteria used by people in comparing or evaluating alternative transportation services (*9, 10, 11*). Service attributes such as safety, reliability, cost, speed, and convenience were found to be important. To be useful to the planner, the evaluation criteria must relate to modal attributes that differentiate beween the alternative service concepts. Through this match, the number of alternative service concepts that need to be evaluated in detail for costing purposes can be reduced. There remain, however, many alternative service

TABLE 5

RANGE OF PUBLIC TRANSPORTATION SERVICES THAT COULD BE PROVIDED BY A VAN

Capacity 8 to 16 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Transit			▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local	Traditional Transit		Jitney		Jitney
Express			▨		
Skip-stop			Jitney		
Rt. Deviat.				Seasonal Charters	Dial-a-Ride
Many-to-Few	Vanpools	Vanpools		Subscription Dial-a-Ride	Dial-a-Ride
Many-to-Many	▨			Dial-a-ride Jitney	Dial-a-Ride

Traditional Transit, etc.	Transportation Alternative Reported in the Literature[1]
	Possible Public Transportation Alternative (Not Reported in the Literature)
▨	Not a Possible Public Transportation Alternative

---

[1] A listing of cities where examples of each of the transportation alternatives were reported is included in Appendix A.

levels (coverage area, headways, fare levels) that need to be considered.

User sensitive attributes that differentiate between alternative transportation modes can be categorized under (1) attributes that affect scheduling, (2) attributes that affect routing and stop location, and (3) attributes that affect vehicle selection.

Attributes That Affect Scheduling

Scheduling affects the ability of a system to meet the user's need for reliable transportation service. Scheduling also affects the user's waiting and riding time. Table 7 lists selected transportation service attributes affected by scheduling that have been found to be important to customers in evaluating the desirability of a transportation service. The degree to which each of the scheduling alternatives attains the service attribute is noted in the table. For example, a flexible fixed schedule service, such as a commuter vanpool, strongly attains short waiting times because the schedule is

TABLE 6

RANGE OF PUBLIC TRANSPORTATION SERVICES THAT COULD BE PROVIDED BY AN AUTOMOBILE

Capacity 2 to 16 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local				▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local	Airport Limousine		Jitney		Jitney
Express			▨		
Skip-stop			Jitney		
Rt. Deviat.					
Many-to-Few		Carpool Taxipool	Taxi	Auto Rental	Taxi Dial-a-Ride
Many-to-Many	▨		Taxi	Public Lim. Shared-Ride Taxi	Taxi Shared-Ride Taxi

Jitney, etc.	Transportation Alternative Reported in the Literature[1]
	Possible Public Transportation Alternative (Not Reported in the Literature)
▨	Not a Possible Public Transportation Alternative

[1] A listing of cities where examples of each of the transportation alternatives were reported is included in Appendix A.

TABLE 7

EXPECTED ATTRIBUTES OF ALTERNATIVE SCHEDULING CONCEPTS

Expected Attributes of the Service	Alternative Scheduling Concepts				
	Fixed Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Short waiting time	M	S	M	W	W
Reliable departure time	S	S	W	S	W
Reliable arrival time	S	S	W	M	W
User confidence in obtaining service	S	S	W	M	M
Small variation in travel time	S	S	W	W	W
Small variation in waiting time	S	S	W	S	W
Freedom to select personal departure time	W	M	W	S	M
Freedom to select personal arrival time	M	M	W	M	M

Attainment of Criteria:

W - weak
M - moderate
S - strong

based on the travel desires of the customers (i.e., vehicle leaves soon after work lets out). A fixed schedule service moderately attains this attribute because the customers can adjust their travel desires to meet the schedule and thereby experience short waiting times.

Vehicle-hail services, such as a cruising taxi service, generally are found only in areas where there is a large demand for this service and large numbers of vehicles are available to provide frequent service. Generally, short waiting times are experienced, but the waiting time is unreliable. With advance request, the customer must request service one or more hours in advance. This time period generally is perceived by the customer as the "waiting time" even though the vehicle may arrive precisely at the time requested. With immediate request service, experience with waiting times has varied. Many dial-a-ride services have average waiting times of a half hour to an hour. Many taxi services can provide shorter waiting times because of the smaller capacity vehicle or policies to carry only one customer at a time. With either service, waiting times are longer during times of peak demand.

Likewise, for "freedom to select personal departure time," neither the fixed schedule nor the vehicle-hail-scheduling options are responsive to individual customers. With advance request, the customer has almost complete control in determining the departure time even though the waiting time is perceived as long. With flexible fixed schedule and advance request services, the customer is able to request a departure time, but the responsiveness of the service is determined by the desires of the other customers using the service.

These rankings do not apply to every situation. There are exceptions to every ranking; some services do better and some do worse. They can be used as a guide in selecting services that will best match local customer needs and desires, but they are not inflexible rules. For example, if the planner decides to recommend a dial-a-ride service but realizes that short waiting times are extremely important to the market segment, steps may be taken to plan a dial-a-ride service with better than average waiting times. During peak periods, perhaps, the service can be operated on a flexible fixed schedule. The rankings should serve as a guide to problems to investigate and solve as well as a guide in selecting service concepts.

Attributes That Affect Routing and Stop Location

Routing and stop locations are the operational strategies that should be considered in addition to the alternative scheduling options in the selection and design of a public transportation service. They determine accessibility of the public transportation system to the potential user. They also affect the over-all travel time, travel time reliability, route directness, and selection of destinations.

Selected user evaluative criteria for transportation services and the corresponding relative ranking of the available routing and stop location options are given in Table 8. Again, these rankings do not apply to every situation. There are exceptions to every ranking. For example, if the market segment to be served lives in high density apartment buildings fronting a major street, doorstep pickup can be attained with fixed-route service. The rankings should serve only as a guide in investigating potential problems before selection, design, and costing of a service.

TABLE 8

EXPECTED ATTRIBUTES OF ALTERNATIVE ROUTING AND STOP LOCATION CONCEPTS

Expected Attribute of the Service	Alternative Routing and Stop Location Concepts								
	Fixed Route			Route Deviation			Point Deviat.	Many-to-Few	Many-to-Many
	Local	Express	Skip-Stop	Local	Express	Skip-Stop			
Doorstep pickup at residence.	W	W	W	S	M	M	S	S	S
Doorstep delivery at non-residence destination.	M	M	M	M	M	M	S	S[1]	S
Short walking time to pickup point from residence.	M	W	W	S	M	M	S	S	S
Clearly identified transit stops.	S[2]	S[2]	S[2]	S/W[3]	S/W[3]	S/W[3]	S/W[4]	W/S[5]	W
User confidence of obtaining service.	S	M	S	M	W	M	M	W	W
Freedom to select own pickup or delivery point.	W	W	W	M	W	M	S	S	S
Shelter at boarding and departure points.	W	S	M	S	S	S	S	S	S
Non-stop direct service between pickup point and destination.	W	S	M	W	M	W	W	W	W
User's freedom to change destinations enroute.	S	W	M	S	W	M	S[6]	W	W

Attainment of Criteria:

W - weak
M - moderate
S - strong

[1] Attainment of doorstep delivery is strong only if the destination is one of the few destinations designated to receive doorstep service.

[2] Many fixed route transit systems are now adopting transit stop identification schemes which aid the customer in using the service. In Rochester, New York, all stops are numbered and coded on the route map.

[3] On the route the stops may be clearly identified. However, it can be difficult for the customer to determine how far or to what destinations the vehicle will deviate to provide doorstep service.

[4] Stops may be clearly identified at the scheduled points of service. However, it can be difficult for the customer to determine how far or to what destinations the vehicle will deviate to provide doorstep service.

[5] Stops may be clearly identified only at the few destinations which are designated to receive doorstep service.

[6] Destinations may be changed at each checkpoint.

Attributes That Affect Vehicle Selection

Vehicle characteristics affect the comfort and accessibility of the transportation service. Selected user evaluation criteria for transportation services and the corresponding relative ranking of the available vehicle alternatives are given in Table 9. Table 9 can help in selection of a vehicle and determination of which vehicle characteristics may need modification. Vehicle manufacturers offer a wide variety of options that can be selected to meet market segment needs and desires. Table 10 lists nonmechanical characteristics of vehicles that should be considered before purchase. Wise decisions concerning these characteristics will make service more appealing to the customer.

Through market segmentation, described in more depth in companion volumes, a set of user sensitive attributes describing the local market segment's needs and desires can be established. Through use of Tables 7 through 9, these attributes can be used to differentiate between and to help select the service concepts identified in Table 2. The expected attribute rankings of alternative scheduling concepts, alternative routing and stop location concepts, and alternative vehicle types can be used to select and design public transportation services. Market segmentation is used to identify different population segments with different needs and desires. These needs and desires then are compared with attributes of the alternative public transportation services. The matching public transportation service is, in theory, most likely to attract ridership. These modes can then be analyzed for feasibility.

TABLE 9

EXPECTED ATTRIBUTES OF ALTERNATIVE TRANSPORTATION VEHICLE TYPES

Expected Attribute of the Service:	Alternative Vehicle Types			
	Bus	Small Bus	Van	Automobile
Guaranteed Seat	W/M[1]	M	S	S
Quiet/Little Interior Noise	M	M	S	S
Little Vehicle Vibration	S	M	M	S
Easy Entry and Exit - adult	S	M[2]	W	M[3]
- child	S	M	W	M[4]
- elderly or restricted mobility	M	M	W	W
- wheelchair	W[5]	W[5]	W[5]	W[5]
- blind	W	W	W	W
Easily Accessible Seat	S	S	W	S
Space for Storage of Packages	M	M	W	S
Privacy	M	M	W	W

Attainment of Criteria:

W - weak
M - moderate
S - strong

[1] During the peak hours of travel the customer's perception of being guaranteed a seat on a full size bus is weak.

[2] Customer must enter and exit through same door.

[3] It is awkward for an adult to slide across a seat to sit in the middle.

[4] Many car doors are difficult for a child to open.

[5] All vehicle types must be specially outfitted in order to provide good service to those in wheelchairs.

TABLE 10

NONMECHANICAL CHARACTERISTICS OF VEHICLES

Vehicle Exterior		Vehicle Interior		Supporting Facilities	
Characteristic	Importance	Characteristic	Importance	Characteristic	Importance
1. Appearance:	The external appearance may be important in attaining new and retaining existing passengers.	1. Entrances and Exits:	Some potential customers (such as the elderly) may be prohibited from using a mode due to entrance design.	1. Fare Collection:	The fare collection system affects passenger safety, leading time, convenience and the perceived user cost.
Exterior size		Door Width		Charge service, billed at end of month	
Silhouette/ Profile		Door Height		Cash only, change given	
Color		Extra Loading Doors		Exact change required	
External Advertising		Elevation		Prepurchase of tokens	
		Step Illumination		Subscribe for service	
		Step Height			
		Step Spacing			
		Suspension Kneeling			
		Floor Covering			
		Handholds			
		Ramps or Lifts			
		Street Visibility			
		Seat Padding			
		Location of Handrail			

TABLE 10 (cont'd)

Vehicle Exterior		Vehicle Interior		Supporting Facilities	
Characteristic	Importance	Characteristic	Importance	Characteristic	Importance
2. Vehicle Identification:	Easily understandable vehicle identification schemes aid new customers in learning how to use the service and aid existing customers in learning how to expand their use of the service.	2. Seating:	Seat accessibility, availability and orientation should reflect the characteristics and desires of the customers. The handicapped may not, for example, be able to travel long aisles on a moving vehicle to reach a seat.	2. Stop Shelters, Terminals:	The provision of shelters or terminals may make an otherwise unaccessible system accessible to the elderly or handicapped. Shelters and terminal design affects safety, comfort, and perceived waiting time.
Destination Sign		Arrangement		Shelter from Weather	
Logo		Seat Height		Seating	
Color		Seat Width		Lights	
		Knee Room		Heat	
		Privacy		Telephone	
		Storage Area		Restrooms	
		Tables		Commercial Services (newspapers, etc.)	
		Visibility from Seat			
		Wheelchair Space and Anchors			

Vehicle Exterior		Vehicle Interior		Supporting Facilities	
Characteristic	Importance	Characteristic	Importance	Characteristic	Importance
		3. Aisles: Width Floor Slope Handholds for Standees	Aisles are necessary for high occupancy vehicles. The design should reflect both passenger capabilities and total passenger turnover.	3. Information System: Transit Stops Identifying Routes Transit Stops Identifying Schedules Transit Stops Coded to Route Maps and Schedules Telephone Information Service Interactive Computer Information Service	The type, location, and design of the origin-to-destination information system affects the accessibility of the transportation service. New and existing customers learn how to use/access the service through the information system.
		4. Interior Design: Aisle to Ceiling Height Seat Floor to Ceiling Height	Interior Design can affect both the actual comfort and the perceived desirability of riding in the vehicle.		

TABLE 10 (cont'd)

Vehicle Exterior		Vehicle Interior		Supporting Facilities	
Characteristic	Importance	Characteristic	Importance	Characteristic	Importance
		4. Interior Design (Continued):			
		Windows - Shape, Tint, Opening and Closing			
		Color and Detailing			
		Transportation System Information (route map mounted inside vehicle, etc.)			
		Advertising			
		Special Accessories (vending machines, bars, telephone)			
		5. Ride Quality:	Ride quality can affect the perceived desirability of riding in the vehicle.		
		Heating/cooling			
		Ventilation			
		Illumination			
		Interior Noise			
		Interior Vibration			
		Acceleration, Deceleration, and Jerk			

Source: Design and Performance Criteria for Improved Nonrail Urban Mass Transit Vehicles and Related Urban Transportation Systems. A report to the United States Department of Housing and Urban Development, Contract No. H757. Washington, D.C.: Highway Research Board, May 1968, pp. 34-54.

CHAPTER THREE

CONTEXTS AND ISSUES OF COST ESTIMATION FOR PUBLIC TRANSPORTATION SERVICE CONCEPTS

Estimating the cost of a public transportation service is a basic task in transit planning. When a decision has been reached on the type or types of transit service to offer a specific market segment, the question of cost must be addressed. There are several different approaches to cost estimation, and, unless the planner is careful to adopt the most appropriate approach, the cost estimate can lead to an incorrect decision.

Cost estimation of fixed transportation facilities, such as highways, is relatively straightforward because their quantity does not vary periodically. Moreover, standard procedures usually are available for determining the size of such facilities along with relative unit costs. In the case of a transit system, however, fixed facilities, such as guideways and terminals, are just one component of the total cost. Other components are the capital cost of vehicles and the operating cost for the service. Estimation of vehicle and driver requirements is not as straightforward as that of fixed facilities because their quantities may vary with operating strategy or work rules and may fluctuate during a day according to the peaking characteristics of demand. The allocation of labor costs and of equipment that is not used continuously is a controversial issue that can affect the final cost estimate.

The approach or technique selected for cost estimation must be compatible with the context of planning, and the planner must understand clearly the issues and implications related to the selected approach. This section presents a brief overview of various planning contexts and some of the important issues related to costing of transit services.

CONTEXTS FOR COST ANALYSES

Cost analyses for transit operations are performed for varied purposes, and the desired degrees of detail and accuracy of the cost estimates may vary from case to case. The components of cost to be included in an estimate are not always the same and depend on the nature of the problem. The costing technique selected must, therefore, consider both the need and the context.

Macroanalysis for an Existing Transit System

In short-range as well as long-range planning studies, an analysis of the future financial situation of the existing transit system has to be performed. Basically, such an analysis involves projecting costs and revenues for the upcoming years so that appropriate strategies can be developed to avoid or limit probable deficits (or to invest probable profits) in the most judicious manner. A macroanalysis usually incorporates all cost items for the entire system and is amenable to a coarse analysis. Thus, even a projection based on the trend analysis of the annual costs for the past several years, recognizing probable inflation, would be appropriate if no substantial changes in size and operational characteristics of the system are anticipated. Ideally, capital costs for equipment should be analyzed separately from operating costs, and the need for vehicle replacement and improvements toward fixed facilities should be considered. Another more refined approach to estimating operating cost may be conducted through the development of an empirically derived cost model (*12-16*).

Cost Estimation for a Public Transportation System

When planning an entirely new urban area transit system, cost estimates of alternative systems are needed for comparison and evaluation purposes. Estimates should include all pertinent items, such as capital costs for fixed facilities and equipment, as well as operating costs. In the case of a new system, neither a trend analysis nor an empirically derived cost model is usually applicable unless one or more existing systems can be identified that are similar in cost characteristics to the proposed service.

The most appropriate approach in this case is to identify the pertinent cost items and use system design procedures to estimate the quantities of various parameters or system output measures for each category. The total cost in each category then can be estimated by multiplying the parametric quantities with appropriate unit cost values. Unit costs, in the case of the system design approach, would relate to clearly identifiable cost categories and may be derived analytically. Data from similar existing systems, if available, may be utilized for this purpose. System design for a large transit system requires considerable skill and expertise, especially if accurate estimates of vehicle and operator requirements are to be obtained. The use of computer programs, such as the one being developed by the Urban Mass Transportation Administration (UMTA), would be ideal for this purpose (*17*).

Cost Analysis for Changes to an Existing Public Transportation System

One of the most common tasks of a transit planner is to evaluate various proposals for adding or deleting transit services in an urban area. As mentioned earlier, cost implications of these proposals play an important part in the evaluation process and the planner has to derive the estimates as accurately as possible. The cost estimation framework in these cases should be flexible with respect to cost items or categories to be included, and the estimates should be based on a recognition of the existing situation in terms of the availability of equipment and manpower as well as the commitments and/or investments already made by the existing transit company. Proposals for incremental changes in service are candidates for an incremental cost analysis.

The incremental cost analysis approach is applicable in a variety of situations and proposals related to an existing transit system. For example, in some cases the equipment needed for a proposed service already may be depreciated fully, leaving labor and operation as the only relevant cost items. In other situations, both equipment and labor are available without extra cost and the proposed service may involve only out-of-pocket vehicle operating cost. The addition of a service for a short daily time period may require high labor costs due to stipulations of minimum pay-hours in the labor contract. In each of these cases the planner has to be fully aware of the situation and decide carefully which cost components to include and how to quantify the magnitude of each.

Empirical cost models are not suitable for incremental analysis because they are not easily adjustable to variable situations (*18*). The unit cost coefficients of the variables, being a combination of several different factors, are not easily decomposable. Moreover, these coefficients reflect an average or systemwide situation and may not be applicable for costing an incremental change. A disaggregate approach for cost analysis based on system design procedures as suggested in this report is ideally suited for the purpose of incremental cost analysis.

A major concern in costing is the allocation of costs to different operations. One of the highly debated issues, for example, is the cost of adding new peak-hour service.

COSTING THE PEAK-HOUR SERVICE

The need for equipment to provide transit service in an urban area varies during the day because of fluctuations in travel demand. However, the costs related to supplying vehicles and labor do not vary proportionately. For example, if a transit system uses 60 vehicles during the peak hours and 40 vehicles during the off-peak period, it implies that there are 20 vehicles used only during the peak period, which lasts for approximately 4 hours per day. The capital investment for these additional vehicles, however, is no less than for the others.

In deriving the hourly cost for service, should capital cost for these 20 vehicles be allocated uniformly over the entire daily service period or just over the four hours of peak service? Logically, the transit system should derive different unit costs for peak and off-peak services and the cost for the 20 vehicles should be included only in the peak-hour unit cost.

A similar situation exists for manpower cost. Because of unionization of labor, public transit systems generally cannot employ part-time drivers. Therefore, in order to run additional vehicles during the peak hours, drivers must be paid for a minimum of eight hours. To be consistent, the total salaries of these drivers also should be allocated to the peak-hour period.

CONTROVERSY ON MARGINAL VS. AVERAGE COST

Estimating peak-hour costs by including all costs attributable to the service, as previously described, reflects the concept of marginal cost. This is a useful concept because of the increasing disparity between travel demand and services during peak and off-peak periods. Transit planners and analysts traditionally have used an average cost for planning, and the average cost has been derived by allocating the cost for extra peak hour equipment and manpower uniformly over the entire day's service. This traditional approach leads to a misunderstanding of the economics of transit operation. In a recent article, Mundy (*19*) pointed out that, whereas many planners may consider peak-hour transit service to be profitable, there is often little or no profit attributable to these service hours because of the need to recover the costs of vehicles and manpower that remain idle during the off-peak period. Further, in some cases a portion of the true cost of providing peak-hour service is hidden because transit systems tend to provide more service in the off-peak period than necessary to utilize otherwise idle vehicles and manpower. If off-peak service were made proportional to the demand, which may be contrary to the policy for transit service in an urban area, the disparity between peak and off-peak requirements for equipment and manpower could be seen more vividly. Following the previous example, it might be argued that a system operating with 60 peak-hour buses is providing 30 to 35 extra buses for the peak hour if 25 to 30 buses would adequately satisfy off-peak demands at an acceptable standard of frequency. In such cases, 50 percent of bus and driver costs should be allocated to the peak period.

The need to examine marginal cost as opposed to average cost for incremental planning is recognized by most planners and analysts. The use of equipment and manpower varies from case to case, and the planner must be familiar with the specific local situation. The planner can avoid many difficulties and pitfalls by using the disaggregate approach, which does not rely on marginal or average cost coefficients. This approach permits the planner to include all relevant cost items attributable to a service in appropriate amounts reflecting the true picture of the situation.

SUMMARY

Different approaches and techniques can be used for estimating the cost of transit services; however, their scope and adaptability vary. Therefore, before selecting a particular technique, the actual context of planning and the anticipated use of the cost information must be examined carefully. The planner also should be aware of the cost implications of incremental service of various types including peak-hour service.

The technique that was found most reliable and adaptable to varying planning contexts was the disaggregate approach relying on systems design procedures. Further discussion on the scope and application of this flexible approach is presented in the next chapter.

CHAPTER FOUR

COST ANALYSIS APPROACH

The decision to experiment with a particular transit concept in a given market situation is a complex one involving many factors. Given the flexible nature of many short-range public transportation options, field demonstrations or incremental analyses become quite attractive. Important elements in a feasibility analysis are determining "what are the costs to be incurred by demonstrating this service?" and "is the ridership suggested from the marketing analysis sufficient to justify the cost?" Revenue need not always equal or exceed cost, as many public transportation services can be justified despite deficits. The role of establishing community goals is important in determining what is expected from public transportation (break-even costs, improved mobility for selected segments of society, diverting lone drivers from their automobiles for energy conservation, etc.). Regardless of the objectives, the planner should be conscious of the resources involved in initiating and demonstrating a new service concept. Also, the planner should seek the most economical transit alternative that provides the desired service level.

This chapter will describe the incremental costing procedures utilized to provide cost estimates for short-range transit service options. Although general economic break-even curves will be presented as a "first approximation" to match market attributes with alternative service concepts, a more refined cost analysis requires a detailed knowledge of the local environment that is highly sensitive to how the service is to be provided. Transit planning is an interactive process, relying on experimentation, feedback, and modification. The general cost relationships developed should provide sufficient information to make "first cut" approximations in order to select candidate services for detailed investigation. The disaggregate costing procedures outlined in this chapter were used to develop general relationships and can also be applied to a more detailed cost investigation of a particular service concept.

DISAGGREGATE COSTING PROCEDURES

The basic approach to costing analysis is to adopt a disaggregate procedure by first identifying major cost items and then designing the service to obtain estimates of the relevant input measures. The approach selected requires that the planner estimate various design parameters, such as number of vehicles, person-hours of labor, etc., before applying appropriate unit cost values. The approach taken is identical to the procedure used in the UCOST model to be incorporated in the Urban Transportation Planning System (UTPS) developed by the UMTA (*20*). The mathematical form of the model may be described as follows:

$$TP = \sum_{I=1}^{N} C(I) \tag{1}$$

where TP is the total cost, $C(I)$ is the operating or capital cost in category I, and N is the number of categories.

The cost in each category can be expressed as:

$$C(I) = \sum_{J=1}^{K} CF(I, J)\ M(J) \tag{2}$$

where $CF(I, J)$ is the unit cost in operating or capital cost category I attributable to causative factor or parameter J, and $M(J)$ is the number of units of the causative factor J (i.e., parametric value of J).

The structure of the second equation implies that for estimating the operating cost in any particular category I, the planner is not restricted to use a single causative factor and can use as many parameters as appropriate. The planner also can select the cost categories considered relevant for the planning context under study.

In the case of items involving equipment and fixed facilities, quantities must be estimated based on system design, and costs can be derived by multiplying quantities by respective unit costs. Initial costs, however, must be amortized to convert them to a proper time unit. Further, in the case of estimating the cost of part of a system, costs must be allotted to the service proportionately.

Since a thorough understanding of physical and operational characteristics of the proposed transit service is required for this disaggregate approach, the analyst/planner has to spend some time laying out routes and scheduling vehicles and drivers. The amount of work involved in a system design varies with the nature and scope of service. For example, the design of a single express bus route and estimation of its vehicle and manpower requirements are not very time consuming compared to the estimation of the same requirements for an entire bus system. The advantages related to the disaggregate structure and accuracy of the system design, however, tend to outweigh disadvantages related to the complexities to be addressed by the procedure. The resources required for the design and estimation of the parametric values for a large system represent a constraint of the disaggregate system design approach. In the future, this disadvantage may be overcome as computer programs incorporating advanced algorithms are developed to assist planners in using this approach for large systems (*20*).

For assistance in applying the disaggregate costing approach system, design procedures for fixed route and fixed schedule bus, express bus, demand responsive services, and ridesharing services are discussed in Appendix B and typical costing examples are presented in Appendix C.

COST CATEGORIES

For the purpose of this study, the following categories of costs were adopted:

1. Cost for guideways and related fixed facilities.
2. Cost of vehicles.
3. Operating cost (out-of-pocket vehicle operating cost (excluding operator's wage), direct maintenance cost, operator's (or driver's) wage, and other operating costs).

This level of aggregation will provide sufficient flexibility to allow the planner to address a specific planning context. Depending on the situation, certain cost items may be excluded or modified. The characteristics of these cost components and their implications in different planning contexts follow.

Cost for Guideways and Related Fixed Facilities

In selected cases, separate guideways (busways) for bus transit service may be provided to ensure a high level of service when a large number of buses interferes with other vehicles in shared rights-of-way. When the guideway is built on a separate right-of-way, costs will include land and construction. If the guideway is built within the existing right-of-way of a roadway facility, such as along the median of an existing freeway, a case can be made for excluding the cost of land, which already is a "sunk cost."

To figure cost on an annual or daily basis, the initial cost of construction with or without right-of-way costs must be amortized, using an appropriate interest rate and service life. The amortized annual cost then can be converted to a daily cost by dividing by the number of days in use during a year. The cost then should be allocated among all the users of the facility (i.e., the different transit routes and/or companies) in proportion to their usage. If necessary, the annual or daily cost can be converted to "unit cost per vehicle-mile" by dividing by the annual or daily vehicle-miles of operation on the guideway.

In the case of a freeway or an arterial with an existing lane reserved for buses only or for buses and high occupancy automobiles, the cost for guideways may be ignored except for the cost of special signs and markings that may be needed to designate the special purpose lanes. If such a lane has to be built as an addition to an existing facility for the exclusive use of buses, the cost of construction should be included in the analysis.

A transit service may require certain fixed facilities related to the guideway, for example, passenger shelters for fixed route and dial-a-ride systems or park-and-ride facilities. Annual and/or daily cost and even unit costs per vehicle-mile can be derived for these fixed facilities based on the same approach used for guideways. Costs for constructing fixed facilities not related to the guideways (e.g., maintenance garage and administrative buildings) are not included in this category.

Cost of Vehicles

The capital cost of transit vehicles is one of the major cost items directly related to providing a transit service. The cost can be amortized using an appropriate interest rate and service life. The amortized annual cost then can be converted to a daily cost by dividing by the number of days in use a year. If necessary, a "unit cost per vehicle-hour" or a "unit cost per vehicle-mile" can be derived. For the purposes of this analysis, it was assumed immaterial how the equipment purchase funds were derived (i.e., federal/state aid programs) and only total cost was utilized. It can be argued that transit vehicles with lives of 8 to 12 years and depreciations of several thousand dollars per year need to be included in the cost analysis. Fleets have to be replaced on a continuing basis and not when a public grant program becomes available (*21*). In some planning contexts the equipment depreciation cost is omitted. For example, if the incremental cost of providing an extension of an existing route is being estimated, the equipment cost may not be included unless the added service makes it necessary to purchase additional vehicles. However, outside of special cases the capital cost for equipment has to be included in the analysis.

Operating Cost

From the standpoint of a planner evaluating a transit service, it is important to distinguish between the components of operating cost that always are incurred and those that may not be relevant in certain planning contexts. For example, the cost of fuel and lubricants needed for operating a bus will be present whenever any vehicle-miles are operated. The costs for transportation operations that include supervision, operator inspection, and instruction increase by discrete increments at large intervals and thus may not be included in the analysis of small increments of service. Based on these considerations, components of operating cost may be grouped into four categories—out-of-pocket vehicle operating cost (excluding operator's wage), direct maintenance costs, operator's (or driver's) wage, and other operating costs (such as communication costs). (Inputs to these cost categories need to be based on the service levels.) Each cost category can be disaggregated into several components. The components of operating cost that will be used for the following explanations are identical to those used in the transit operating cost model UCOST, which is to be incorporated in UTPS (*17*). It should be noted that a standard accounting system known as FARE has been proposed for all transit systems. The cost categories used in UCOST are either individual FARE categories, an aggregation of FARE categories or parts of individual FARE categories. The FARE functions corresponding to each category are shown.

Out-of-Pocket Vehicle Cost (Excluding Operator's Wage)

Out-of-pocket vehicle operating costs represent mandatory expenditures for vehicle operation. Driver's wages are treated separately because of stipulations in labor contracts (drivers sometimes are paid even when they are not operating a vehicle) and because it may be possible to utilize such idle manpower without incurring an incremental cost. Thus, the out-of-pocket vehicle operating cost includes the following:

1. Fuel, lubricants, and power (including fuel taxes for revenue vehicles) (FARE functions 503-08-030, 504-01-030, and 510-05-030).
2. Tires and tubes for revenue vehicle operation (FARE function 501-02-030).

The unit cost for this category usually is available on the basis of vehicle-miles of operation including in-service and deadhead travel.

Direct Maintenance Cost

This category covers the maintenance costs that are directly related to the amount of use of a vehicle. (The corresponding FARE function is 060.) The unit cost for direct maintenance expenditures should be expressed in terms of vehicle-miles of operation. This category typically would cover the cost of inspection and maintenance of revenue vehicles. It should be noted that the cost of "servicing of revenue vehicles" (FARE function 050) has been included in the category of "other operating costs" because its unit cost usually is determined with "number of vehicles" as the causal factor. However, a planner may combine these two cost items into one category.

Operator's (or Driver's) Wages

The cost of labor accounts for a substantial portion of the total operating cost, usually 60 to 80 percent. In addition, wage rates may vary significantly by location. Therefore, it is essential to separate costs related to wages of drivers and other on-board attendants, if any. The following items are included in this cost category:

1. Operators' (and attendants') salaries (FARE function 501-01-030).
2. Fringe benefits and other salaries for revenue vehicle operation (FARE functions 501-02-030 and 502-15-020).

The unit cost for this category should be based on individual service hours, and the cost should cover all paid hours—in-service, deadhead, and other guaranteed pay hours. The following equation can determine labor cost for the specific service that is provided (*21*):

$$\mathrm{LAC} = [[(\mathrm{MIN})(\mathrm{DWR}) + (\mathrm{REG})(\mathrm{DWR}) + 1.5\,(\mathrm{OT})(\mathrm{DWR})] \times (1 + \%\ \mathrm{Supervision}) + (1 + \%\ \mathrm{Fringe})] \qquad (3)$$

where LAC is the labor associated costs per day, MIN is the minimum hours guaranteed according to contract, DWR is the driver wage rate, REG is the regular hours work in excess of minimum, OT is the overtime driver hours required to provide service, % Fringe is the cost of fringe benefits based on a percent of salaries paid, and % Supervision is the cost of supervision as a percent of driver salaries paid.

Other Operating Costs

There are several other items that are not as sensitive to the magnitude of the actual service or operation. These costs usually change only when appreciable increases or decreases in the size of the operation occur. These costs may not be relevant in some planning contexts, especially when small changes are made to an existing operation. This category includes:

1. Transportation operations (FARE function 010).
2. Leases and licensing of revenue vehicles (FARE functions 506-04-030 and 510-04-030).
3. Servicing of revenue vehicles (FARE function 050).
4. Repairs to vandalized revenue vehicles (FARE function 070).
5. Fuel, service, inspection, and maintenance of service vehicles (FARE functions 080 and 090).
6. Ticketing and fare collection equipment (FARE functions 110 and 150).
7. Operation and maintenance of power facilities (FARE function 140).
8. Other maintenance and maintenance administration (FARE functions 040, 100, 120 and 130).
9. Scheduling and general administration (FARE functions 020 and 160).
10. General functions (FARE function 180).

The methods for deriving unit cost for this combined category vary with the different items. The cost for most of these items may be correlated with the size of the fleet or number of peak-hour vehicles. However, for the purpose of estimating the cost of providing service on an existing or new portion of a transit system, it would be convenient to use unit costs based on vehicle-miles of service.

It should be noted also that there are cases when it is appropriate to separate some items within this group and form additional categories. For example, in the case of a demand responsive system, the cost of dispatching and monitoring vehicles and controlling their movement may be substantial, and it may be desirable to identify this cost item clearly. In the case of vanpools, fixed costs—which include insurance, parking, and vehicle registration—become important components of total cost. The institutional cost of providing ridesharing services, such as promotional programs and administration, can become significant. To ensure that comparative cost analyses are not biased, the costs included in one option must be similar to those included in a second option.

Unit Cost Values

A final element of a cost analysis involves deriving the appropriate unit cost figures. Secondary sources of cost data exist, but none can provide up-to-date information for systems. Therefore, local planners must make some efforts to obtain either specific data for their areas or adequate information with which they can adjust data from secondary sources to fit their situations. A number of sources for cost data are available. One of the best is the handbook, "Characteristics of Urban Transportation Systems," which is also included in UTPS (*22*). A local planner would find this handbook useful for reference and to verify data—either original or from secondary sources.

LEVEL OF SERVICE AND CAPACITY CONCEPTS

In order to compare the costs of various service concepts, it is necessary to specify a desired level of service. In the case of a service that is repeated periodically throughout the day, headway becomes the common denominator. In the case of ridesharing, people make arrangements to travel together and service is not provided on a repeated basis or with a headway during the day. Thus, service is provided that involves only two trips per day and headway is not a good indication of level of service.

There are many factors (quantifiable as well as subjective) that determine the level of service. Level of service should be based on a combination of these factors. However, such a combined index usually tends to become very complex and would be difficult to utilize. Based primarily on considerations of practicality, frequency of service was selected as the sole independent variable in developing a level of service measure for fixed schedule service. Number of vehicles was used for demand responsive service, and trip time was used for ridesharing service.

A second element is the maximum number of riders that can be handled in a fixed time period. Capacity serves as a physical constraint and limits the service to certain ridership levels.

The next chapter will apply the general costing approach discussed in this chapter to suggest how a "first cut" economic feasibility test could be used when selecting an initial service concept for a predetermined market segment. Economic viability spaces will be developed based on the interaction of cost, level of service, and capacity.

CHAPTER FIVE

CAPACITY AND BREAK-EVEN ANALYSIS

A transit service can be defined in terms of the technological characteristics and service levels provided. The technological characteristics depend on the guideway, vehicles, and operating strategy utilized, whereas the level of service is influenced by such factors as the frequency of service and loading standards. For a given set of technological characteristics and level of service, specific information can be derived regarding the maximum passenger carrying capacity and cost. When the cost of providing the service is known, the minimum ridership that is necessary for a financially break-even operation can be estimated and fare levels determined. Break-even analysis helps determine not only ridership levels necessary for the service to break even financially, but also the minimum levels of fare and service required to break even if potential ridership has been estimated. Again, for a given set of technological characteristics including the operating strategy, different values for capacity and break-even ridership can be calculated for varying levels of service.

This chapter will present break-even curves for three classes of transit service:

1. Headway oriented fixed route, fixed schedule service (express bus on a busway (or exclusive lane), express bus on a shared freeway lane, bus on an arterial roadway bus lane, and conventional bus).
2. Demand responsive areawide service, nonheadway oriented service.
3. Ridesharing service (carpool, vanpool, and buspool).

USES OF CAPACITY AND BREAK-EVEN CURVES

Capacity and break-even curves can be derived for a variety of transit services. Transit planners can use them in determining the feasibility of a particular type of service for a given level of demand. These curves are developed for generalized sets of characteristics. Ideally, planners should develop their own capacity and break-even curves for the specific system configurations and operating strategies using local cost data. However, for the purpose of this preliminary feasibility analysis, a planner may use a prederived curve to check whether the proposed service matches reasonably with the derived system characteristics and the level of cost incurred. In some cases even when unit costs change, the shape of the curves indicates the sensitivity of capacity and cost to varying levels of service. If the estimated demand for a specific type of transit service is less than the break-even demand, the planner may conclude that the service is not economically feasible unless subsidized in some manner. The capacity and break-even curves can be used also to define viability spaces comparing alternative service concepts and to define the alternative types of service that are economically feasible for different ranges of ridership.

DERIVATION OF BREAK-EVEN CURVES FOR A FIXED ROUTE, FIXED SCHEDULE BUS

The use of viability spaces, as described in this chapter, is similar to those advanced by Morlock (*23*) and Rea and Miller (*24*). Ridership by unit time was taken as a measure of travel demand. Daily ridership is a common unit of expressing passenger travel demand. However, recognizing variations in service hours and fluctuations in travel demand during a day, "passengers per hour" was chosen to be the dependent variable. Headway, expressed in minutes, was taken as a measure of the level of service.

The estimation of break-even ridership, which by definition generates revenue equal to the cost of providing the service, is a relatively straightforward procedure and involves developing a relationship where either revenue equals cost or number of passengers times average fare equals cost.

When the cost and fare are known, the number of passengers can be determined from the foregoing equation. Cost can be estimated by the disaggregate costing approach described in the previous chapter. For example, in the case of the express bus service on a busway discussed in Appendix C, the total cost based on the system design approach was determined to be $1,103.48 per day for a 4-hour period of service with a 20-minute headway. Thus, the hourly cost is $275.87.

Estimation of revenue based on ridership and fare is a relatively simple process where there is a flat fare structure. However, where a graduated fare structure exists, revenue estimation requires a breakdown of ridership by fare level. For the majority of transit systems, a flat fare is charged irrespective of the distance traveled; this practice is especially true for commuter services. For the purpose of this analysis, three alternative flat fares (corresponding to low, average, and high fares) were assumed for each service listed as follows:

1. Express bus on a busway = $0.60, $0.75, and $1.00 per passenger.
2. Express bus on a shared freeway lane = $0.50, $0.60, and $0.75 per passenger.
3. Bus on an arterial roadway bus lane = $0.30, $0.40, and $0.50 per passenger.
4. Conventional bus = $0.30, $0.40, and 0.50 per passenger.

A third component of the break-even analysis is the computation of capacity. The capacity function basically depicts the physical ability of a particular type of transit service to transport passengers, and the break-even function defines its limit of economic viability. A detailed discussion of capacity computations is presented in Appendix D. Thus, these two functions can be used to identify all combinations of ridership and level of service (i.e., the region of output space) for which a given type of service is feasible both physically and financially. This viability space is represented in Figure 9 by the area between the two curves. The viability space exists when the break-even curve lies to the left of the capacity curve. If the break-even curve is found to be on the right of the capacity curve, it will imply that the service is not feasible financially at the given fare level, even if maximum ridership is attained.

In the example case of the express bus service on a busway (App. C), assuming a fare of $0.75 per passenger, the break-even ridership for the service with 20-minute headway is ($275.87 ÷ $0.75) or 368 per hour, which is more than the estimated capacity of the service. This is an impractical or technologically infeasible service level.

Characteristics of Capacity and Break-Even Curves

The capacity and break-even curves jointly define the viability space as shown by the striped area in Figure 9. The capacity curve for a particular type of service is fairly stable, and it cannot change unless the vehicle loading characteristics are altered. A break-even curve, on the other hand, is likely to change over time because of changes in unit costs and fare levels. For the purpose of planning at a given time, the unit costs are fixed, and it is the fare level that is a variable for decision-making. If the system configuration for a particular type of service is a variable for decision-making, break-even curves should be derived for alternative configurations. A break-even curve would be sensitive to those system characteristics that influence the cost of service. For example, route length and speed of travel dictate round-trip mileage and time; these influence the vehicle-miles of travel and the number of vehicles and drivers—all important determinants of cost.

Four types of fixed-route bus transit have been selected as representative of services currently available (see Figs. 10 through 13). The route layout and a few key assumptions made as part of the analyses are presented. Break-even curves for low, proportional, and high cost allocations at an average fare level, plus the respective capacity curves, are shown in Figures 14 through 17. The three break-even curve categories result from the way costs are allocated, depending on availability of equipment and facilities described in the following.

Low-cost break-even curves represent a situation in which the guideway and vehicles necessary for providing service are already available, and the decision is to be made based on incremental cost only. Guideway costs and depreciation of vehicles are excluded from the cost analysis. Driver and vehicle operating costs are proportional to the actual service provided.

Proportional-cost break-even curves represent a situation in which guideway costs are shared by all routes and services using the facility, and vehicles are utilized during the entire daily service period. Guideway and vehicle costs are included in the cost analysis but are allocated to the service in question in proportion to the use of these facilities by the service and with respect to their total use by all services. Driver and vehicle operating costs are proportional to the actual service provided.

High-cost break-even curves represent a situation in which additional drivers hired for the service are not utilized during the base period but must be paid for a minimum of eight hours. All other costs are proportional to the actual service provided.

On the other hand, Figures 18 through 21 show break-even curves for high, average, and low fare levels. Costs have been allocated proportionately to derive the curves.

Viability of Fixed-Route and Fixed-Schedule Services

The viability spaces of different modes can be compared to identify break-even points that might suggest patronage levels for which a particular mode or modes might be most appropriate. Planners, however, should compare similar and truly substitute modes. For example, it may not be meaningful to compare an express bus service with a conventional service because they are not good substitutes for each other. An express service on a busway, on the other hand, may be compared with an express service on a shared freeway lane. In comparing their capacities and break-even curves, it is found that the passenger carrying abilities of both modes are very similar, while their break-even curves are quite different. For obvious reasons, an express bus

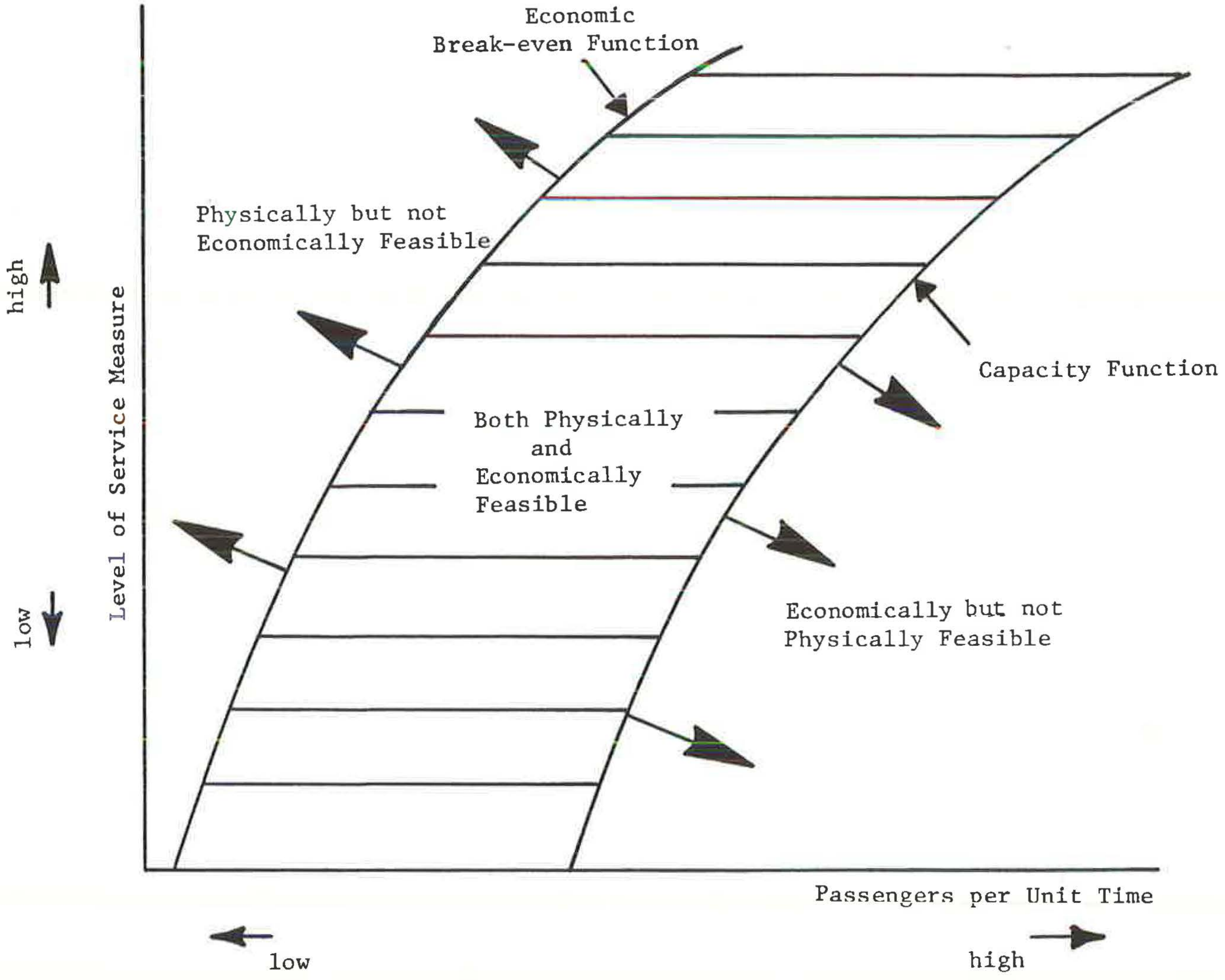


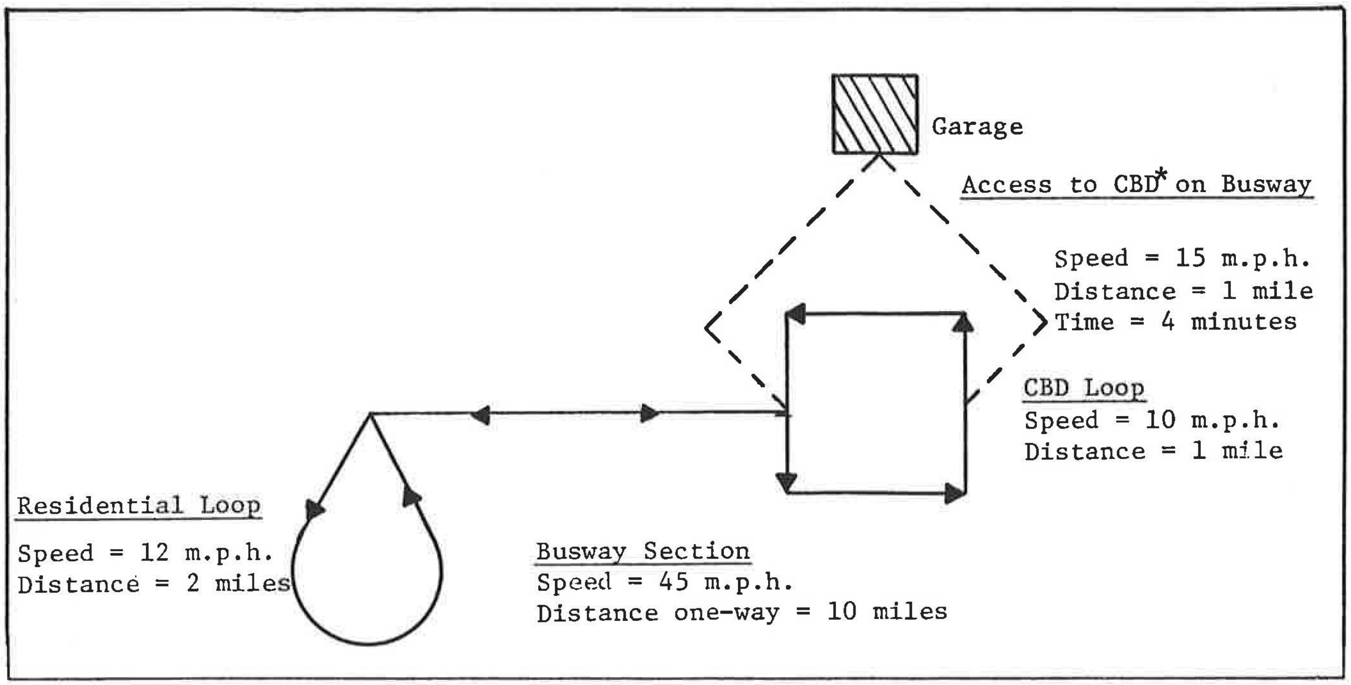
Figure 9. Hypothetical capacity and break-even ridership functions for a specific type of transit service.

service on a busway would require high fare and patronage levels for meeting its large investment in fixed guideways. Actually, even for a fare of $1.00 per ride, the capacity curve was found to be to the left of the break-even curve, implying that it would be impossible to generate enough revenue to match the cost. In the case of an express bus service on a shared freeway lane, the guideway cost is avoided and, thus, it has a good potential for at least a break-even operation.

Comparing the capacity of an express bus service on a reserved bus lane along an urban arterial with that of conventional bus service shows similar characteristics. It also may be noted that conventional service capacity is greater than that of the express bus modes, primarily because of higher passenger turnover. A comparison of break-even curves for the two regular frequent-stop bus services shows that bus service along a reserved bus lane would require fewer passengers than conventional service for a break-even operation. The greater viability of bus service on a bus lane is partly derived from the higher speed allowable, which increases productivity of equipment and labor. It also should be pointed out that the guideway-related cost for the reserved bus lane was assumed to include a few items of implementation cost, such as expenditures for traffic signs and pavement markings. It is interesting to note that in the case of a conventional bus service at the low fare of $0.30 per ride, the break-even curve was to the right of the capacity curve, which implies that it would be impossible to generate enough revenue to match the cost at that fare level.

Application of Break-Even Curves for Bus Service

Break-even curves provide a convenient tool for planners in a quick preliminary assessment of the feasibility of a proposed service. For instance, a market segmentation study may reveal there is potential for a commuter express service between a residential area and the CBD, with approximately 100 residents of the area using the service in the morning peak hour, provided it has a headway of 20 minutes or less and the fare is kept below $0.60 per ride. With this information the planner can examine the break-even curves in Figure 15 (which are derived for a fare level of $0.60) and three different contexts for cost. The capacity curve immediately reveals that it is physically



Assumptions:

1. Cost of guideway = $2.5 million per mile.
2. Warrant for guideway and cost allocation basis:
   50 buses per hour in peak direction
   Cost allocation based on proportion of peak direction buses used in desired service during 4 hours of peak service per day.
3. Equipment cost = $64,000 per 50 passenger bus (salvage value = $16,000 has been deducted, where service life = 12 years) or $3.13 per vehicle-hour.
4. Driver wages = $8.00 per pay-hour including fringe benefits.
5. Operating costs - $0.35 per vehicle-mile.

*Central Business District

Figure 10. Route layout and other characteristics of express bus service on busway.

feasible to accommodate 100 riders with a 20-minute headway, the capacity of such a service actually being close to 200 riders per hour. However, from the standpoint of cost and revenue, the minimum hourly ridership that would be necessary for a break-even operation is 95, 115, and 145 for the low-, proportional-, and high-cost options, respectively. With this information, the planner can contact the transit authority to determine the availability of labor and equipment. If, for instance, the planner finds that the situation necessitates the high-cost option, because additional drivers must be hired and paid for a minimum of 8 hours of service, the planner will know that the expected ridership of 100 is far less than the break-even ridership of 145. Under these circumstances the planner will have to find a source of subsidy if the express service is to be provided. Otherwise, the planner may advise the transit authority to wait until a situation arises when the conditions corresponding to the low-cost option would prevail.

Another example may be cited of a regular frequent-stop bus service along an arterial roadway. A city may agree to provide a reserved bus lane along the roadway, provided certain related costs, such as pavement markings and new traffic signs, are borne by the transit authority. The question may arise as to whether these costs are reasonable through increased efficiency or if a new source of subsidy has to be found. The planner can compare break-even curves for the existing regular bus service with those for the expedited service to get a feel for the consequences, if any, of such a change. The curves of Figures 16 and 17 indicate that the new service along a reserved bus lane would require fewer passengers for a break-even operation. Such a service may be expected to be cost effective because of increased productivity of the buses. It is reasonable to assume that the ridership will remain stable and may even increase; therefore, the financial situation of the route may improve. It is possible that the additional costs for implementation would be recovered. Again, factors other than cost need to be considered in an evaluation process, but cost will remain an important element in assessing the practicality of an incremental change in transit service.

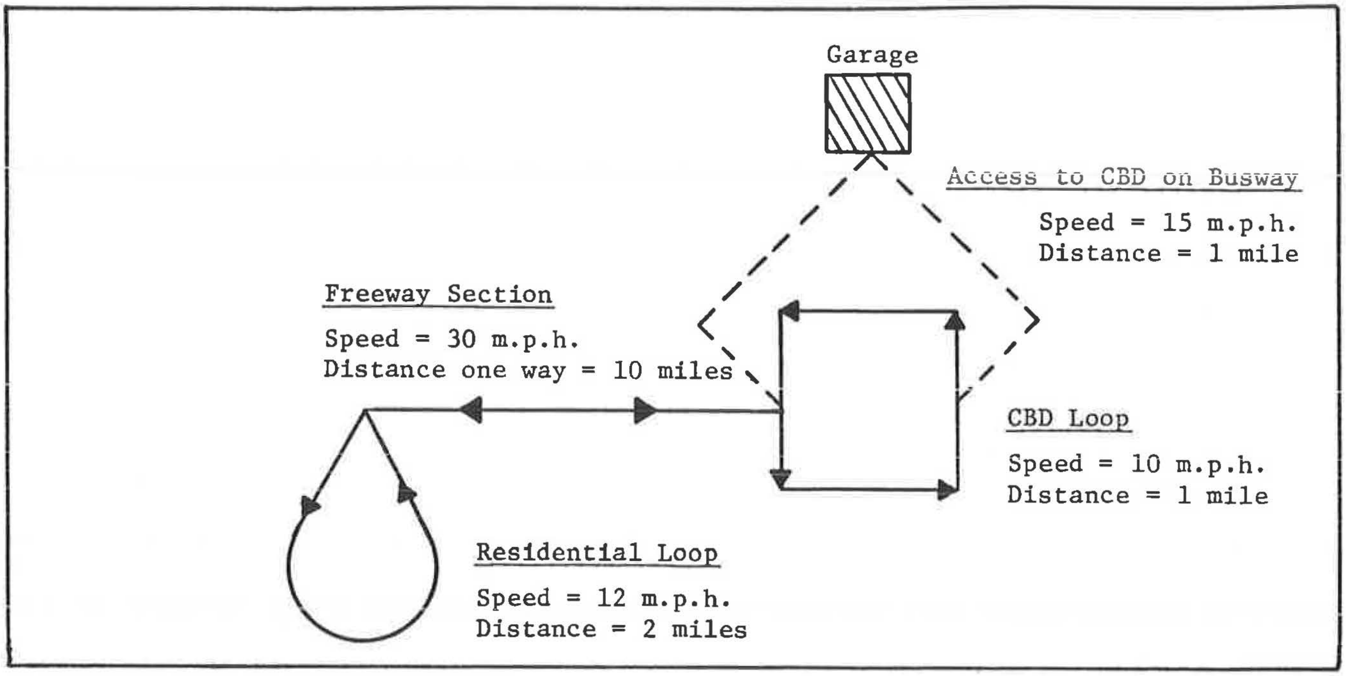
DERIVATION OF CAPACITY AND BREAK-EVEN CURVES FOR DEMAND RESPONSIVE SERVICES

There is a subtle, but significant, difference between the supply characteristics of a fixed-route, fixed-schedule service and a demand responsive system. As discussed earlier, one of the important measures of the level of service of a fixed-route, fixed-schedule service is the frequency (which is related directly to the passenger carrying capacity) of the service. Thus, level of service and capacity can be increased simultaneously by increasing the number of vehicles, because the productive capacity of individual vehicles remains constant. In the case of a demand responsive service, the productive capacity of individual vehicles varies inversely with the level of service. Thus, when the level of service is improved by increasing the number of vehicles (which decreases wait and travel times), system capacity would not increase because capacity productivity of individual vehicles would decrease. Similarly, if the number of vehicles is increased for the purpose of increasing capacity and if productivity of the individual vehicles does not change, level of service cannot be improved.

For demand responsive service, level of service and capacity cannot be maximized simultaneously by increasing the supply of vehicles. This is a deterrent to the derivation of the viability space in the same manner as used for the fixed-route, fixed-schedule services (i.e., by plotting both capacity and break-even cost values as functions of the level of service). The viability space of a demand responsive service can be derived by analyzing the capacity and break-even cost values as functions of the number of vehicles in use. This procedure can be repeated for different values of levels of service, and a viability space can be derived for each value.

System Design Procedure for Deriving Capacity and Break-Even Cost Values

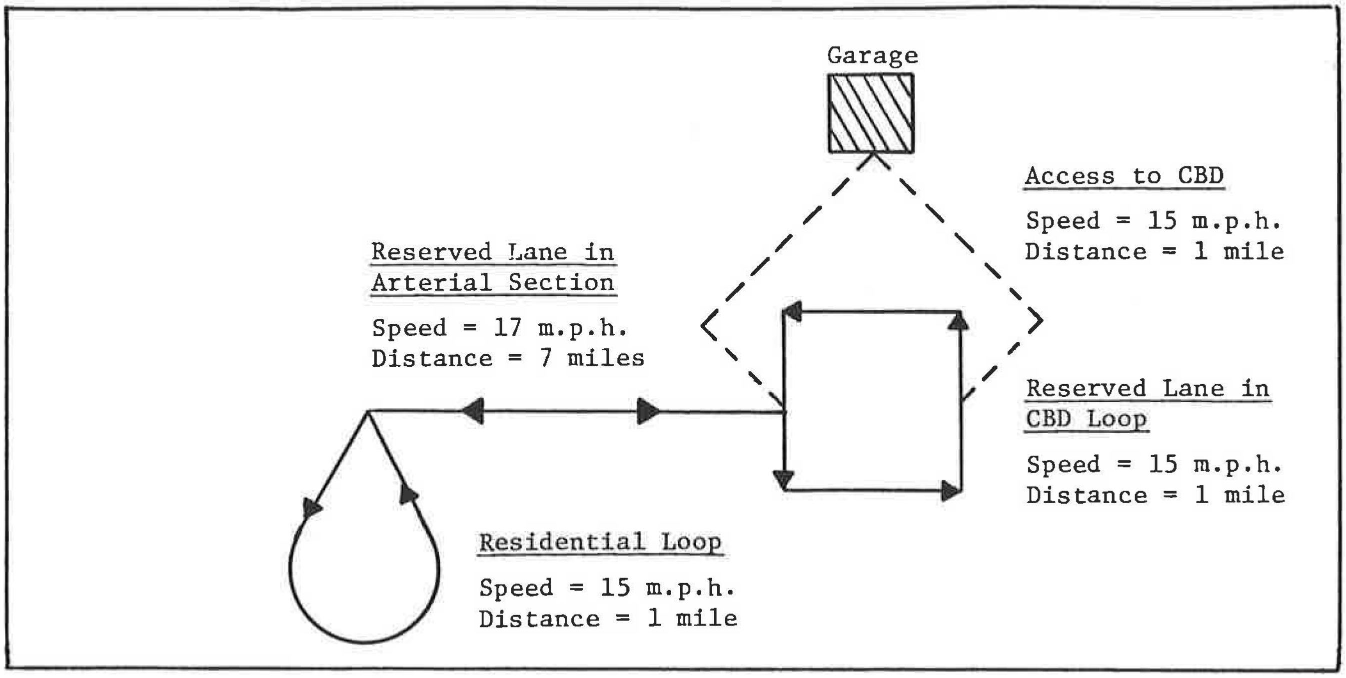
Unlike the case of a fixed-route, fixed-schedule service, many operating characteristics of a demand responsive service are not predictable. No straightforward relationship between the number of vehicles and their productive capacity can be developed similar to that for a fixed-route,



Assumptions:

1. Cost of roadway = Disregarded
2. Equipment cost = $64,000 per 50-passenger bus ($16,000 salvage value already deducted), service life of 12 years, $3.13 per vehicle-hour.
3. Driver wage = $8.00 per hour (including fringe benefits).
4. Operating cost = $0.35 per vehicle-mile (including maintenance, fuel, oil and tires).

Figure 11. Route layout and other characteristics of express bus service on shared freeway lanes.



Assumptions:

1. Reserved guideway implementation costs = $75,000
2. Warrant for implementation and cost allocation basis: 30 buses per hour in peak direction during four peak hours plus 10 buses per hour during eight off-peak hours.
3. Equipment cost = $64,000 per 50-passenger bus (16,000 salvage value already deducted), service life = 12 years, $3.13 per vehicle-hour.
4. Driver wages = $8.00 per hour (including fringe benefits).
5. Operating costs = $0.35 per vehicle-mile (including maintenance, fuel, oil and tires).

Figure 12. Route layout and other characteristics of bus service on reserved bus lanes or urban arterials.

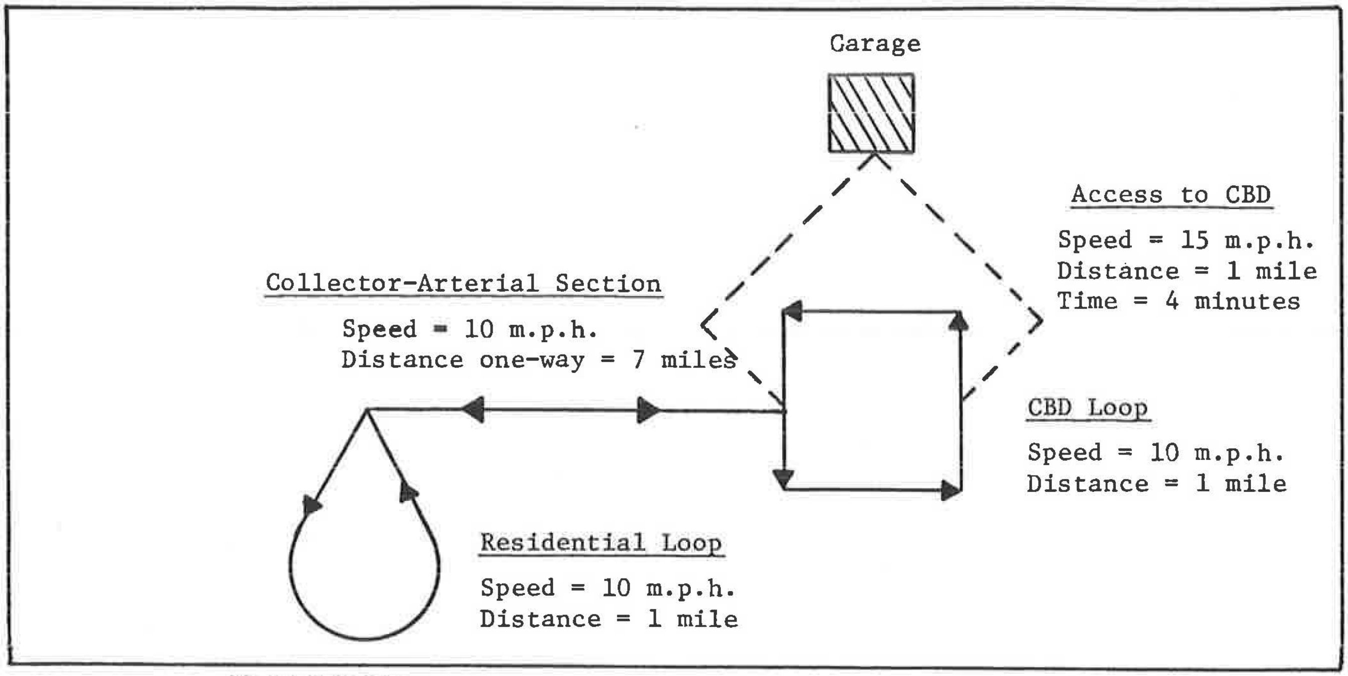
fixed-schedule service. The synthesized equation developed at Massachusetts Institute of Technology, based on a simulation analysis (see App. B), is one of the only tools available at this time to estimate capacity values corresponding to different numbers of vehicles. This model, however, includes several other parameters—service area and vehicle speed—which may vary from case to case. The operating strategy also may vary. There are numerous situations with unique capacity characteristics. The same is true for break-even cost values because unit costs will vary from case to case.

It is important not to overlook the unique characteristics of each area and its transit service. An analysis of a typical case would give insight into the capabilities and constraints of similar services. Therefore, capacity and break-even curves were derived for a system with the following characteristics:

1. Service area = 6.25 and 12.0 sq mi.
2. Vehicle speed = 15 mph.
3. Operating strategy = many-to-many.

The capacity curves shown in Figures 22 and 23 were derived for four specific levels of service represented by values of 3, 4, 5, and 6, respectively, where L is the ratio of total time (wait time plus ride time) for a dial-a-ride service to the total time for an automobile. Break-even curves were derived for flat fares of $0.50, $0.75, and $1.00 per ride. Unit cost values of different items and other assumptions used in the analysis are given as follows:

1. Driver cost = $8/hour, including fringe benefits.
2. Capital cost (amortization of depreciation used 10 percent interest rate; useful life of van is 4 years; useful life of radio, farebox, and dispatch console is 10 years):
    a. Van = $9,600 or $12,000 cost $2,400 salvage value.



Assumptions:

1. Cost of roadway = disregarded
2. Equipment cost = $64,000 per 50-passenger bus ($16,000 salvage value already deducted), service life of 12 years, $3.13 per vehicle-hour.
3. Driver wages = $8.00 per hour (including fringe benefits).
4. Operating costs = $0.35 per vehicle mile (including maintenance, fuel, oil and tires).

Figure 13. Route layout and other characteristics of conventional bus service.

   b. Radio = $1,500/van.
   c. Farebox = $500/van.
   d. Dispatch console = $4,000 (including base radio).
3. Gas, oil, and maintenance = $2.92/hour.
4. Dispatcher wages = $8/hour, including fringe benefits.

Viability of Demand Responsive Service

An examination of capacity and break-even curves for a demand responsive service in two locales of different sizes revealed a few noteworthy characteristics. The capacity in terms of the number of passengers served per hour appeared to be very low for a high level of service, which is reflected by a low value of L. For example, in the case of the service area of 6.25 sq mi, the number of passengers that can be served with five vehicles at the level of service represented by L = 3 is 22 per hour. With a lower level of service represented by L = 4, the capacity with the same number of vehicles increases to 43. The capacity also increases more than proportionately as more vehicles are added, which implies that the productivity of vehicles is related to the number of vehicles in operation in a given area.

It is clear from the capacity and break-even curves that only where there are low levels of service and high fare levels can demand responsive service be expected to generate enough revenue to cover costs. Of course, cost characteristics may vary from case to case, and this observation is valid for the assumptions related to cost described earlier.

Application of Break-Even and Capacity Curves for Demand Responsive Service

Fixed-route loop bus routes circulating through residential areas are fairly common in small and medium size urban areas, and proposals for replacing them with demand responsive feeder service are made frequently. Capacity and break-even curves can be useful in evaluating such proposals. For example, if the demand responsive service is to accommodate 30 passengers per hour in a service area of approximately 6.25 sq mi, and provide a level of service

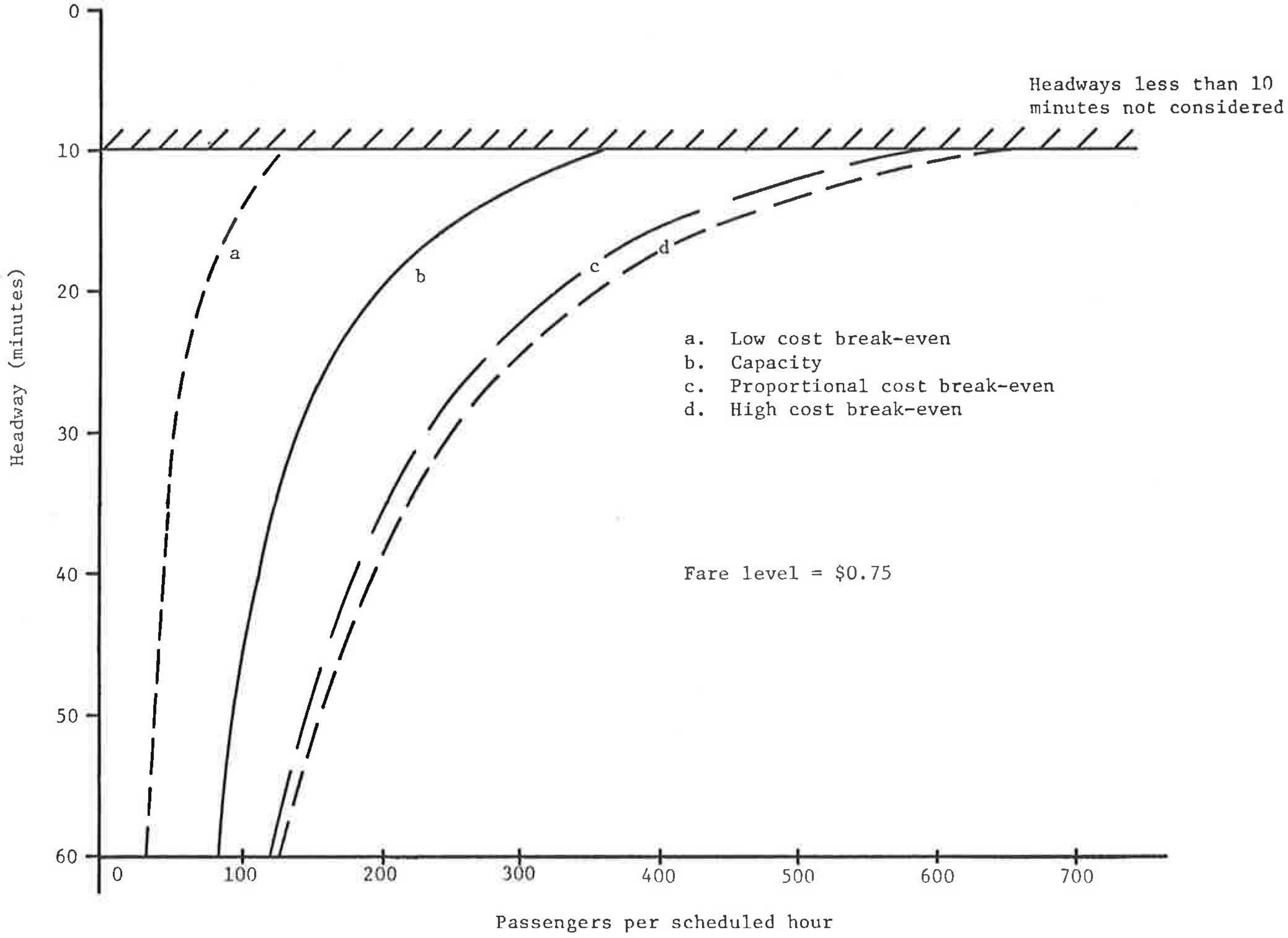


Figure 14. Break-even curves for express bus on busway.

represented by L = 4, the planner can refer to Figure 22 and find that at least four vehicles must be operated. The planners also can see that the proposed service will not break even, even if the fare is $1.00 per ride. To find out the level of ridership that will be required for a break-even operation at $1.00 per ride with four vehicles, reference can be made to the curves: required ridership is 56 passengers per hour. The level of service for this situation would be very low, represented by L = 6.

RIDESHARING COSTS AND SERVICE LEVELS

Ridesharing has been defined as "a form of para-transit which entails prearranged shared rides for people traveling at similar times from approximately the same origin to the same destination" (*25*). In lightly populated areas with diffuse trip patterns, ridesharing involves informal pooling via van or automobile. In higher density areas, opportunities are available to form larger pools and van/auto pooling can be supplemented by subscription or express bus service tailored to the travel needs of a specific travel market.

The term "ridesharing" commonly is associated with individuals traveling together between residential areas and work sites on a regular basis. Work trips are highly structured and repetitive, thereby affording opportunities to increase transportation efficiencies (i.e., reduced vehicle-miles of travel (VMT)) through higher vehicle occupancies. In fact, ridesharing can be applied to other trip purposes for individuals living in a common area, such as a senior citizen complex or neighborhood. Many of these services already are provided through informal arrangements, neighborhood clubs, and social service agencies. As with work trips, the choice of rideshare mode must depend on a detailed assessment of travel needs and costs. For many applications, ridesharing may be a private responsibility with public sector input serving as a catalyst and promoter.

One characteristic of ridesharing is that the service is provided on a prearranged basis and headways are not maintained. Thus, it is not possible to define the viability spaces discussed in the previous sections for fixed-route and fixed-schedule services with regular headways. The cost elements to be included in a ridesharing analysis depend on how the services are provided. For example, carpools and some private vanpools have participants driving their own private vehicles either for cash compensation or free transportation in exchange for driving responsibilities. Employee or third party provided vans and bus operations usually involve payment for a ride, independent of whether the vehicle is owned by a club, employer, public agency, or transit service. Usually, in a subscription service, the driver receives compensation and the passengers pay in advance (*26*). Often pools, particularly carpools, rely on informal arrangements, and the driver may not receive direct financial compensation. However, some rideshare services are organized formally, and in some cases are required to meet certain regulatory and insurance requirements. Typically, organizational and marketing costs are internally borne by public agencies or major employers and are not included in the cost of providing service. The type of drivers used (e.g., volunteers, part-time, or full-time (generally unionized)) will affect service costs. The need to deadhead a vehicle at the beginning and end of a rideshare trip also will influence operating costs. Cost estimates must then consider who is providing the service and how the service is provided. Table 11 summarizes different rideshare modes and shows the diversity of operators and users generally encountered. Appendix E contains a summary of cost relationships used in this section.

Carpooling

The total cost per person to travel 21 work days per month, 10 and 20 mi, respectively, is noted for different vehicle occupancies ranging from 1 to 6 persons per vehicle in Figure 24. Cost estimates are based on unit costs (including fixed and variable costs) of $0.179/mi, $0.146/mi and $0.126/mi to operate a standard, compact, and subcompact car, respectively. For simplicity, a composite cost figure was developed based on a typical distribution of vehicle classes within a local area. For the computations, 52 percent standard, 21 percent compact, and 27 percent subcompact vehicle distributions were assumed, yielding a weighted average of $0.158/mi. Because of the additional vehicle-miles of travel associated with picking up riders and discharging them, trip lengths were increased by 5 percent for an occupancy level of 3 persons per vehicle and by 10 percent for 6 persons per vehicle.

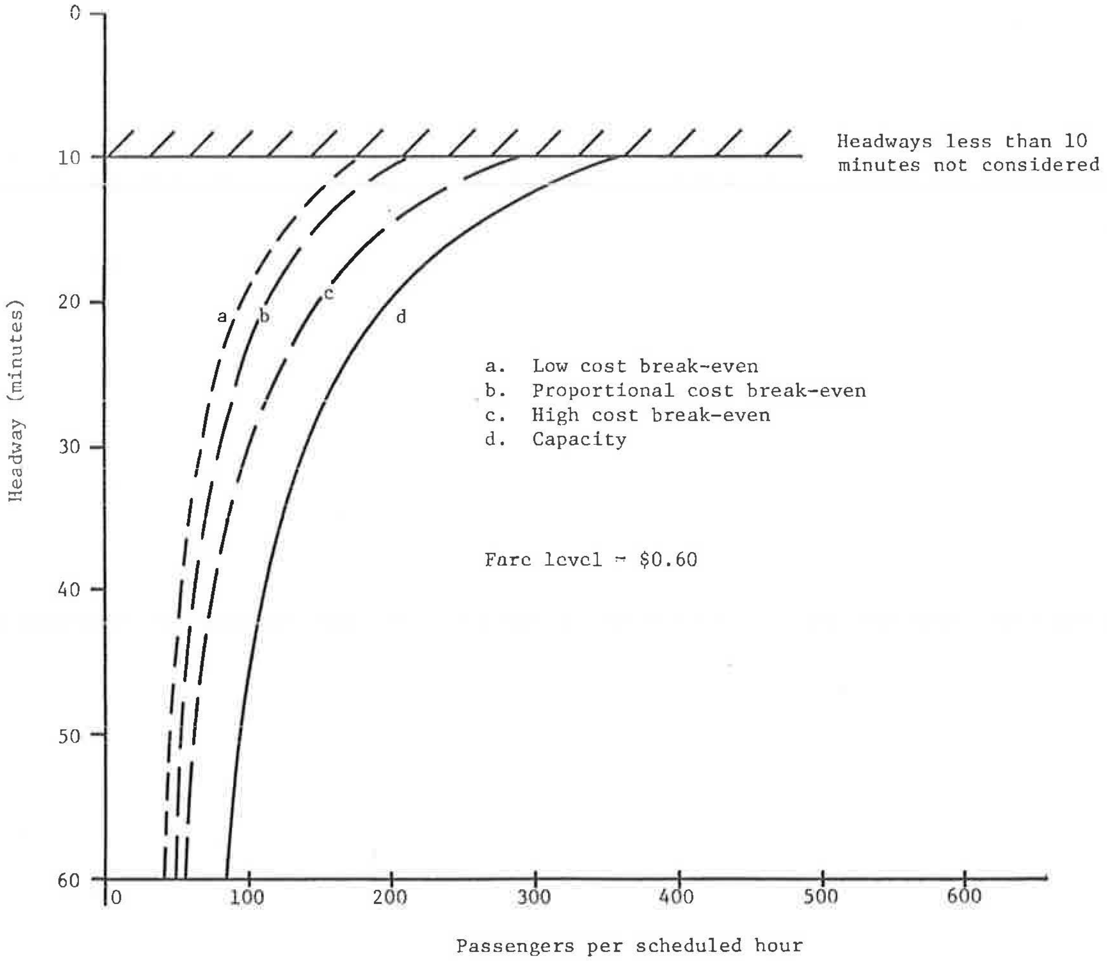


Figure 15. Break-even curves for express bus on shared freeway lanes.

The resulting generalized cost estimates illustrate the impact of vehicle occupancy and trip length on monthly commuting costs per person. The type of automobile utilized (standard vs. subcompact) can easily account for a 30 percent variation in monthly commuting cost. Driving additional miles for picking up and discharging passengers is well within the range of costs encountered by varying the vehicle class.

Figure 24 cannot be used directly to estimate user savings due to increased vehicle occupancies. For example, in the case of rotated driving responsibilities, the commuting vehicle is not sold and the user still needs to pay fixed costs, such as depreciation, license, and insurance. Although these might be at a slightly reduced rate, the real savings result from the elimination of out-of-pocket expenses due to reduced vehicle use. Typically, variable costs represent about 50 percent of the total cost of operating a private automobile.

Vanpooling

The costs of vanpools can vary extensively. In employer-based programs, an indirect subsidy generally is provided for the organization, administration, and promotion of the program. In some programs, incentives might be provided through preferential free parking privileges or direct monetary incentives to van users. As a program matures, "front-end" costs will be eliminated and program administration costs moderated to just sustain the program. Start-up costs have been estimated to be in the range of $15,000 to $50,000 to cover legal, advertising, sales, and administrative costs before the vans begin to operate. Overhead costs are estimated at $20,000 to $40,000 per year for programs using up to 50 vans. These figures were not included in the cost analysis, because they are generally considered as a vanpool subsidy and absorbed. Fixed and variable costs were based on two vanpool programs in operation (see App. E). The curve titled "low cost" represents a vanpool with a monthly fixed cost of $191 and a variable cost of $0.10/mi. The second curve titled "high cost" involves a fixed cost of $278 and a variable cost of $0.13/mi (based on 1976 dollars). For both programs, the unit cost values are within the range typically encountered for vanpools

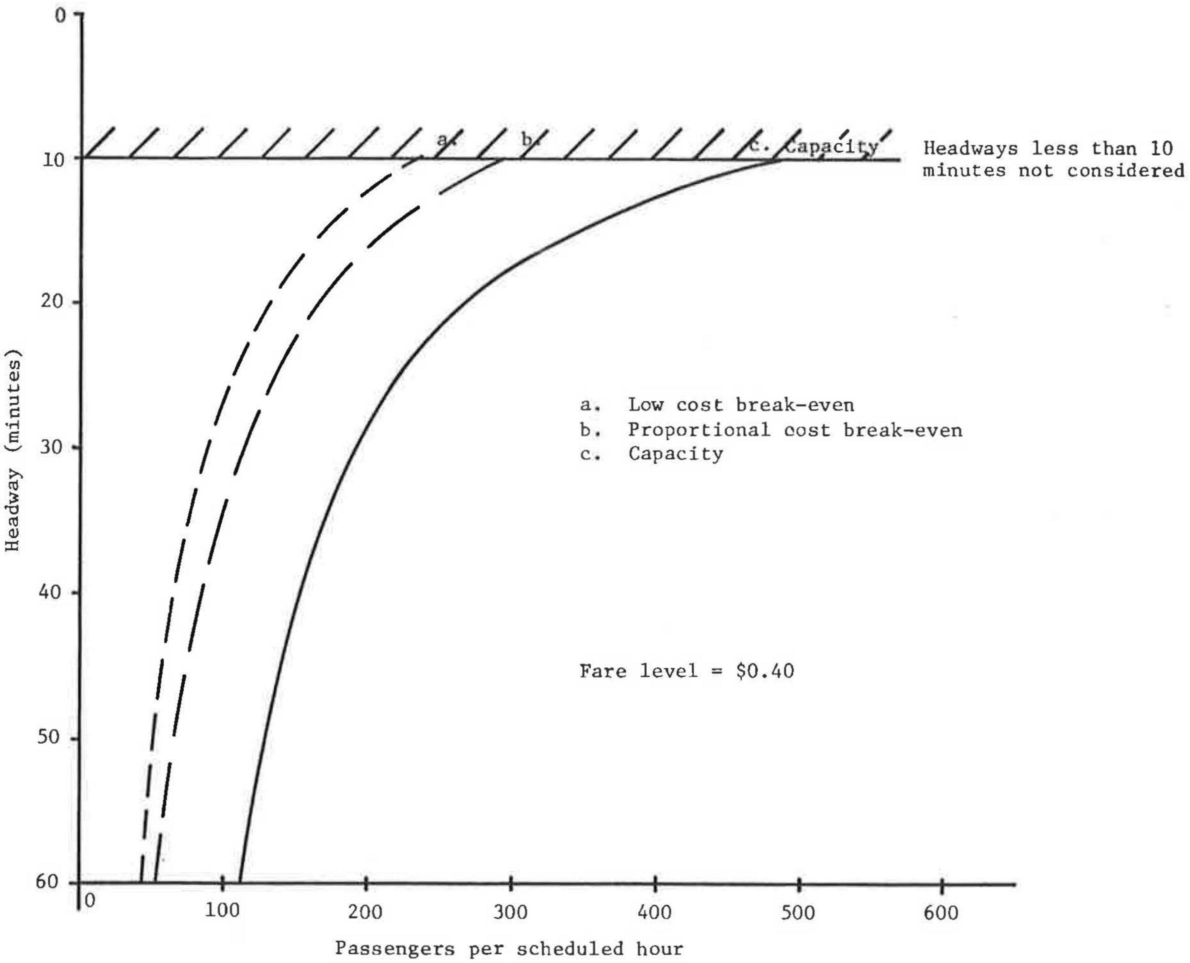


Figure 16. Break-even curves for regular bus on reserved bus lane on urban arterials.

attempting to cover all operational but not administrative costs. Cost variations between the two programs depend on vehicle size, number of back-up vehicles, size of the program, and administrative details.

For comparative purposes, part- and full-time labor charges for the driver of a van were included in the cost analysis of vanpool programs. In reality, these costs rarely are involved in commuter operations as the driver usually receives free transportation as compensation. In the case of many social service van operations, however, labor charges (either part- or full-time) are involved, and if third party agencies become involved in vanpooling, labor charges for the driver may become more significant.

In operating a van, excess mileage is required in order to pick up and discharge the riders. On the basis of experiences of several vanpool programs, it is estimated that trip lengths might increase by 10 to 30 percent over the corresponding home-to-work-trip distance when driving alone. These distance and time delays can be minimized if there is a good match between riders, but the scope varies with the density of development and the method of pickup (i.e., at door or at a centralized meeting place) (*25, 27*). For the calculations, excess miles were assumed to be 10 percent for vanpools with occupancies of 10 and 15 persons per vehicle.

Typical monthly vanpooling costs per person are plotted in Figure 25 as a function of vanpool sizes for a one-way trip of 10 miles. In Table 12, for the purpose of a sensitivity test, costs of deploying vans using different types of labor were compared for one-way trip lengths of 10 and 40 miles, with an average vehicle occupancy of 10 persons. For analysis purposes, a van cost of $191 per month plus $0.10/mi was used. Table 12 shows that labor costs can have a substantial impact on the cost of vanpooling. With smaller vehicle capacities, it is impractical to absorb full-time labor charges. Even the use of part-time labor almost doubles monthly costs per rider. The attractiveness of vanpooling lies in its low cost, which can be attained only when labor charges are avoided.

A second aspect of vanpooling is the additional costs incurred in picking up and delivering riders along the route. It has been reported that front door pickups can require 10 to 30 percent additional vehicle-miles; the resulting costs are given in Table 12. Excess vehicle-miles

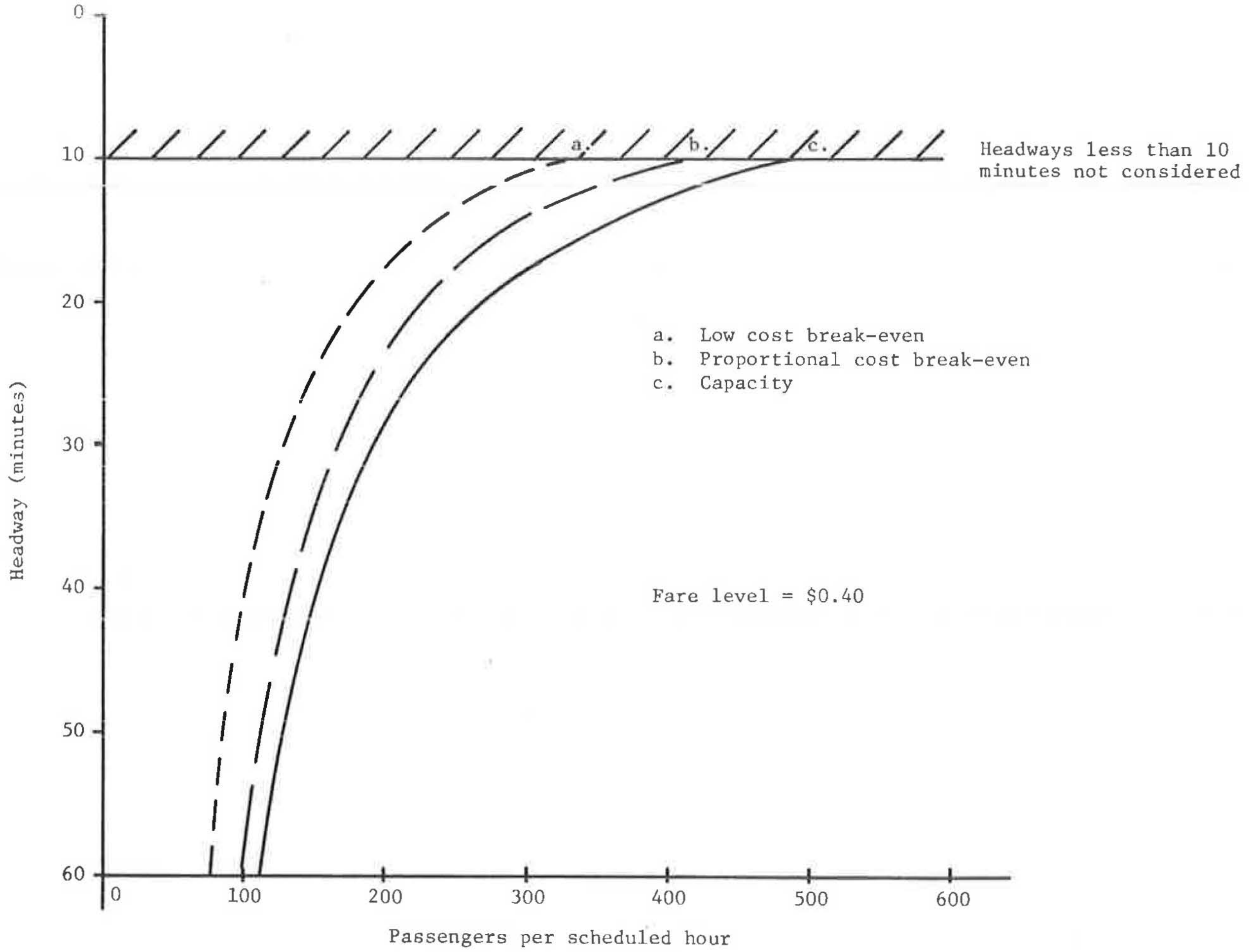


Figure 17. Break-even curves for conventional bus service.

have little influence on monthly cost per rider, even if trip lengths are increased 30 percent. Of course, if labor costs and deadhead miles are added, the cost becomes greater.

Buspooling

The cost of subscription bus service varies extensively with equipment, routing, and labor agreements. Buspools can be operated in a fashion similar to vanpools by using part-time paid drivers, and by avoiding deadheading through parking the bus at the driver's home and work site. If full-time professional driver wages are to be included, the higher cost will seriously affect the appeal of pooling. Many public transit services with unionized labor are restricted to utilizing full-time drivers. Profitable service in these cases depends on the ability to utilize full-time drivers and equipment effectively during off-peak hours between express runs. Deadhead mileage can also become a significant cost factor (*28*). Private operators are able to utilize part-time drivers, reducing both the hours of commitment to the drivers and resulting wage payments. For the generalized analysis, unit costs for labor of $8.00 per hour, depreciation of $3.13 per hour, and out-of-pocket costs of $0.35 per mile were used in the base case for analyzing express bus service. These costs vary for different assumptions of hourly wage, need for deadheading, and availability of compensatory work. Monthly buspooling costs per person are plotted in Figure 26 for a one-way commuting distance of 10 miles. These calculations illustrate the importance of providing compensatory work for the driver in order to spread labor and depreciation costs across various services. When deadhead miles are reduced, driver and equipment become available for other functions and cost reductions can be achieved.

Depending on accounting procedures, vehicle depreciation costs frequently are ignored or taken only at 10 to 20 percent of full value to represent cost sharing in vehicle purchase. As noted, these assumptions can have a significant impact on the resulting cost to provide service. Ignoring depreciation will tend to underestimate the total cost of bus service.

The generalized cost analysis can be modified to reflect localized unit costs and the service specifications being considered by the planner. However, cost variations point

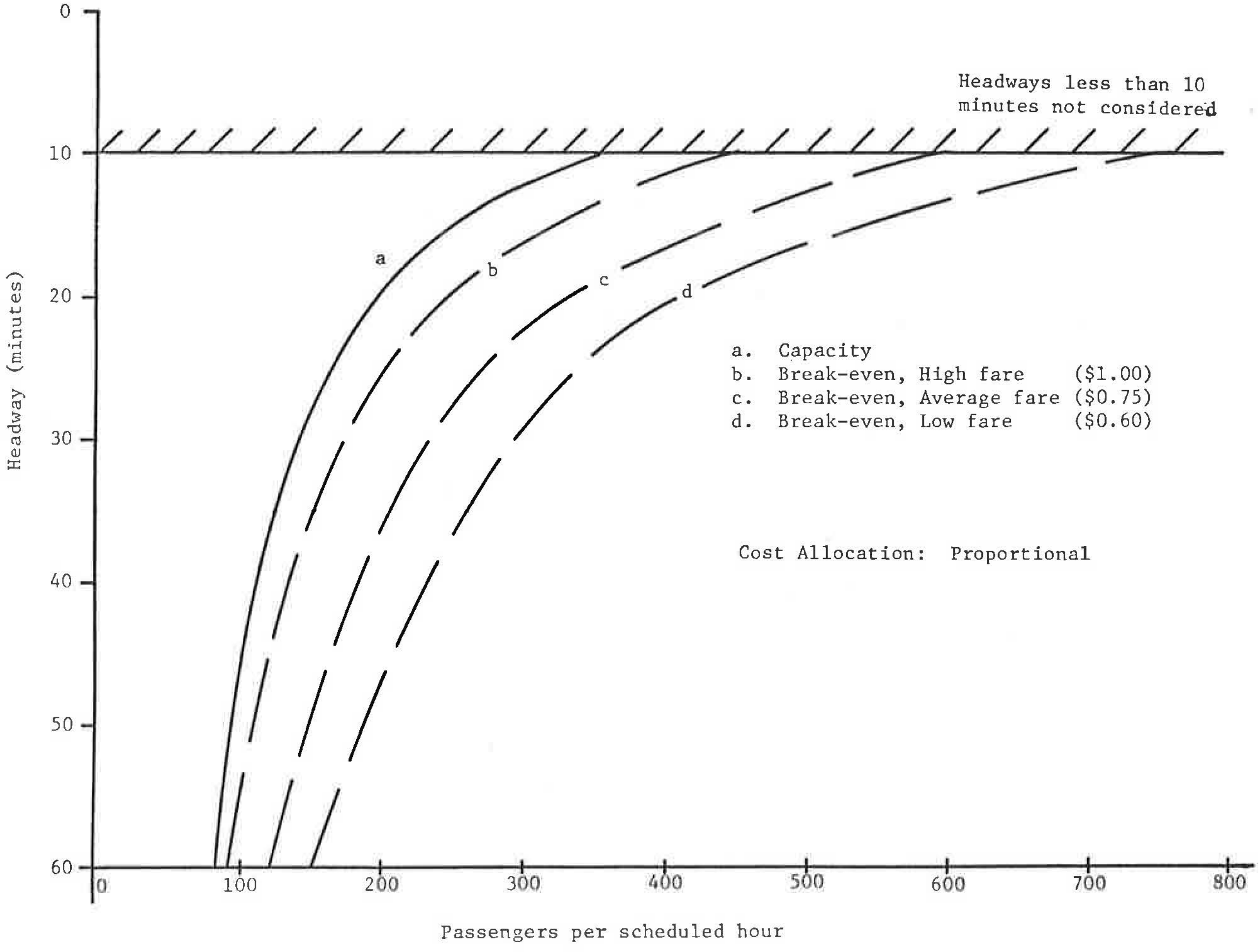


Figure 18. Capacity and break-even curves for express bus on busway.

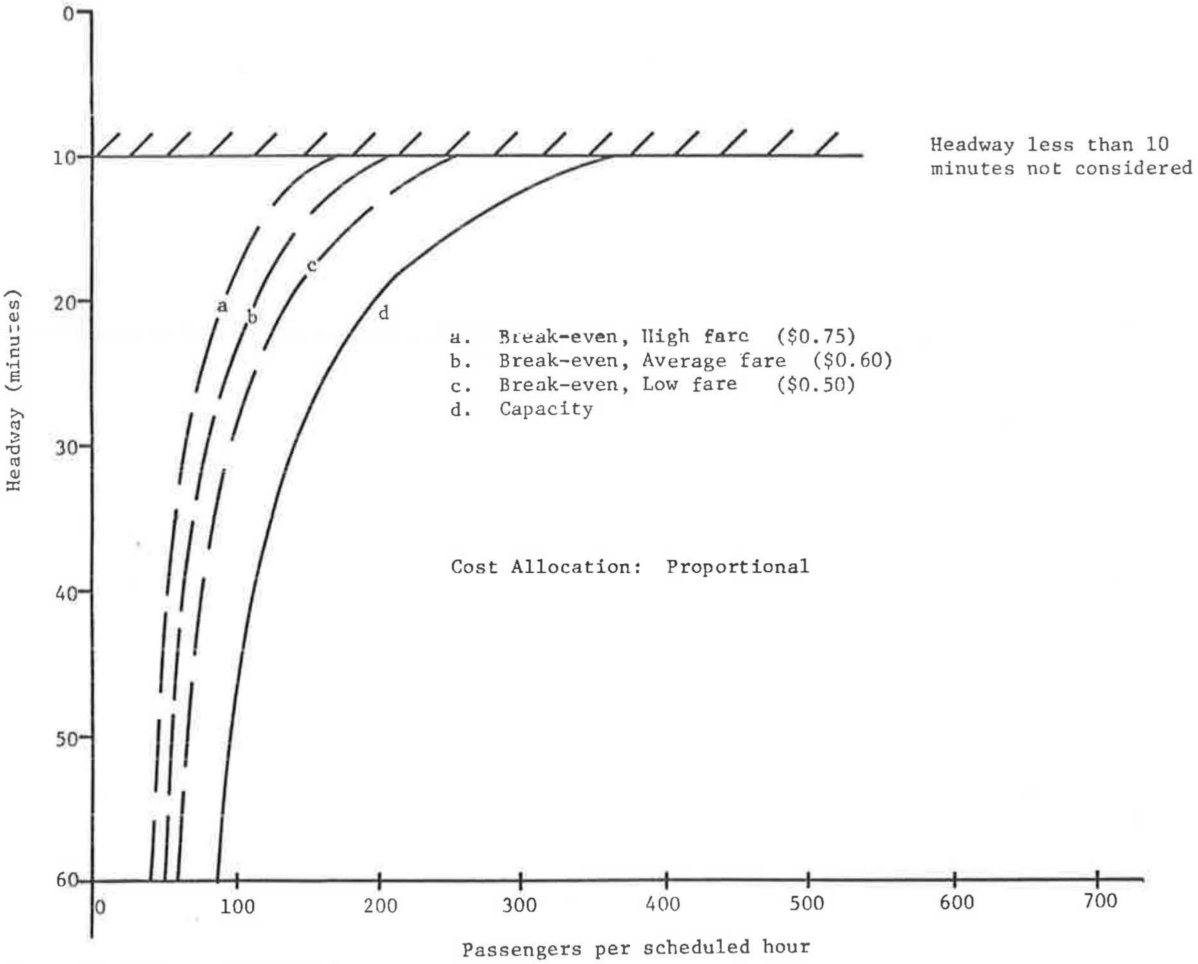


Figure 19. Capacity and break-even curves for express bus on shared freeway lanes.

out the need to consider details of how the service is to be provided. Lowest costs can be achieved if part-time labor can be used, if off-peak hour compensatory work can be found, and if deadhead miles can be reduced. In general, as trip length increases and pool size increases, the percentage differences between different buspooling service options narrow in cost, although absolute dollar differences might remain significant.

RIDESHARE BREAK-EVEN ANALYSIS

The decision as to which ridesharing mode or mix of modes to select for a particular market segment depends on the specific characteristics of that market. On the basis of the assumption that cost is a major factor in the decision, break-even points can be identified for carpools, vanpools, and buspools. These are defined as the pool size at which one rideshare mode becomes less costly per person than another. All unit cost values are based on the assumed values presented in this report, and they should be adjusted before application to a local analysis. The intent of this section is to provide generalized relationships that can be used as a first approximation for assessing the potential application of a rideshare mode to a predefined market

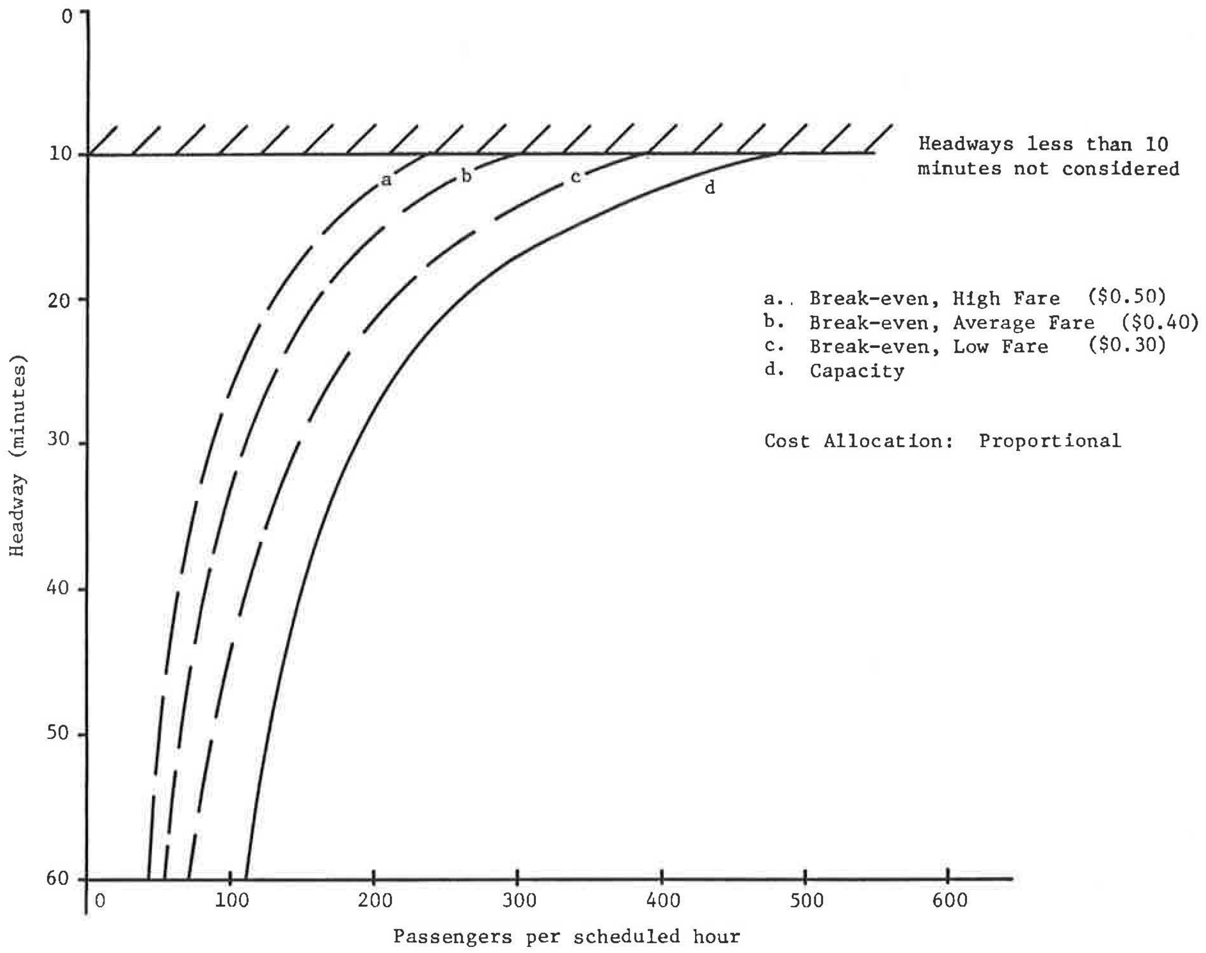


Figure 20. Capacity and break-even curves for regular bus or reserved bus lane on urban arterials.

segment. The values given in Tables 13, 14, and 15 suggest the group sizes required to support a particular rideshare mode as the minimum cost option for different trip lengths.

Reference can be made to these tables to obtain the general viability of a particular rideshare mode. For example, Table 13 suggests that on a one-way 60-mile trip it would require a group size of four to justify a buspool as the lower cost alternative if a part-time driver could be employed, if the vehicle could be parked at the work site and residence of the driver, and if a fully depreciated vehicle could be used. This is based on the assumption that the alternative travel mode in the comparison would be individuals driving alone in their private automobiles. As private automobile occupancies increase to 2 and 3 persons per vehicle for the situation cited, the minimum buspool size increases to 7 and 10 persons, respectively. At an average automobile occupancy of 6, the buspool would be selected only with a minimum pool size of 13. Of interest to the planner is the finding that this particular buspooling option does not require large groups to justify the service.

In fact, services similar to this have proven to be quite effective. For example, it has been reported that Colonial

Transit Company in Virginia has been successful in operating a subscription bus service with "moonlighting" drivers who are employed at the work site (*29*). Drivers are paid for their driving time, and all passengers have reserved seats. A conductor, who also works at the employment site, collects fares and serves as transportation coordinator and receives free commuter service in lieu of direct payment. In order to avoid deadheading, the bus is parked at the plant and the driver's home.

As the buspooling option accumulates more labor and depreciation costs and requires deadheading, the minimum pool size also increases. With a 60-mile trip length at carpool occupancies of 6 persons per vehicle and with full labor charges being allocated against the buspool (no compensatory work available for the driver), buspools fail to be cost competitive.

A comparison of vanpools with carpools (Table 14) shows that only when a person is driving a private vehicle

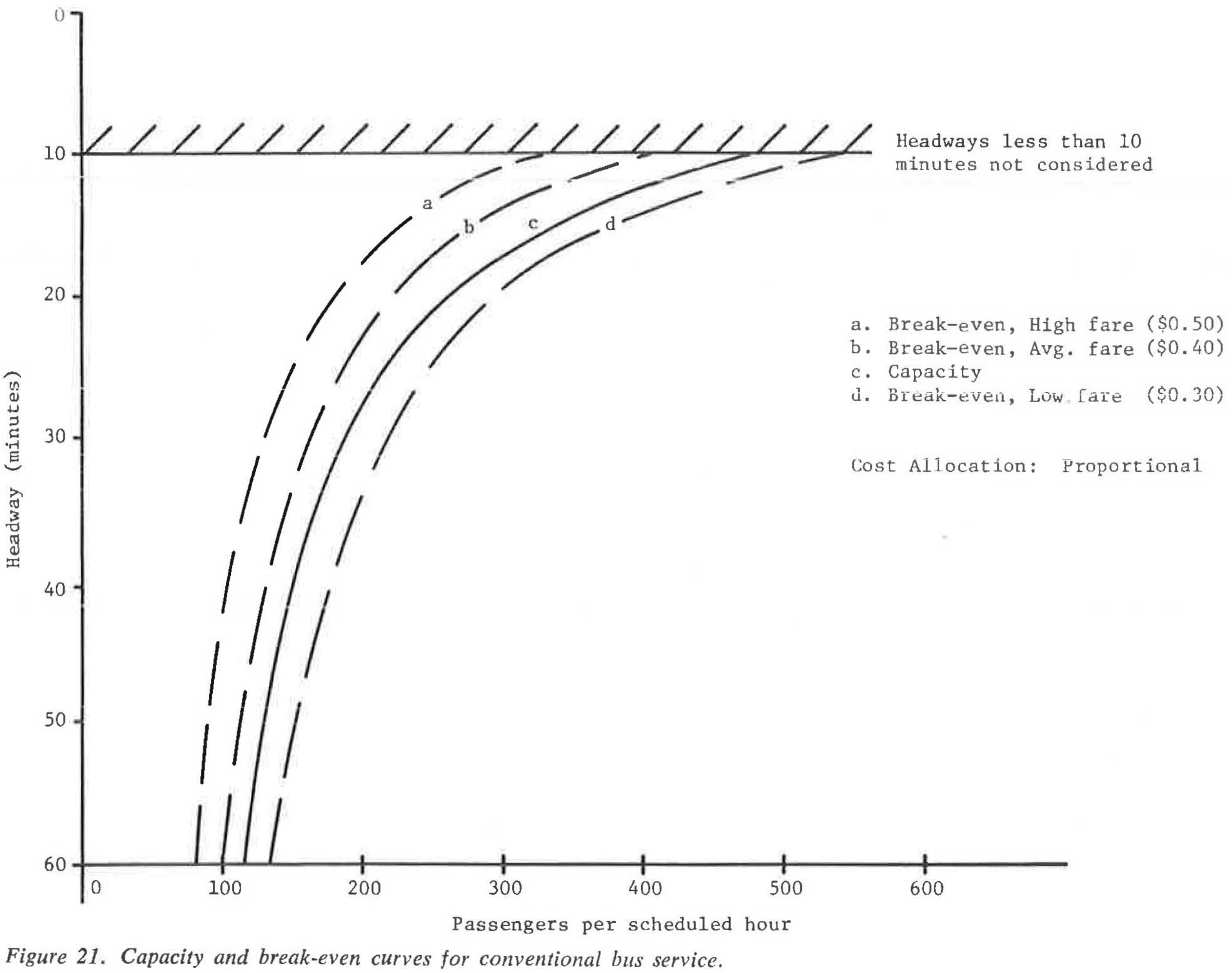


Figure 21. Capacity and break-even curves for conventional bus service.

alone can the cost of full-time labor for driving a van be absorbed. Similarly, part-time labor charges for van driving can be absorbed only when the competing mode is driving alone or carpooling with two persons per vehicle. Vanpools are most competitive with carpools when no labor charges are involved and at trip lengths in excess of 10 mi. A sensitivity check revealed that for the range of vanpooling costs used in this study and with van occupancies of 10 and 15 persons per vehicle, the minimum group sizes increase only by a few persons from those stated in Tables 14 and 15. However, if it is assumed that the fixed cost of private vehicle ownership cannot be eliminated and only variable costs can be reduced when fewer vehicles are used, the minimum pool size required to support buspools and vanpools in comparison to carpools would be double those values cited.

Table 15 provides a cost comparison of buspooling vs. vanpooling. The table identifies the smallest pool size re-

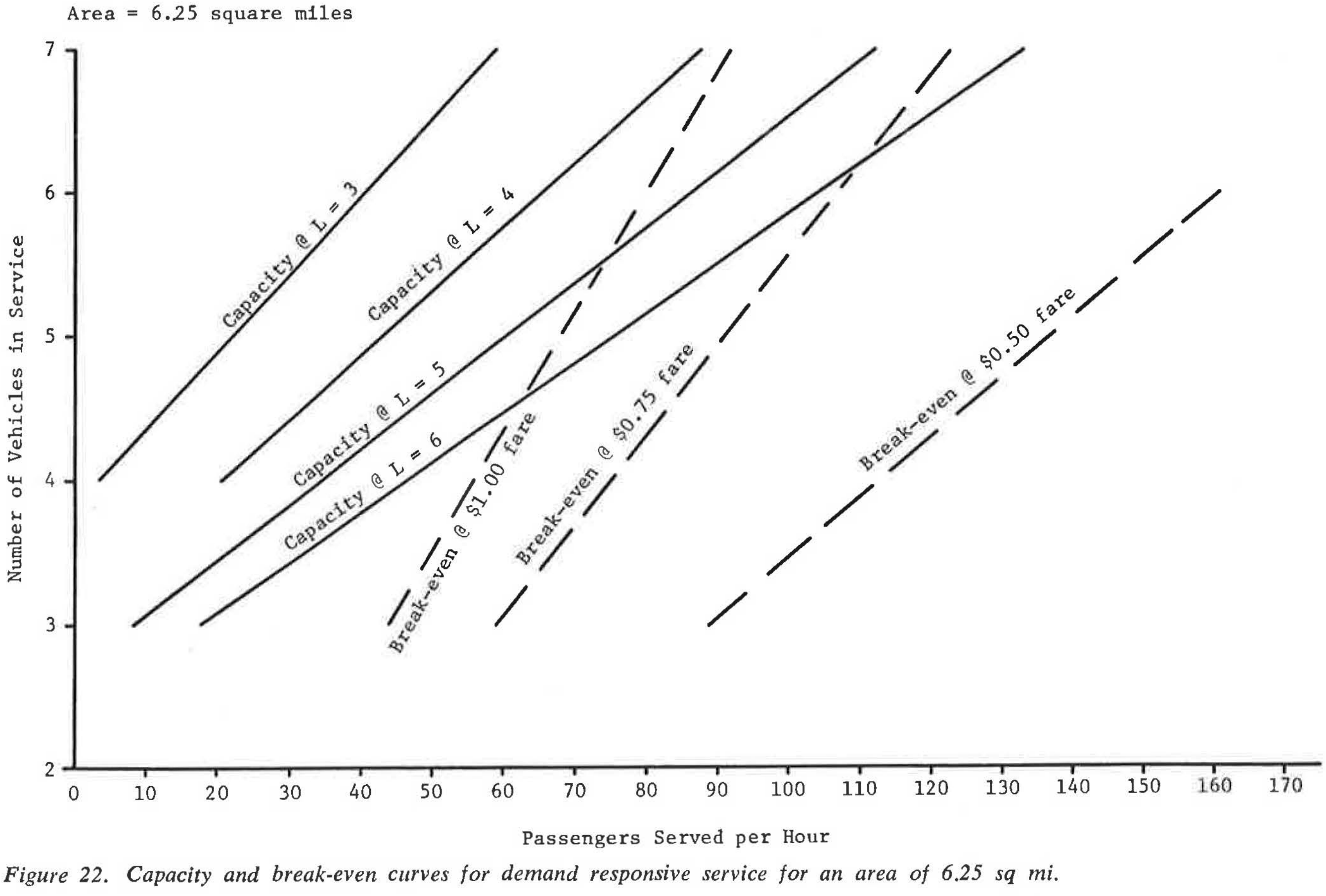


Figure 22. Capacity and break-even curves for demand responsive service for an area of 6.25 sq mi.

quired to support buspooling. Again, labor costs are an important factor in determining the minimum cost alternative. It is important to note that the inclusion of depreciation charges against the bus significantly affects the minimum group size required.

These two-way cost comparisons provide some "first-cut" guidance on the minimum pool size required to support a particular rideshare mode. Because determining which mode is to be selected for further study and experimentation may depend on the local validity of the cost comparison, it is important that planners account for all relevant costs and closely consider the average vs. marginal cost issue. Although the two-way comparisons were provided for specific unit cost values and vehicle occupancies,

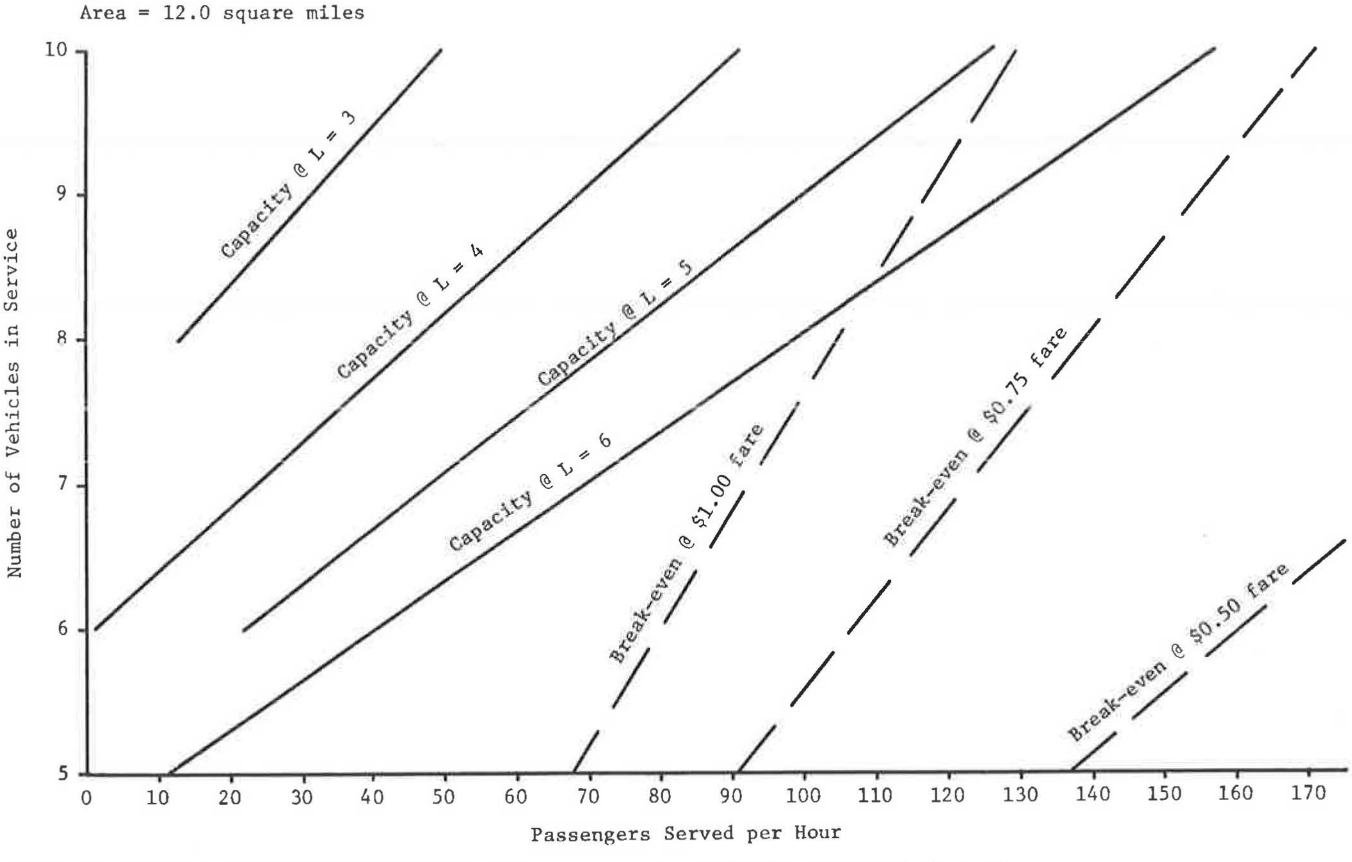


Figure 23. Capacity and break-even curves for demand responsive service for an area of 12 sq mi.

the material in Appendixes C and E should permit the planner to tailor the cost comparison to the local situation.

SUMMARY

This chapter has defined the viability spaces of various headway-oriented bus services and demand responsive services and the minimum pool sizes required for economically supporting various rideshare modes. An analysis of these relationships permitted the development of some generalizations. However, for an actual application, the planner should refer to Appendixes B through E and to the procedures on how to tailor the cost estimate to the local situation. Costs were found to be highly sensitive to trip

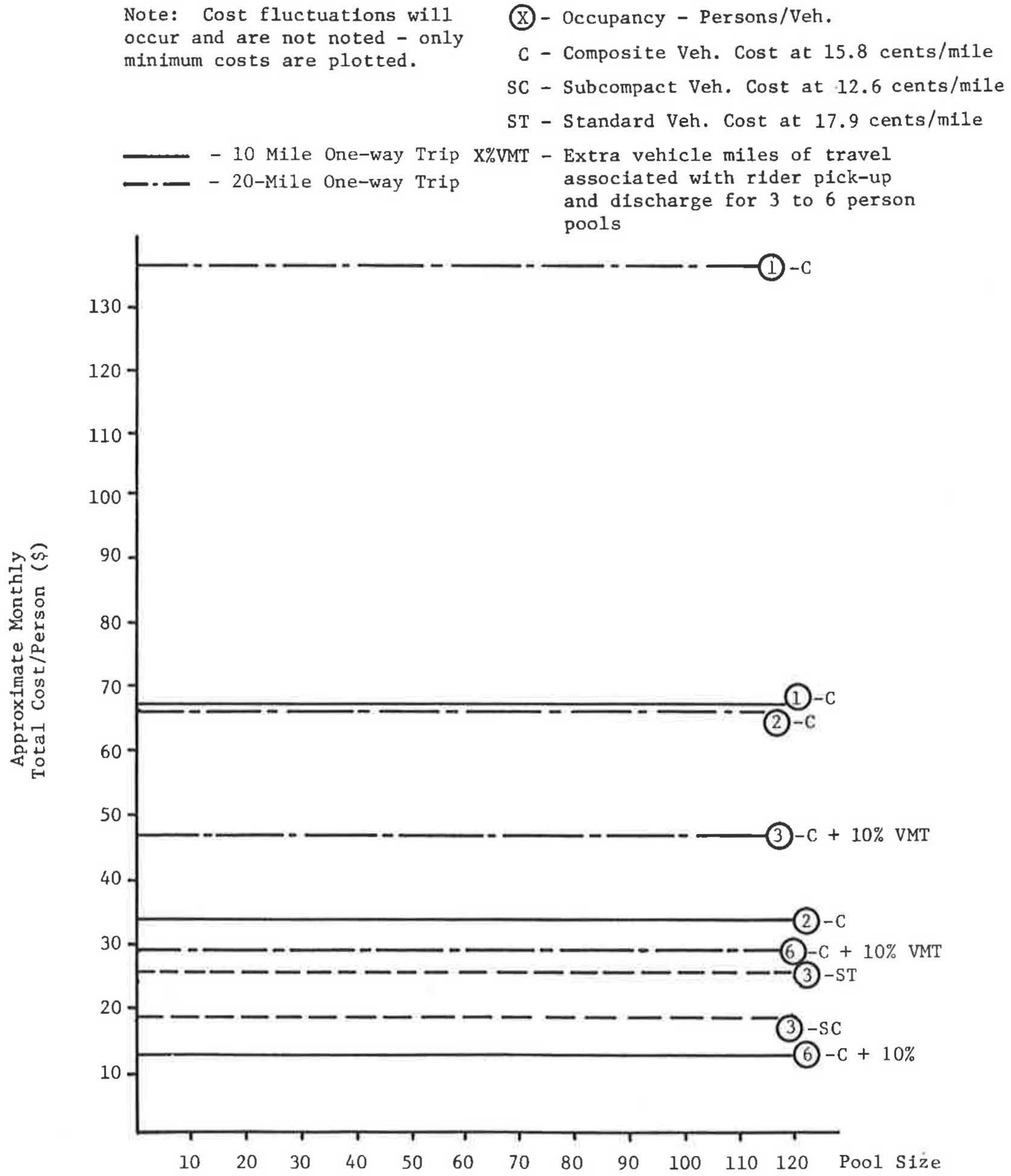


Figure 24. Monthly carpooling costs for 10- and 20-mi one-way trips (varying occupancies and pool size).

length, labor charges, and allocation of labor and vehicle depreciation charges. This suggests that the issue of marginal vs. average cost can be quite significant in selecting an alternative service concept and service level.

The material presented in this chapter is intended to be used to find relationships that can be applied to specific situations. Although other parameters besides cost are important in the selection of service concepts and service levels, the planner should be conscious of the resources involved in initiating incremental changes in transit service.

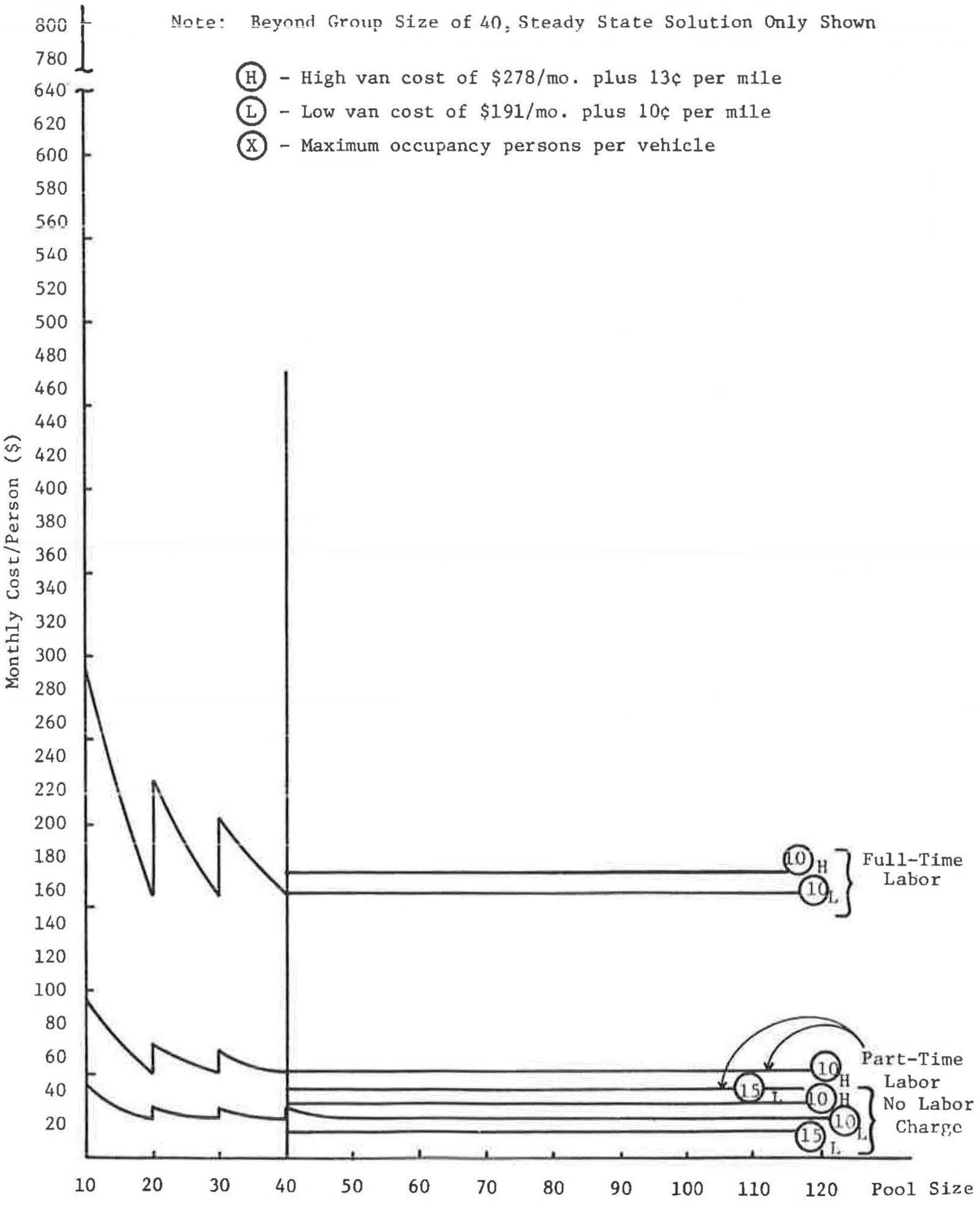
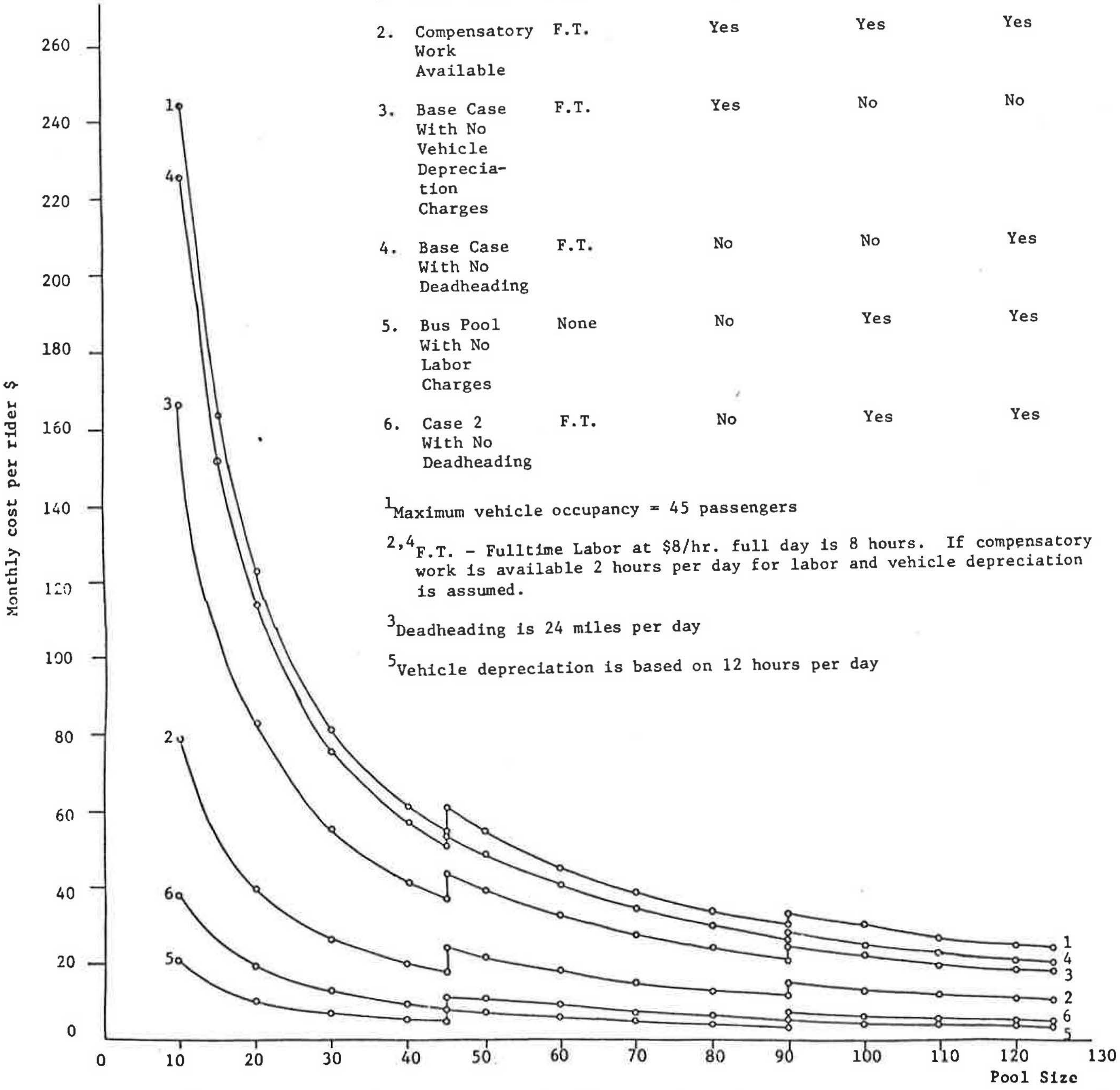


Figure 25. Monthly vanpooling costs for one-way 10-mi trips (varying occupancies and pool sizes).



Service Options[1]

		1 Wage Cost[2]	2 Deadheading Miles[3]	3 Compensatory Work[4]	4 Depreciation Included[5]
1.	Base Case	F.T.	Yes	No	Yes
2.	Compensatory Work Available	F.T.	Yes	Yes	Yes
3.	Base Case With No Vehicle Depreciation Charges	F.T.	Yes	No	No
4.	Base Case With No Deadheading	F.T.	No	No	Yes
5.	Bus Pool With No Labor Charges	None	No	Yes	Yes
6.	Case 2 With No Deadheading	F.T.	No	Yes	Yes

[1] Maximum vehicle occupancy = 45 passengers

[2,4] F.T. - Fulltime Labor at $8/hr. full day is 8 hours. If compensatory work is available 2 hours per day for labor and vehicle depreciation is assumed.

[3] Deadheading is 24 miles per day

[5] Vehicle depreciation is based on 12 hours per day

Figure 26. Monthly buspooling costs for 10-mi one-way trip for different service options.

TABLE 11

DIVERSITY IN RIDESHARE OPERATIONS

	Rideshare Mode		
Alternative Responsibility Mixes	Carpool	Vanpool	Buspool
Program Operator	• Individual	• Individual • Employer • Public Agency	• Individual • Commuter Clubs • Employer • Public Agency
Driver of Vehicle	• Individual (Same as rotating)	• Individual • Part-time Driver	• Part-time Driver • Public/Pvt. Full-time Driver
Owner of Vehicle	• Individual	• Individual • Employer • Public/Private Transit Company • Third Party Provider	• Individual • Employer • Public Private Transit Company
Organizer and Market	• Employer • Public Agency	• Individual • Employer • Public Agency • Third Party Provider	• Neighborhood or Commuter Club • Employer • Public Transit Company • Public Agency

TABLE 12

TYPICAL MONTHLY VANPOOL CHARGES FOR AN OCCUPANCY OF 10 PERSONS PER VEHICLE

	Monthly Cost/Rider ($)	
a. Labor Charges Variable: (No Excess Miles Included)		
	One Way Trip Length	
	10 Miles Low*	40 Miles Low*
Base Case (No labor charge)	$23	$36
Part Time Labor ($5/hour)**	$43	$68
Full Time Labor ($8/hour - No compensatory work)***	$158	$170
b. Excess Pickup and Discharging Miles Variable: (No labor charge included)		
	10 Miles Low*	40 Miles Low*
Base Case with No Excess Miles	$23	$36
Base Case with 10% Excess Miles (Due to pickup and discharge of riders)	$25	$38
Base case with 30% Excess Miles (Due to pickup and discharge of riders)	$27	$41

*Cost of $191 per month and 10 cents per mile

**Assumes $5/hour for duration of travel time which is 25 minutes for 10 mile one-way trip with an additional 30 minutes deadheading and vehicle preparation time at trip end. For 40 mile one-way trip the travel time is 60 minutes plus an additional 30 mile deadheading and vehicle preparation time at trip ends.

***Assume $8/hour with driver available 8 hours per day.

TABLE 13

BUS POOL SIZE REQUIRED TO BE MINIMUM COMMUTER COST RIDESHARE SERVICE WHEN COMPARED TO CARPOOLING[1]

Alternative Bus Pooling Arrangements[2]

Alternative Carpooling Arrangements[2]	Part Time Driver No Veh. Depreciation		Full Time Driver with Compensation Worked & Vehicle Depreciation		Full Time Driver with No Compensatory Worked & No Veh. Depreciation		Full Time Driver No Compensatory Worked & Veh. Depreciation	
	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip
Drive Alone[3]	6	4	12	8	26-45 & 51	8	38-44 *	10
Carpool-2 person/veh	11	7	23-45 & 47	17	N	15	N	19
Carpool-3 person/veh[4]	16	10	37-45	22	N	22	N	20-45 55
Carpool-6 person/veh[5]	61	13	N	37-45 79-90 100	N	85	N	N
Specific Assumptions								
Veh. Depreciation Cost Labor Costs Veh. Deadheading Required	NONE $5/hr.[6] No		$3.13/hr. $8/hr. Yes		NONE $8/hr. Yes		$3.13/hr. $8/hr. Yes	

[1] Tested Over Group Sizes of 1 to 125 persons

[2] Bus Assumed to have 45 seats, auto 6 seats

[3] Auto Costs - 15.8¢/mile

[4] Vehicle Miles Increased 5% for pick-up and discharge of passengers

[5] Vehicle miles increased 10% for pick-up and discharge of passengers

[6] 1.8 hours of work per day for 10 mile trip and 3.4 hours for a 60 mile trip. Includes time for travel and 30 minutes for miscellaneous duties of trip ends.

N - Buspool never lowest alternative over range searched

* - Cost fluctuations, trend is unstable and a special investigation is required

X - Group size where bus pool first becomes minimum cost and continued to be min. cost service over full ranged searched

T - Taken as 2 times revenue miles, plus 4 miles per day for access to garage

TABLE 14

VANPOOL SIZE REQUIRED TO BE MINIMUM COMMUTER COST RIDESHARE SERVICE WHEN COMPARED TO CARPOOLING[1]

Alternative Vanpooling Arrangements[2,7]

Alternative Carpooling Arrangements[2]	No Labor Cost		Part Time Labor Cost[6]		Full Time Labor Cost	
	10 mile one-way trip	60 mile one-way trip	10 mile one-way trip	60 mile one-way trip	10 mile one-way trip	60 mile one-way trip
Drive Alone[3]	4-10 15	2	7-10 &14	3	N	7-10 &14
Carpool-2 person/veh	7-10 15	3	N	5	N	*
Carpool-3 person/veh[4]	*	4	N	7-10 &13	N	N
Carpool-6 person/veh[5]	N	7	N	N	N	N
Specific Assumptions						
Labor Rate	None		$5/hr.		$8/hr.	

[1] Tested Over Group Sizes of 1 to 125 persons

[2] Van Assumed to have 10 seats, auto 6 seats

[3] Auto Costs - 15.8¢/mile

[4] Vehicle Miles Increased 5% for pick-up and

[5] Vehicle miles increased 10% for pick-up and discharge of passengers

[6] 1.8 hours of work per day for 10 mile trip and 3.4 hours for a 60 mile trip. Includes time for travel and 30 minutes for miscellaneous duties of trip ends.

N - Buspool never lowest cost alternative over range searched

* - Cost fluctuations, trend is unstable and a special investigation is required

X - Group size where bus pool first becomes minimum cost and continues to be min. cost service over full range searched

[7] Van Cost taken at $190/mo fixed cost and 10¢/mile variable cost. Veh-miles increased 25% for pick-up and discharge of passengers. Van costs are adequate (1976) to cover all cost except administration and interest for vehicle purchase for a fleet of 50 vehicles

---

CHAPTER SIX

KEY LEGAL, REGULATORY, AND INSTITUTIONAL ISSUES IN PROVIDING PUBLIC TRANSPORTATION SERVICES

A major policy activity in the market-oriented public transportation process is the evaluation of proposed public transportation alternatives based on legal, regulatory, and institutional issues. Evaluation of proposed services with regard to these issues is necessary throughout the planning process because legal, regulatory, or institutional obstacles to service changes or innovations frequently exist. This is particularly likely if the new public transportation service is different from current service in the community. These obstacles may be overcome through innovative management and interagency coordination, new legislation, or court action. They should not be ignored. A legal, regulatory, or institutional obstacle may prevent implementation of a new service even after funding has been secured, or it may increase the operator's liability after the service has been initiated unless steps are taken early in the planning process to remove the obstacle. This chapter reviews the key legal, regulatory and institutional issues which are likely to impact public transportation improvements in a local community. No attempt has been made to provide any

TABLE 15

BUS POOL SIZE REQUIRED TO BE MINIMUM COMMUTER COST RIDESHARE SERVICE WHEN COMPARED TO POOLING [1]

Alternative Bus Pooling Arrangements[2]

Alternative Vanpooling Arrangements[2]	Part Time Driver No Veh. Depreciation		Full Time Driver with Compensation Work & Vehicle Depreciation		Full Time Driver with No Compensatory Work & No Veh. Depreciation		Full Time Driver No Compensatory Work & Veh. Depreciation		Labor Rate
	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip	10 miles one-way trip	60 miles one-way trip	
No Labor Cost	11	21-45 &51	31-45 &61	N	N	N	N	N	None
Part Time Labor Cost	11	11	11	31-45 61-80 &101	30-45 71-90 &111	31-45 &71	N	N	$5/hr[4]
Full Time Labor Cost	1	1	1	11	11	11	11	21	$8/hr
Specific Assumptions									
Veh. Depreciation Cost Labor Costs Veh. Deadheading Required	NONE $5/hr.[6] No		$3.13/hr. $8/hr. Yes		NONE $8/hr. Yes		$3.13/hr. $8/hr. Yes		

[1] Tested Over Group Sizes of 1 to 125 persons

[2] Bus Assumed to have 45 seats, van 10 seats

[3] Van Cost taken at $190/mo fixed cost and 10¢/mile variable cost. Veh-miles increased 25% for pick-up and discharge of passengers. Van costs are adequate (1976) to cover all cost except administration and interest for Vehicle purchase of a fleet of 50 vehicles

[4] 1.8 hours of work per day for 10 mile trip and 3.4 hours for a 60 mile trip. Includes time for travel and 30 minutes for miscellaneous duties of trip ends.

N - Buspool never lowest alternative over range searched

* - Cost fluctuations, trend is unstable and a special investigation is required

X - Group size where bus pool first becomes minimum cost and continued to be min. cost service over full ranged searched

[5] Taken as 2 times revenue-miles, plus 4 miles per day for access to garage.

solutions or provide guidelines that can be followed in evaluation. Rather, it can be expected that alternatives will be impacted by these issues and should be addressed by the alternative analysis.

There are five key legal, regulatory, and institutional issues that impact public transportation service. These issues are:

1. Accident liability and insurance.
2. Regulation.
3. Organized labor.
4. Local apportionment of deficits.
5. Availability of service providers.

The major aspects of each of these issues and the effects of the issue on alternative public transportation services are outlined in the following sections of this chapter.

ACCIDENT LIABILITY AND INSURANCE

There are six major issues with regard to accident liability and insurance that may affect the feasibility of implementing an alternative public transportation service in a local community. These issues are:

1. Cost of insurance.
2. Availability of insurance.
3. Adequate insurance coverage.
4. Employer liability for employer-sponsored transportation services.
5. Rider liability.
6. Rider's personal security from crime.

Cost of Insurance

State laws generally require that public transportation providers have adequate insurance to cover liability claims or demonstrate the capability to self-insure. Insurance for public transportation is expensive because of the possibility of high losses with a high-occupancy vehicle (*30*). Only two insurance companies (Transit Casualty and Canal) have a special insurance category for public transportation operations. Other insurance agencies do not have statistical information concerning the risk involved in insuring public transportation. There is little competition in insuring public transportation services, and the resulting rates are relatively unfavorable to both traditional transit and paratransit operators. Considerable savings can be realized by being self-insured. The procedure and dollar amounts required for self-insurance generally are regulated by the city or state. In New York City, for example, taxi companies are required to make deposits with a bonding agent (*26*). Savings may also be realized by staggering the levels of insurance coverage and spreading the risk between several companies. For example, a public transportation operator could self-insure for claims up to $25,000, purchase insurance from company A for claims from $25,000 to $100,000, and purchase insurance from company B for claims over $100,000.

The cost of insurance most seriously affects the small operator as cost per vehicle is higher for small fleets. The range in insurance costs per vehicle has been $1,200 to $2,500 per year. Small operators are less likely to be financially able to self-insure (*31*). High insurance costs sometimes prevent small operations from forming. For example, if vanpool drivers must purchase their own insurance, the fare may be too expensive to attract riders.

Insurance costs also impact the cost of providing service for large operators (such as traditional bus companies), and may increase the extent to which their service needs to be subsidized. Insurance costs can also affect operating decisions for large public transportation operations because insurance rates for large operators are often based on gross revenues. Insurance costs should, therefore, be considered in making decisions concerning service expansion and fare increases.

Availability of Insurance

Availability of insurance is as great an issue as cost, because only a few insurance companies will insure public transportation operations of any type. Until recently, carpools and vanpools were unable to obtain insurance because they were not classified or rated for insurance purposes. Companies would not risk insuring vanpools or would charge exorbitant rates. The Insurance Services Office (ISO) now has established rates for vanpools and carpools, subject to approval by each state. Privately owned carpools and vanpools may be insured as private vehicles under the ISO recommendation and, therefore, should no longer be affected by either the cost or availability of insurance (*30*). Volunteer and social service agency transportation services still have difficulty obtaining an insurance rating. Consideration must also be given to "no-fault" insurance where it is of concern.

Adequate Insurance Coverage

Insurance generally is written with an over-all limit on payment for bodily injuries. This amount may not be sufficient if several adults are injured (*32*). The driver of a multipassenger vehicle must have high policy limits to protect the passengers adequately. In addition, some sort of uninsured or underinsured motorist coverage is required to protect riders if the driver of another vehicle is at fault. Only seven states offer underinsured motorist coverage.

Employer Liability for Employer-Sponsored Transportation Services

Generally, employers are not responsible for their employees while they are commuting to and from work. However, if the employer owns the vehicle, contracts to another agency for the service, or offers cash or merchandise incentives to employees who use the service, the employer may assume responsibility for the employee's safety (*32*). If the employer guarantees the safety of the ride (inspects vehicles or investigates drivers and/or riders), the employer may also assume responsibility (*32*). Employer's Workmen's Compensation may cover liability claims, depending on the state law. At this time, there are no cases that have definitively outlined the responsibility of the employer (*33*). This issue will affect carpooling, vanpooling, and subscription bus transportation if employer sponsorship is involved.

Rider Liability

In some cases, the riders, as well as the driver, may be liable for an accident. This would be the case if the riders and driver were considered a joint enterprise or partnership (*31*). This may affect organizational arrangements for carpooling, vanpooling, and subscription services.

Rider's Personal Security from Crime

There is some risk involved in sharing rides with strangers, and many public transportation alternatives have no access to radios to call for help. Vanpool and carpool matching services may be held liable for matching riders with a criminal element (*31*). All transportation systems are responsible for guaranteeing the behavior of their drivers. Recent court decisions in Illinois and Louisiana found the public transportation system responsible within reason for protecting passengers from criminal actions by other passengers (*34, 35, 36*).

Insurance Issues Affecting Public Transportation Alternatives

The relationship between documented public transportation services and the six insurance issues indicates that almost all the issues are likely to apply to each public transportation alternative. Because liability and insurance issues vary by state law and local precedent, there may be local exceptions.

REGULATION

Public transportation is extensively regulated by federal, state, and local agencies. The Interstate Commerce Commission (ICC) regulates public transportation modes that cross state lines, unless the mode remains within one city, is school transportation, or is a taxicab operation.

Public transportation systems that do not cross state lines are regulated by state and local government agencies. At the state level, the regulatory agency is usually the state public service commission or state public utility commission. Although state public service commissions used to regulate all traditional public transportation systems except taxicabs, many states now exempt publicly owned transportation systems. Vanpools and carpools generally are not regulated unless the driver receives a profit. In some states, vanpools and/or carpools operated on a share-the-cost basis are regulated and required to obtain a contract carrier permit.

At the local level, public transportation may be regulated by the county, by the city, or by a joint metropolitan commission. The regulatory body might be an elected general purpose body or an appointed transportation authority, a government department, or one employee. Sometimes local regulation is split between agencies. For example, the city council may have the power to franchise taxicabs; and the transportation authority, the power to regulate the type of service taxicabs provide. There also may be local jurisdictional disputes. Most local public transportation authorities regulate their own services and set their own fares and safety standards. Privately supplied transportation, such as taxis, generally are regulated by a different agency. Vanpools or carpools are generally not regulated locally. It is also possible to have more than one agency regulate particular services. For example, transportation to a medical facility might be regulated by the transportation regulating agency as well as the state department of health.

AREAS OF REGULATION

Public transportation providers may be regulated in four areas:

1. Safety and financial responsibility.
2. Rates or fares.
3. Service patterns.
4. Entry and exit restrictions (of the number of providers).

Safety and Financial Responsibility

All providers of transportation are required to meet safety and financial responsibility standards. These regulations are designed to protect the general public. Financial responsibility standards require that a transportation service provider use good accounting practices and have adequate insurance. Safety standards concern vehicle type and driver qualifications. Vehicle requirements may specify the number of doors the vehicle must have, the presence of warning lights, and the adherence to federal safety standards (*37*). Sometimes, vehicle safety standards are based on only one type of vehicle (e.g., a large bus) and, thereby, effectively prohibit the use of other vehicles (such as small buses or vans). A driver is usually required to obtain a chauffeur's license, pass a physical examination, and have a good driving record (*37*). Drivers may be required to exceed a minimum age, to speak English, to have a certain level of education, to have passed a first aid course, to not be addicted to alcohol or drugs, and to submit character references. Individuals who have served prison terms may be automatically prohibited from employment. Personal neatness and uniforms may be required (*31*). Some driver requirements, such as to speak English, are now being declared illegal.

Rates or Fares

Regulation of rates or fares is designed to protect the public from high fares while assuring the public transportation provider an adequate rate of return. There are two ways in which rates or fares may be controlled. The regulatory body may require that the rate or fare be publicly declared (filed for public information purposes) to assure that every rider is charged the same fare or rate. The regulatory body also may have the authority to approve or reject rates or fares. The primary basis for approval or rejection is the rate of return the fare would give the provider (*37*). Generally some fixed rate of return is specified. A low fixed rate of return may discourage innovation, the provision of special services to the handicapped, or any other service that involves cost risk. High cost services include peak-hour service, service to low-density destinations, service to dangerous destinations, and service after midnight. On the other hand, a high fixed rate of return may flood the market area with providers and prevent low-income transit dependents from being able to use the service.

One other basis for rate or fare approval or disapproval is the prevention of discriminatory rates or fares. The general principle is that all persons are to receive more or less equal value for the same fare (*38*). If distance is used to determine rates, equal fares should not be charged for unequal distances. If zones are used to determine fares, the zones should be approximately the same size. If strictly applied, this type of fare regulation discourages innovation, because innovation generally involves the provision of different services for different markets. It may thus be difficult to receive approval to charge premium fares for premium services. This could ultimately lead to subsidizing public transportation for upper income individuals who could and would pay a higher rate for the service.

Service Patterns

There are many ways in which service patterns may be controlled through regulation. The most serious is the omission of new service patterns in old regulations. A service may be prohibited if it is not specifically allowed. This affects flexible route and flexible schedule service options, multimodal services, and new companies. A service pattern may also be specifically prohibited as is frequently the case with jitney service patterns.

Service pattern regulations tend to promote the status quo and prevent experimentation and innovation. In addition, every service change or experimental service requires new approval, which can lead to delays and expenses that affect both the responsiveness and the cost of the service. It is also possible, by regulating the service pattern of a mode, to effectively eliminate a service. Many cities have used service regulations to eliminate jitneys (*39*).

Many publicly owned systems are exempted from service regulation by an external government body, even if the service is similar to that provided by private operators. In this respect, service regulations may cause two problems. Regulations may prevent private operators from developing new services, such as shared-ride taxis, while the same service (dial-a-ride) may be allowed to be developed at public expense. The regulations mask the fact that the service might have been provided without subsidy.

Specific service patterns that may be regulated are routes, service areas, passenger capacity, stops or solicitation policies, and service availability.

Routes

Public transportation providers operating on fixed routes may be required to obtain a certificate of public convenience and necessity that states the route is necessary to operate on a route. On the other hand, a public transportation provider may not be able to discontinue a route even after proving there is little demand for service on the route (*37*).

Service Areas

Public transportation providers operating on either fixed or variable routes may be required to obtain a certificate of public convenience and necessity to operate within designated boundaries (*37*). These regulations prohibit the provision of service outside of the established boundaries.

Passenger Capacity

Different types of services generally are legally distinguished by passenger capacity of the vehicle. These regulations determine passenger capacity of the vehicle that can be used to provide service. For example, if a limousine is defined by law as a 9-passenger vehicle, neither a standard car nor a small bus could be used to provide limousine service, regardless of demand.

Stops or Solicitation Policies

Policies regarding the acceptable location of transit stops on fixed routes or permissible ways of soliciting customers on variable routes are sometimes established by regulation. On fixed routes, hailing, waiting for regular passengers, and minor route deviations might be prohibited, permitted, or required. On variable routes, cab stands, radio dispatching, telephone calls, hailing, or call boxes may be variously prohibited, permitted, or required.

Service Availability

The conditions under which a driver may refuse to accept a rider or compel a rider to leave the vehicle usually are established by regulations (*26*). Hours of service and service schedules for fixed-schedule alternatives also may be regulated.

Entry and Exit Restrictions

Entry and exit restrictions are designed to protect the supplier from competition and to guarantee the continuance of existing services. There are three control methods used to restrict the number of transportation suppliers: certificate of public convenience and necessity, franchise, and contract carrier permit.

Certificate of Public Convenience and Necessity

The ICC, state public service commissions, and local ordinances require common carriers such as traditional buses, express buses, and dial-a-ride services to obtain a certificate of public convenience and necessity before offering transportation service. If operated between states, they are regulated by the ICC. Unless specifically excluded from regulation by state law, they are regulated by the state public service commission. Other modes also may be defined by state law as common carriers.

To obtain a certificate of public convenience and necessity, the public transportation supplier must demonstrate to the regulatory commission that there is a need for the service and that the supplier is properly able to provide the service. If another public transportation supplier already provides the same service to the same customers, the regulatory commission generally will conclude that there is no need for the additional service. Before ceasing operation a common carrier must also secure permission, which is frequently difficult to obtain from the regulatory commission.

Franchise

Local governments frequently require a traditional public transportation service (privately owned bus and taxicab) to obtain a franchise before beginning service. The total number of available franchises frequently is limited by law, thus restricting the providers to some predetermined number of vehicles. Otherwise, a local government may use the franchise in a manner similar to a certificate of public convenience and necessity by requiring a potential provider to demonstrate need for the service. In some areas, jitneys have been excluded from operating by requiring that they obtain franchises, and then not issuing franchises on the premise that there is no need for the service (*39*).

Contract Carrier Permits

The ICC and the state public service commissions issue contract carrier permits to public transportation providers that only offer their services to regular passengers on a contract basis. Subscription buses, vanpools, carpools, special charters, and limousine services may be defined as contract carriers, depending on state law. To obtain a contract carrier permit, the transportation provider must demonstrate that there is an unmet need for the service and that all required standards will be met.

Effect of Entry and Exit Restrictions

Entry and exit restrictions are major obstacles to new or innovative services. A certificate of public convenience generally is issued only if the new business will not attract riders from existing operators. Sometimes regulations require that all innovations must be offered first to existing companies before a new company can offer the service (*40*). Numerical restrictions may apply even if the type of service is different from those in existence (*40*). An unsuccessful experimental, innovative service may not be permitted to cease operation even if it is costly and inefficient. Entry restrictions primarily affect private operators. Publicly owned systems may be exempted from regulation even if a service similar to private service is provided.

The procedure and cost involved in applying for a certificate of public convenience, a franchise, or a contract carrier permit may discourage small providers. If small operators do not comply, however, they are subject to penalties of the regulatory act if the fact is brought out in a lawsuit (*37*). They may also be declared a public nuisance and prohibited from operating.

EFFECT OF REGULATORY ISSUES ON PUBLIC TRANSPORTATION ALTERNATIVES

The relationship between regulatory issues and documented public transportation services is presented in Table 16. The table indicates which type of regulation is most likely to apply to each of the public transportation alternatives. Because regulatory practices vary by state law and local practice, this table may not be accurate for a specific community. However, it can be used as a guide in determining the existence of pertinent regulations and indicate which regulatory issues need to be investigated.

ORGANIZED LABOR AND LABOR PROTECTION

Section 13(c) of the Urban Mass Transportation Act (UMTA) of 1964 as amended assures that all workers who potentially may be affected by UMTA-funded transportation services will have their bargaining rights, wages, and working conditions protected and that they will be given priority for employment or reemployment. The only UMTA-funded program that is specifically exempt from this provision is transportation services for the elderly and handicapped. Section 13(c) labor agreements usually are negotiated between management and local union officers and certified by the Secretary of Labor. The process can be long and involved, delaying receipt of funds or changing the scope of the project. UMTA funds may be withheld if the local union opposes the new service due to proposed labor practices such as the use of nonunion or part-time employees (*41*). There are also other issues unrelated to Section 13(c), which should be considered, such as the formation of unions where none previously existed or the impact of union negotiated settlements on nonunion employees.

EFFECT OF LABOR PROTECTION LEGISLATION

All flexible route, flexible schedule transportation options raise yet unresolved questions about which workers must be protected by Section 13(c) and who represents them. Presently, the Department of Labor relies on the UMTA to define the scope of 13(c) coverage. This generally excludes taxicabs, vanpools, and other nontraditional services (*42*). There have been cases in which dial-a-ride services were judged to be competing with other transit services, even when both were run by the same operator. Frequently, taxi drivers who are in business for themselves (either own or lease a taxi) are not unionized. They usually are not concerned with traditional labor agreements (wage rates, benefits, work rules), but they also do not invite competition from publicly subsidized operators. If they are included in the 13(c) bargaining process, they are likely to demand that shared-ride taxi service be implemented instead of dial-a-ride service. Shared-ride taxis are viewed by traditional bus employees as a threat to their jobs when public transportation is provided more cheaply by taxi drivers who receive less than union wages. In the Haddonfield, N.J., dial-a-ride demonstration project, dial-a-ride drivers were paid union wages, and the local taxi company was compensated for lost revenue (*37*). This double payment for service may not be very attractive for a local government not receiving federal demonstration funds. Vanpools also may be viewed as competition for traditional bus service and a threat to union drivers. When an UMTA vanpooling demonstration project was initiated in Knoxville, Tenn., the 13(c) agreement guaranteed to maintain the size of the existing bus company labor force for four years (*37*). The decision as to what existing transportation services will be involved in the 13(c) bargaining process, therefore, may determine both the services provided and the cost of providing the services.

A second unresolved issue with regard to the Section 13(c) bargaining process is the determination of the magnitude of change to existing services necessary before labor agreement is required. Some unions feel that the purchase of only one bus may be sufficient cause for renegotiation of an entire labor contract. This kind of labor dispute can delay, even prevent, minor service expansions because the U.S. Department of Labor is reluctant to override union decisions.

Section 13(c) also affects employee costs by encouraging

TABLE 16

EFFECT OF REGULATORY ISSUES ON CURRENT PUBLIC TRANSPORTATION ALTERNATIVES

Current Public Transportation Alternatives	REGULATORY ISSUES												
	Safety Standards		Rates or Fares		SERVICE PATTERNS						Entry Restrictions		
	Vehicle Specifications	Driver Qualifications	Publically Declared	Set Level	Routes	Service Areas	Passenger Capacity	Stops	Solicitation	Service Availability	Certificate of Public Convenience	Franchise	Contract Carrier Permit
Bus Alternatives:													
Traditional Bus	X			X	X					X	X or	X	
Express Bus	X			X	X			X		X	X or	X	
Subscription Bus	X		X ?		X			X					X
Dial-a-Ride Bus	X			X		X				X	X ?		
Small Bus Alternatives:													
Traditional Bus	X			X	X		X			X	X or	X	
Subscription Bus	X		X ?		X		X	X		X			X
Dial-a-Ride Bus	X			X		X				X	X ?		
Minibus	X			X		X				X	X ?		
Jitney	X	X		X	X				X	X	X or	X	
Special Charters													X ?
Van Alternatives:													
Traditional Transit	X			X	X		X			X		X	
Vanpools	X												X
Dial-a-Ride Bus	X			X						X	X		
Minibus	X			X						X	X		
Jitney	X	X		X	X				X	X	X or	X	
Special Charters													X ?
Automobile Alternatives:													
Airport Limousine			X										X ?
Jitney	X	X		X	X				X	X	X or	X	
Carpools													X
Taxi	X	X		X		X	X	X	X	X	X or	X	
Shared-ride Taxi	X	X		X		X	X	X					
Public Limousine													X

unions to represent workers in negotiating Section 13(c) agreements. Union labor generally has higher wages and less flexible work rules. Labor compensation (wages and benefits) is the major operating cost element in most public transportation systems, and work rules dictate the number of employees that must be hired. Work rules restricting management's prerogatives in scheduling split runs or in assigning part-time runs can significantly increase the number of drivers that must be hired (*43*). The effect of 13(c), therefore, generally is to increase the cost of providing traditional public transportation service and to delay the implementation of new service (both innovative and traditional).

LOCAL APPORTIONMENT OF DEFICITS

Local funding is usually a major source of subsidies for public transportation. If the public transportation service operates in more than one community, apportionment of the deficit may be a problem. Five possible methods are to:

1. Apportion deficit based on the population of the communities.
2. Apportion deficit based on ridership from each community.
3. Apportion deficit based on route miles or area of coverage in the community.
4. Develop separate transportation services for each community and make some arrangement for transfer between the services.
5. Subsidize the transportation user.

Many other deficit appropriations could be added, but for purposes of discussion only the foregoing five will be considered. The manner in which the deficit is apportioned may suggest or require certain transportation designs to assure that adequate financial support will be available.

EFFECT OF DEFICIT APPORTIONMENT MEASURES

Deficit apportionment based on community population would suggest that the most populous community should receive the most service. The subsidy, however, is usually not tied to any measure of service and this means that there is little financial control over the service by the communities providing the subsidy.

A deficit apportionment based on ridership does tie the subsidy to one level-of-service measurement. This policy usually assures that the community with the most transit dependents must pay the highest cost. This could mean that the community least able to pay subsidizes the public transportation service. Unfortunately, this policy also tends to be cyclical. The community of transit dependents supports the service, therefore the service is designed to serve transit dependents. The incentive to attract new patrons may be removed.

An apportionment based on route miles or area of coverage must also consider service frequency and ridership. Where there are long loop routes with one-hour headways in a community, this would, in effect, increase the coverage area by creating long travel and waiting times.

Having each community support its own system solves the deficit apportionment problem. However, if transfers from one service to another are required, the service will not be desirable to choice riders.

All of the foregoing four deficit apportionment methods involve provider-side subsidies. Provider-side subsidies are monies given to the transportation provider. In development of a transportation system design that will receive a provider-side subsidy, specific standards or effectiveness criteria are used in evaluating, monitoring, and controlling the service. Ideally, these standards measure both the service level and the efficiency with which the service is provided (*44*). These standards are difficult to establish (particularly for flexible route, flexible schedule service) and frequently are controversial because they are only indicators and not direct measures of service desirability.

The transportation user also can be subsidized. Each community subsidizes only those citizens who need and cannot afford transportation service. User-side subsidies are provided in the form of free or discount tickets that can be used to purchase rides. Transportation providers are compensated for each coupon they receive. The provider is subsidized only to the extent that the subsidized users actually use the service. User-side subsidies can be used to both direct and/or limit public support of public transportation.

If a user-side subsidy is used, the subsidy itself measures both service desirability and service efficiency. The provider receives the subsidy only if the service is efficient. Specification of the population group(s) that will receive the subsidy is, however, controversial. Also, there is no guarantee that the service will be offered. The provider might be forced to cease operation if an inefficient service is established that is neither profitable nor financially feasible.

AVAILABILITY OF SERVICE PROVIDERS

Private operators can and, in many areas, do provide effective and efficient public transportation services with little or no public subsidy. Because of the many legal restrictions discussed earlier in this chapter, it may be desirable for a local urban area to encourage the development and expansion of private operations. It should be realized, however, that implementation of a public transportation alternative that involves private transportation providers can be difficult. The service providers might not currently exist, or existing providers might be resistant to change. A local government cannot decree what private operators will do, but it can work cooperatively with private operators. A thorough understanding of the problems facing the private operator is necessary (*40*). Providers must be shown how they may benefit or, at least, how to avoid large losses.

Many alternative modes that traditionally are privately owned and operated (taxicabs, jitneys, subscription buses) may need subsidies if they are to develop in a local area where they do not exist already. The subsidy assures them that a certain level of profit can be obtained if they risk offering the service. Local governments may not be willing to subsidize a private operator or an operation that is uncertain. They also may be unwilling to own and operate a system that traditionally is owned privately. In these cases, user-side subsidies may be a possible compromise. Ridership is encouraged by the low fare, and the supplier is subsidized only to the extent that the public uses the service. Other indirect subsidies that can be provided to a private transportation supplier are dispatching services, customer referrals, tax waivers, leased vehicles, and group insurance.

SUMMARY

This chapter has outlined the five key legal, regulatory, and institutional issues that are likely to impact public transportation improvements in a local community. These issues are accident liability and insurance, regulation, organized labor, local apportionment of deficits, and the availability of service providers. Every issue will not apply to every community. The local planner should use this discussion as a guide in researching issues that might apply to the community and to the specific alternative public transportation service(s) being proposed. The legal, regulatory, and institutional issues may be obstacles in the development of a new service, but they can be overcome. Political support is necessary, usually, to deal with these issues. For this reason, evaluation of alternatives with regard to legal, regulatory, and institutional issues is an important activity in the market-oriented planning model.

CHAPTER SEVEN

CONCLUSIONS

A fairly wide range of alternative public transportation service concepts is available to an urban area. Public transportation can make all forms of intraurban passenger transportation available to the community, including publicly as well as privately owned services. It has been suggested that effective public transportation relies on an interactive process of identifying market segments desiring transportation attributes that can be served by one or more service concepts, of specifically identifying candidate services possessing those attributes, and of determining the feasibility of implementation through a cost analysis, field testing, demonstration, evaluation, and refinement. The proposed approach of instituting incremental change to public transportation services is consistent with the concern for implementing short-range management alternatives. The planner must take a broad view of the array of service concepts available and must not restrict the search to traditional services or titles. The planner must relate the inherent operational attributes of the proposed service to the needs defined by the market segment.

This report has suggested a general procedure to match desirable service attributes resulting from a market segmentation study with alternative service concepts to determine which alternative services are appropriate for a local area. Alternative service concepts were classified as to vehicle type, degree of right-of-way control and operational strategy (routing, scheduling, and stop location). This comprehensive classification structure included many useful service concepts not currently in wide use. Traditional services reflect only a limited spectrum of the full array of service concepts available. The classification chart should suggest opportunities for service that are not being explored currently.

An important element in a feasibility analysis is to select a particular concept for further testing. This involves suggesting a prototype design and establishing cost/revenue relationships. Although other elements influence the evaluation decision, it is important for the planner to appreciate the resource implications of making an incremental change to transit services and to then select the lowest cost service concepts that possess the desired attributes. First cut approximations to assist in determining ridership levels sufficient to cover costs for selected service levels and fares were illustrated in economic break-even capacity curves.

Generalized curves for many service levels and alternative service concepts have been presented. It is recommended that the planner undertake a detailed cost analysis relying on a disaggregate costing procedure. The cost estimation framework should be flexible with respect to cost items and categories to be included, and the estimate should be based on routing, scheduling decisions, a recognition of the existing situation in terms of availability of equipment and manpower, and on commitments or investments already made. Cost categories used in this report reflect the service concept classification scheme developed to aid the planner in considering all alternatives. The costing analysis demonstrated that sizable differences can occur, depending on who is responsible for providing the service (public vs. private), service levels achieved through routing and scheduling, and other operational strategies (work rules, etc.). Rather than provide generalized answers, the planner should refer to the rough feasibility analyses to limit the range of alternatives and then perform "customized" cost analyses with the design guidelines and example cost analyses presented in this report. In order to provide a reasonable decision it is imperative that the planner consider all cost elements as incurred rather than "hiding" true costs in systemwide averages.

Finally, the application of a service concept to a particular market will depend on factors in addition to cost and service levels. A discussion of key legal, regulatory, and institutional issues is presented to make the planner aware of how these considerations can limit deployment of a particular service concept. In the long-term many institutional barriers can be overcome if a viable cost-effective concept has been identified.

REFERENCES

1. Burbank, C. J., "Transit Financing: Trends and Outlook for the Future." Urban Mass Transportation Administration. Presented at the Transportation Research Board Conference on Government Responsibilities for Financing Efficient Urban Transportation, Sept. 11-14, 1977.
2. Mumford, L., *The City in History: Its Origins, Its Transformations, and Its Prospects.* Harcourt, Brace and World, Inc. (1961).
3. Vuchic, V. R., "Comparative Analysis and Selection of Transit Modes." *Transportation Research Record 559* (1976) pp. 51-62.
4. Mitric, S., "Methodology of Comparing Modes in Urban Transport." Paper presented at the 56th meeting of the Transportation Research Board, January 1977.
5. *Demand Responsive Transportation, State-of-the-Art Overview.* U.S. Department of Transportation, Transportation Systems Center (Aug. 1974).
6. Roos, D., and Alschuler, D., "Para-Transit—Existing Issues and Future Directions." Paper presented at the 56th meeting of the Transportation Research Board, January 1977.
7. *Paratransit, LEA Transit Compendium.* Vol. 1, No. 8 (1974).
8. Cravens, D. W., Hills, G. E., and Woodruff, R. B., *Marketing Decision Making Concepts and Strategy.* Richard D. Irwin, Inc., Homewood, Ill. (1976).
9. Rosinger, G., et al., *Design of Urban Transportation for the User,* cited by Robert B. Woodruff, et al., "Methodology for Analyzing Urban Transportation Markets." University of Tennessee, College of Business Administration (Apr. 16, 1974) (Working Paper).
10. Paine, F. T., et al., *Consumer Conceived Attributes of Transportation: An Attitude Study,* cited by Robert B. Woodruff, et al., "Methodology for Analyzing Urban Transportation Markets." University of Tennessee, College of Business Administration (Apr. 16, 1974) (Working Paper).
11. Solomon, K., et al., *Passenger Psychological Dynamics, Sources of Information on Urban Transportation, Report #3,* cited by Robert B. Woodruff, et al., "Methodology for Analyzing Urban Transportation Markets." University of Tennessee, College of Business Administration (Apr. 16, 1974) (Working Paper).
12. *Traffic, Revenue, and Operating Costs.* W. C. Gilman and Co. and Alan M. Voorhees and Associates (1969).
13. Ferreri, M. G., "Development of a Transit Cost Allocation Formula." *Highway Research Record 285* (1969) pp. 1-9.
14. Miller, D. R., and Holden, W. H. T., "An Algorithm for Determining Transit Operating Costs." Transit Research Foundation of Los Angeles, Calif. (Unpublished).
15. Miller, D. R., "Cost Functions in Urban Bus Transportation." Northwestern University, Ph.D. dissertation (1967).
16. Wells, J. D., et al., *Economic Characteristics of the Urban Public Transportation Industry.* U.S. Government Printing Office (Feb. 1974) pp. 75-79.
17. Bodin, L., Rosenfield, D., Kydes, A., and Roark, A. L., "A Transit Operating Cost Model Based on Direct Systems Characteristics" (Undated).
18. Roess, R. P., "Operating Cost Models for Urban Public Transportation Systems and Their Use in Analysis." *Transportation Research Record 490* (1974) pp. 40-54.
19. Mundy, R. A., "The Economic Use of Subsidies for Urban Mass Transportation." *Transportation,* Vol. 5, No. 2 (June 1976) pp. 123-133.
20. *Urban Transportation Planning System (UPTS),* Urban Mass Transportation Administration. U.S. Government Printing Office (1977).
21. Davis, F., et al., *Increased Transportation Efficiency Through Ridesharing: The Brokerage Approach.* University of Tennessee, Transportation Center (June 1976).
22. Sanders, D. B., and Reynen, T. A., *Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners.* Deleuw Cather and Co. (May 1974).
23. Morlock, E. K., *An Analysis of Transport Technol-*

ogy and Network Structure. Northwestern University, Transportation Center, (1970).

24. REA, J. C., and MILLER, J. H., *A Comparative Study of Urban Transit Technologies: The Service Specification Envelope Approach.* Pennsylvania State University, Pennsylvania Transportation and Traffic Safety Center (Aug. 1972).
25. INTERPLAN CORP., *Transportation System Management: State of the Art.* Office of Policy and Program Development, Urban Mass Transportation Administration (Sept. 1976).
26. KIRBY, R., ET AL., *Paratransit—Neglected Options for Urban Mobility.* The Urban Institute, Washington, D.C. (1974).
27. HINES, E., *Vanpooling—A New Low Capital Transportation Alternative.* Regional Planning Council, Baltimore, Md. (Nov. 1975).
28. DAVIS, F., ET AL., *Ridesharing and the Knoxville Commuter.* University of Tennessee, Transportation Center (Aug. 1975).
29. *Economic Feasibility of Independent Vanpool Operators.* Office of Energy Conservation and Environment, Federal Energy Administration (Sept. 1976).
30. DAVIS, F. W., JR., ET AL., *Insurance for Vanpools: An Analysis of Current Issues and Progress.* University of Tennessee, Transportation Center (May 1977).
31. LEE, D., JR., and VALLE, A., *Economic Evaluation of Taxicab Regulation.* University of Iowa, Institute of Urban and Regional Research (June 1976).
32. *Transportation Pooling.* U.S. Department of Transportation (Jan. 1974).
33. WICKHAM, D., DAVIS, F. W., and MUNDY, R., "Institutional Factors that May be Caused by or Result from Implementation of Transportation Services." University of Tennessee, Transportation Center (Working Paper).
34. McCoy v. CTA 358 N.E. 2nd 1279 (Illinois Appellate 1976).
35. Campov New Orleans PFC 347 So. 2nd 324 (Louisiana Appellate 1977).
36. Orr v. New Orleans PFC 349 So. 2nd 417 (Louisiana Appellate 1977).
37. "Paratransit." *TRB Special Report 164* (1976) 232 pp.
38. *Study and Evaluation of Urban Mass Transportation Regulation and Regulatory Bodies.* U.S. Department of Transportation, Urban Mass Transportation Administration, Vol. 2 (May 1972).
39. BROOKE, T., III., *An Analysis of an Urban Jitney System in Chattanooga, Tennessee.* University of Tennessee, Transportation Center (Sept. 1976).
40. MARROW, J. F., "A Discussion of Regulation in Urban Mass Transportation." U.S. Department of Transportation, Office of the Secretary (Aug. 1972).
41. KENDALL, D., ET AL., *Small City Transit Characteristics: An Overview.* U.S. Department of Transportation, Transportation Systems Center (Mar. 1976).
42. LEIB, R. C., *Labor in the Transit Industry.* U.S. Department of Transportation (May 1976).
43. MUNDY, R., and THELEN, K. M., "Can Urban Areas Afford Traditional Transportation." University of Tennessee, Transportation Center (Mar. 15, 1976).
44. KIRBY, R. F., and MCGILLIVRAY, R. G., *Alternative Subsidy Techniques for Urban Public Transportation.* The Urban Institute, Washington, D.C. (Oct. 1975).

APPENDIX A

DOCUMENTATION OF CURRENT PUBLIC TRANSPORTATION SERVICES

TABLE A-1

PUBLIC TRANSPORTATION SERVICES CURRENTLY BEING PROVIDED BY A FULL-SIZE BUS

Capacity 30 to 60 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Bus Transit (1)			▩	▩
Express	Express Bus (2)	Subscription Bus (3)	▩	▩	▩
Skip-stop	Express Bus (4)		▩	▩	▩
Rt. Deviat. Local					
Express			▩		
Skip-stop					
Rt. Deviat.					
Many-to-Few					Dial-a-ride (5)
Many-to-Many	▩	Subscription Bus (6)		Jitney (7)	Dial-a-ride (7)

Dial-a-ride, etc.	Transportation Alternative in Current Use
☐	Possible Public Transportation Alternative
▩	Not a Possible Public Transportation Alternative

Selected Examples of Currently Existing Services

Number from Table	Example Location	Reference Where Described
(1)	Knoxville, Tennessee	Knoxville Metropolitan Area Public Transportation Study. Transportation Center, The University of Tennessee, June 1977.
(2)	St. Louis, Missouri	Kirby, R. F., et al. Para-transit: Neglected Options for Urban Mobility. The Urban Institute, 1974. pp. 236-238.
(3)	Reston, Virginia	Ibid., pp. 241-245
(4)	Honolulu, Hawaii	Bus Transportation Strategies. Transportation Research Record, No. 60, 1976. pp. 6-11.
(5)	Kingston, Ontario	TransGuide. California Departments of Transportation. May 1977. p. SOA-2.44.
(6)	Kingston, Ontario	Ibid., p. SOA-2.44.
(7)	Buffalo, New York	Ibid., p. SOA-2.22.
(8)	Stratford, Ontario	Demand Responsive Transportation, State-of-the-Art Overview. U.S. Department of Transportation, August 1974.

TABLE A-2

PUBLIC TRANSPORTATION SERVICES CURRENTLY BEING PROVIDED BY A SMALL BUS

Capacity 10 to 30 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Bus (1)	Subscription Bus (2)		▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local			Dial-a-ride (3) Jitney (4)		Dial-a-ride (5) Jitney (6)
Express			▨		
Skip-stop			Jitney (7)		
Rt. Deviat.	Minibus (8)			Seasonal Charters (9)	
Many-to-Few			Dial-a-ride (10)	Subscription Dial-a-ride (11)	Dial-a-ride (12)
Many-to-Many	▨			Dial-a-ride (13) Jitney (14)	Dial-a-ride (15)

Dial-a-ride, etc.	Transportation Alternative in Current Use
☐	Possible Public Transportation Alternative
▨	Not a Possible Public Transportation Alternative

Selected Examples of Currently Existing Services

Number from Table	Example Location	Reference Where Described
(1)	Rochester, New York	TransGuide. California Department of Transportation. May 1977. p. SOA-2.66.
(2)	Denver, Colorado	Demand-Responsive Transportation Systems and Other Paratransit Services. Transportation Research Record, No. 608. 1976. pp. 70-75.
(3)	Columbus, Ohio	Paratransit, LEA Transit Compendium. Vol. 1, No. 8, 1974. p. 17.
(4)	Atlantic City, New Jersey	Ibid., p. 38.
(5)	Columbus, Ohio	Ibid., p. 17.
(6)	Batavia, New York	Kirby, R. F., et al. Para-transit: Neglected Options for Urban Mobility. The Urban Institute, 1974, pp. 129, 154-155.
(7)	Atlantic City, New Jersey	Ibid., pp. 170-171.
(8)	Merrill, Wisconsin	Flusberg, Martin. "An Innovative Public Transportation System for a Small City . . ." Prepared for the 55th Annual Meeting of the Transportation Research Board, January 1977.
(9)	Batavia, New York	TransGuide, op. cit., p. SOA-2.15.
(10)	Rubidoux, California	Ibid., p. SOA-2.68.
(11)	Regina, Saskatchewan	Kirby, R. F., op. cit., pp. 155-157.
(12)	Regina, Saskatchewan	Ibid., pp. 155-157.
(13)	Batavia, New York	TransGuide, op. cit., p. SOA-2.15.
(14)	Buffalo, New York	Paratransit, LEA Transit Compendium, op. cit., p. 39.
(15)	Batavia, New York	TransGuide, op. cit., p. SOA-2.15.

TABLE A-3

PUBLIC TRANSPORTATION SERVICES CURRENTLY BEING PROVIDED BY A VAN

Capacity 8 to 16 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local	Traditional Transit (1)			▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local	Traditional Transit (2)		Jitney (3)		Jitney (4) Minibus (5)
Express			▨		
Skip-stop			Jitney (6)		
Rt. Deviat.				Seasonal Charters (7)	Dial-a-ride (8)
Many-to-Few	Vanpools (9)	Vanpools (10)		Subscription Dial-a-ride (11)	Dial-a-ride (12)
Many-to-Many	▨			Dial-a-ride (13) Jitney (14)	Dial-a-ride (15)

Dial-a-ride, etc.	Transportation Alternative in Current Use
	Possible Public Transportation Alternative
▨	Not a Possible Public Transportation Alternative

Selected Examples of Currently Existing Services

Number from Table	Example Location	Reference Where Described
(1)	Southeast San Diego County, California	TransGuide. California Department of Transportation. May 1977. p. OOS-2.71.
(2)	Southeast San Diego County, California	Ibid., p. OOS-2.71.
(3)	San Juan, Puerto Rico	Andrle, Stephen J. and Jose L. Rodriguez. "The Organization and Economies of Jitney Operations in San Juan, Puerto Rico." Paper presented at the Annual Meeting of the Transportation Research Board, January 1977.
(4)	Batavia, New York	Kirby, R. F., et al. Paratransit: Neglected Options for Urban Mobility. The Urban Institute, 1974, pp. 129, 154-155.
(5)	Placer County, California	TransGuide, op. cit., p. SOA-2.62.
(6)	Atlantic City, New Jersey	Paratransit, LEA Transit Compendium. Vol. 1, No. 8, 1974, p. 38.
(7)	Batavia, New York	TransGuide, op. cit., p. SOA-2.15.
(8)	Stratford, Ontario	Paratransit, LEA Transit Compendium, op. cit., p. 37.
(9)	Menlo Park, California	Kirby, R. F., op. cit., p. 235.
(10)	Knoxville, Tennessee	Wegmann, Frederick J. and Douglas Wiersig. "Comparison of an Employer-Based and a Community Wide Rideshare Demonstration Program--Knoxville, Tennessee Experience." Presented at the Transportation Research Forum, Atlanta, Georgia, October 1977.
(11)	Batavia, New York	Kirby, R. F., op. cit., pp. 129, 154-155.
(12)	Ann Arbor, Michigan	Demand-Responsive Transportation Systems and Other Paratransit Services. Transportation Research Record, No. 608, pp. 16-20.
(13)	Scott-Carver Counties, Minnesota	TransGuide, op. cit., p. SOA-2.74.
(14)	Buffalo, New York	Paratransit, LEA Transit Compendium, op. cit., p. 39.
(15)	La Mirada,	Paratransit, LEA Transit Compendium,

TABLE A-4

PUBLIC TRANSPORTATION SERVICES CURRENTLY BEING PROVIDED BY AN AUTOMOBILE

Capacity 2 to 16 passengers

ROUTING/ STOP LOCATION	SCHEDULING				
	Fixed-Schedule	Flexible Fixed Schedule	Vehicle Hail	Advanced Request	Immediate Request
Fixed-route Local				▨	▨
Express			▨	▨	▨
Skip-stop			▨	▨	▨
Rt. Deviat. Local	Airport Limousine (1)		Jitney (2)		Jitney (3)
Express			▨		
Skip-stop			Jitney (4)		
Rt. Deviat.					
Many-to-Few		Carpool (5) Taxipool (6)	Taxi (7)	Auto Rental (8)	Taxi (9) Dial-a-ride (10)
Many-to-Many	▨		Taxi (11)	Public Lim. (12) Shared-ride Taxi (13)	Taxi (14) Shared-ride Taxi (15)

Dial-a-ride, etc.	Transportation Alternative in Current Use
☐	Possible Public Transportation Alternative
▨	Not a Possible Public Transportation Alternative

Selected Examples of Currently Existing Services

Number from Table	Example Location	Reference Where Described
(1)	Many cities. No specific reference found.	Kirby, R. F., *et al*. Para-transit: Neglected Options for Urban Mobility. The Urban Institute, 1974, p. 59.
(2)	Pittsburg, Pennsylvania	Ibid., pp. 180-181.
(3)	Pittsburg, Pennsylvania	Ibid., pp. 180-181.
(4)	Atlantic City, New Jersey	Ibid., pp. 166-176.
(5)	Portland, Oregon	Paratransit. Transportation Research Board, Special Report 164, 1976, pp. 55-62.
(6)	Long Island, New York	Voorhees, Alan M., and Associates, Inc. Transportation Pooling. U.S. Department of Transportation, January 1974, pp. 193-195.
(7)	New York City, New York	Kirby, R. F., op. cit., pp. 106-109.
(8)	Short-term auto rental, still experimental. Montpellier, France	Ibid., pp. 204-209.
(9)	New York City, New York	Ibid., pp. 106-109.
(10)	Detroit, Michigan	Paratransit, LEA Transit Compendium, Vol. 2, No. 8, 1975, p. 38.
(11)	Washington, D.C.	Kirby, R. F., op. cit., pp. 109-111.
(12)	Many cities. No specific reference found.	Ibid., p. 59.
(13)	Madison, Wisconsin	Ibid., p. 159.
(14)	Washington, D.C.	Kirby, R. F., op. cit., pp. 109-111.
(15)	Davenport, Iowa	Heathington, K. W. and J. D. Brogan. Demand Responsive Transportation Systems. Transportation Center, The University of Tennessee, pp. 7-9.

APPENDIX B

SYSTEM DESIGN GUIDELINE

FIXED-ROUTE TRADITIONAL AND EXPRESS BUS SERVICE

The complete procedure for designing a fixed-scheduled service on a single or multiple route system involves the following sequential steps:

1. Route layout.
2. Preparation of schedule or headway table.
3. Vehicle assignment.
4. Driver assignment or run-cutting.

Specifications for route layouts and headway tables should be obtained from marketing study results that identify the market segment and system attributes. The route layout, for instance, should reflect such service attributes as speed of travel and desired proximity of the target riders' origins and destinations to transit stops. The headway table, similarly, should be based on the desired frequency of service and loading standards.

Allocating vehicles and drivers to provide the services as specified by the route layout and headway table requires special considerations for minimizing the cost. In the case of a single route, the procedures are relatively straightforward; however, for multiple routes these tasks would require some experience and training. The driver assignment or run-cutting procedure often becomes complicated because of the constraints of the labor contract. With small transit systems, vehicle assignment and run-cutting usually are accomplished manually with a trial and error procedure. For larger systems, computer programs incorporating advance optimization algorithms are available for use.

The number of vehicles and the trips per vehicle needed to provide the proposed service are obtained from vehicle assignment. Vehicle-miles of operation are based on the length of each trip and deadhead mileage figures obtained from the route layout. The number of drivers, man-hours of service, and actual pay hours including overtime and idle hours are estimated based on the run cuttings. In the case of express bus service, which is only provided for a few hours per day, it is necessary to account for the utilization of the driver and equipment during the base period.

The system design process for fixed route or express bus service operating on a headway is depicted in Figure B-1. Details of the procedure for the various steps of route layout, preparation of headway tables, vehicle assignments, and run-cutting can be explained most effectively using typical examples. Two examples of system designs for fixed schedule service on single routes are given in Appendix C.

DEMAND RESPONSIVE SERVICES

The system design of a demand responsive service and the estimation of its output measures are characterized by uncertainty. In the cases of fixed route and express bus service every vehicle trip and its distance are known in advance. For a demand responsive service, the number of trips, their origins, and destinations cannot be predicted accurately. However, based on the results of simulation analysis and the actual experiences of dial-a-ride services in a number of cities, guidelines for system design and estimation of output measures can be assembled. A step-by-step approach is presented in the following.

Delineate Service Area and Identify Focal Points

The service area, A, should be delineated into zones based on the findings of a market segmentation study, density of development, and natural features of the area. Focal points for travel destinations, such as shopping centers, fixed route transit service terminals, CBD, and other work sites and community centers within the service area should be identified. The size of a zone would vary, depending on the density of development, and may contain 2,000 to 5,000 population. Usually, one or two vehicles would be assigned to each zone.

Select an Operating Strategy

The operating strategy or mode of operation of a demand responsive service would depend on the market segment to be served. For example, if the service is to be provided in a residential area for commuters, a many-to-one operation focusing on the terminal of a line-haul service should be selected. Many-to-few operations would be appropriate where multiple focal points are identified in the marketing study. Cases in which travel destinations are widely dispersed would be candidates for many-to-many operations. Route deviation type service may be appropriate, in some cases, depending on the development pattern and the roadway network.

Determine Level of Service and Demand Rate

The output measures of service in a given area depend on the level of service and magnitude of patronage, both of which should be determined based on a market analysis. The level of service for a dial-a-ride system usually is expressed in terms of either the total time, T, from phone call to delivery at destination or the ratio, L, of the total time, T, to comparable time to make the same trip by automobile, T_a. The total time for a dial-a-ride trip includes the wait time, which is one of the primary determinants of the level of service.

The measure of demand that is most directly related to the operation of a demand responsive service is the number of requests per unit time. This demand rate, R, must be distinguished from the patronage rate, R', which is expressed as the number of passengers per unit time. The

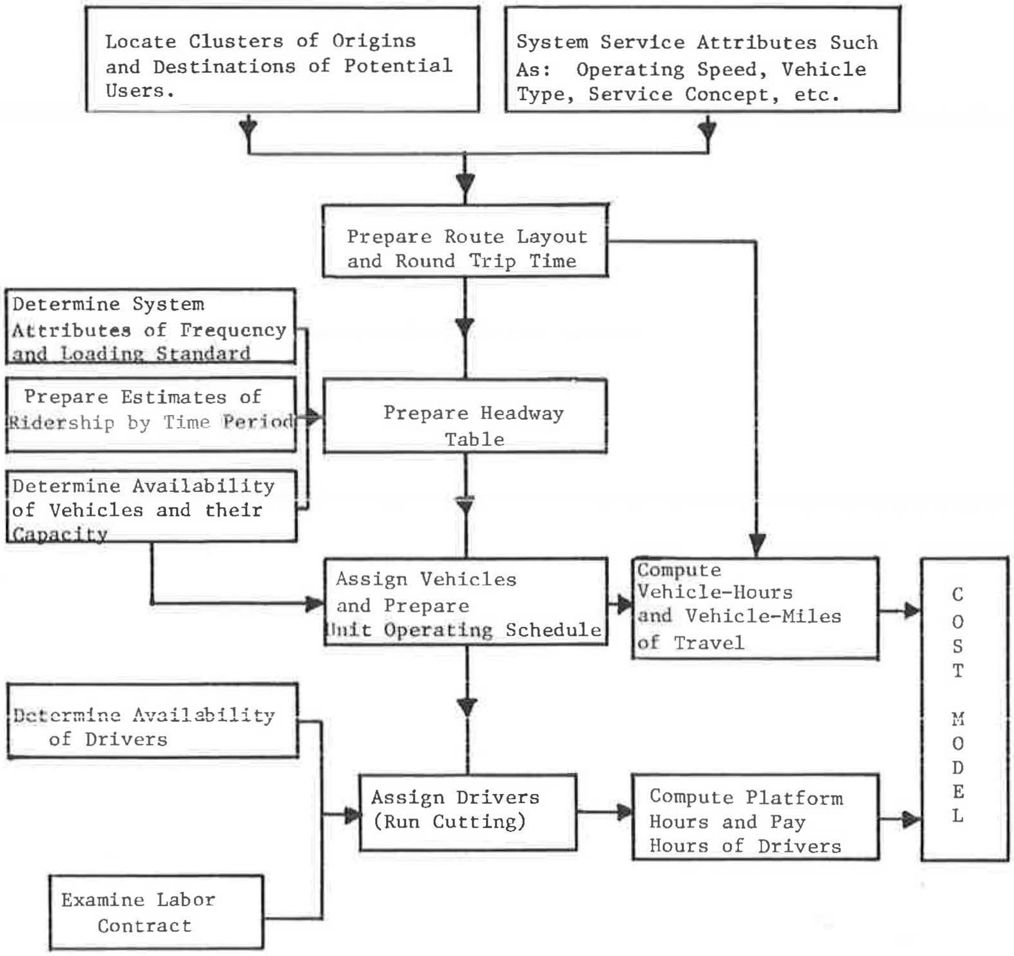


Figure B-1. System design process for fixed route and express bus service.

patronage rate would be higher than the demand rate if several passengers with common trip origins and destinations can be served in response to a single request. The patronage estimate thus may be reduced somewhat to obtain the demand rate to be used for system design. In the absence of specific local information, the demand rate may be estimated as follows:

$$R = R' \div 1.2 \qquad \text{(B-1)}$$

Variations in the desired level of service and fluctuations of demand, if any, during the service period should be noted and taken into account in estimating the number of vehicles.

Estimate Number of Vehicles

The number of vehicles, N, may be estimated based on a formula developed at the Massachusetts Institute of Technology. The following formula first was derived based on the results of a simulation analysis and subsequently was calibrated to reproduce the characteristics of an actual demand responsive system.*

$$N = (0.86A + 0.092R) \div [ST \div 32.4\ (A)^{1/2} - 1]^{1/2} \qquad \text{(B-2)}$$

or

$$N = (0.86A + 0.092R) \div [L\text{-}1]^{1/2} \qquad \text{(B-3)}$$

where: A = service area, sq mi;
R = hourly demand rate;
S = vehicle speed, mph;
T = total time from phone call to delivery, min; and
L = ratio of total time to comparable time by automobile.

The foregoing formula was derived for a many-to-many operation, but may be used also for many-to-one or many-to-few services with an adjustment factor. The productivity of vehicles has been found to be higher for many-to-one and many-to-few services. The vehicle requirement for these operations would be approximately 85 percent of that of a many-to-many service.

An alternative procedure to estimate the number of vehicles is to assume a value for the productive capacity of each vehicle based on the experience gained from the actual

---

* *Dial-A-Bus Feasibility in the North Central Texas Region.* Dave Systems, Inc. (December 1974).

operations of demand responsive services. However, it should be noted that the vehicle productivity values reported in various documents in some cases may not represent the productive capacity for the desired level of service, but instead may be the actual productivity experienced with respect to a different demand rate as well as level of service.

Estimate Various Output Measures

When service-hours and the number of vehicles to be used during different time periods are known, vehicle-hours and platform-hours of drivers can be estimated. Vehicle-miles of operation also may be estimated by assuming an average speed of the vehicles. Pay-hours of drivers have to be computed after a careful examination of the availability of drivers and requirements of the labor contract.

An example application of the system design of a dial-a-ride service and derivation of various output measures for cost estimation are given in Appendix C.

RIDESHARING SERVICES

The design of a rideshare service is relatively straightforward, because no headway level is maintained. The first step is to specify a route layout from the definition of market segment to be served. The market segment will suggest an origin-destination pattern and time schedule. The number of rideshare vehicles can be determined based on the rideshare mode to be introduced, average vehicle occupancy, and size of market to be served. In development of the routing, maximum efficiency would be achieved, resulting with a full passenger load commuting the greatest distance. This should be the prime factor in selecting routes. Also, rideshare routes should be as direct as possible over the fastest highway links. Additional vehicle-miles of service need to be added to account for pickup and delivery for ridesharing circulation at the trip origin and destinations.

With ridesharing, the planner has to serve as a catalyst-facilitator and coordinator, attempting to interest individuals and organizations in developing and maintaining ridesharing services. Because of this activity, there are "front-end" administrative costs involved in locating suppliers, securing vehicles, and matching rideshare demands with suppliers. These administrative expenses might impose additional costs. Examples of rideshare cost analyses are presented in Appendix C.

SELECTED READINGS

Cost Models for Transit Services

Traffic, Revenue, and Operating Costs. W. C. Gilman and Co. and Alan M. Voorhees and Associates (1969).

Ferreri, M. B., "Development of a Transit Cost Allocation Formula." *Highway Research Record 285* (1969) pp. 1-9.

Bodin, L., Rosenfield, D., Kydes, A., and Roark, A. L., "A Transit Operating Cost Model Based on Direct Systems Characteristics" (Undated).

System Design of Fixed Route and Fixed Schedule Bus Systems

Lundberg, B. D., and Brown, R. L., "Transit Route and Schedule Planning." *Proceedings of the Lecture Series on Urban Transportation,* 1971-72, Milwaukee, Wis., Marquette University (June 1973).

Mass Transit Management: A Handbook for Small Cities. Indiana University, Institute for Urban Transportation (1971).

Shortreed, J. H. (Ed.), *Urban Bus Transit—A Planning Guide.* The Transport Group, Department of Civil Engineering, University of Waterloo, Waterloo, Can. (May 1974).

"Recommended Standards, Warrants, and Objectives for Transit Services and Facilities." *Procedure Manual 8A,* Chicago, National Committee on Urban Transportation, Public Administration Services (1958).

System Design of Demand Responsive Services

Heathington, K. W., and Brogan, J. D., *Demand Responsive Transportation Systems.* University of Tennessee, Transportation Center (Aug. 1974).

Guenther, K. W., "Demand-Responsive Transportation in Ann Arbor: Operation." *Transportation Research Record 608* (1976) pp. 20-25.

Hoey, W. F., "Dial-A-Ride in the Context of Demand-Responsive Transportation: A Critical Appraisal." *Transportation Research Record 608* (1976) pp. 26-29.

Cost Data and Related Parameters for Passenger Transportation Services

Wells, J. D., et al. *Economic Characteristics of the Urban Public Transportation Industry.* Institute for Defense Analyses (Feb. 1972).

Sanders, D. B., Reynen, T. A., *Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners.* Deleuw Cather & Co. (May 1974).

"Vol. I: Results of a Survey and Analysis of Twenty-one Low Cost Techniques," and "Vol. II: Results of Case Studies and Analysis of Busway Application in the United States." *Low Cost Urban Transportation Alternatives: A Study to Increase the Effectiveness of Existing Transportation Facilities,* R. H. Pratt Assoc. (Jan. 1973).

Reed, M. E., *The Economic Cost of Commuting: Technical Study Memo. No. 13.* Highway User's Federation, Washington, D.C. (July 1975).

Tennyson, E. L., *Economic Relationships Among Urban Transit Modes. Transportation Research Record 552* (1975) pp. 19-30.

Kirby, R. F., et al., *Para-Transit: Neglected Options for Urban Mobility.* The Urban Institute (1974).

Small City Transit: Summary of State Aid Programs.

U.S. DOT (May 1976). Note: In addition to summary, individual reports on 16 different services are available.

Davis, F. W., et al., *Ridesharing and the Knoxville Commuter.* University of Tennessee, Transportation Center (Aug. 1975).

Levinson, H. S., Adams, C. L., Hoey, W. F., "Bus Use of Highways—Planning and Design Guidelines." *NCHRP Report 155* (1975) 161 pp.

Transportation Economics. Highway Research Record 285 (1969) 131 pp.

Kooner, J., et al., *Investigation of A Light Rail System for the San Diego Region.* Review Draft, Department of Transportation, County of San Diego, Calif., Vol. 2 (Apr. 1975).

Brooke, T., *An Analysis of an Urban Jitney System in Chattanooga, Tennessee.* University of Tennessee, Transportation Center (Sept. 1976).

APPENDIX C

COST ANALYSIS EXAMPLES

COST ANALYSIS EXAMPLE FOR AN EXPRESS BUS SERVICE ON A BUSWAY

Scenario

The transportation planning agency is examining alternative commuter-transit services. One alternative is fast express bus service during peak commuting hours between selected residential areas and the CBD. A cost example of bus service to and from a specific residential area is required.

Specifications for Service

The market analysis and other studies prior to the selection of alternatives help determine not only the residential areas to be served but the following specifications of the service:

1. The bus should circulate through the residential area to minimize walking distance to bus stops. (The routing should be designed carefully to avoid an excessively long loop and still achieve good coverage.) The route through the CBD should connect the specified employment centers.
2. Bus service should be provided for two hours in the morning, the first trip leaving the residential area at 7:00 a.m.; and for two hours in the afternoon, the first trip leaving the CBD at 4:00 p.m.
3. Headway for the service should be 20 minutes.
4. Travel time by bus should be less than that by automobile. This requires bus lanes or a busway that is to be built for the exclusive use of buses during peak hours.
5. The local transit company will have to purchase new buses for this service. However, the new buses can be used for other purposes during the day.
6. None of the present operators are available to drive the express buses. Additional operators have to be engaged and they have to be paid for a minimum of 8 hours. The maximum spread time without premium pay is 12 hours.

System Design

The planner proceeds through the various steps of system design on the basis of the given specifications. The route layout is shown in Figure C-1 and the headway table is given in Table C-1. The following travel time estimates were necessary for constructing the headway table.

1. Travel time for a one-way trip between residential terminal and CBD terminal = time required to travel 2 mi at 15 mph in residential area + 10 mi at 45 mph along freeway + 1 mi at 10 mph in the CBD = $(8 + 13 \cdot 3 + 6)$ min $= 27.3$ min or 28 min.
2. Travel time from garage to residential terminal (or reverse) = time required to travel 1 mi at 15 mph for freeway access + 10 mi at 45 mph along freeway + 2 mi at 15 mph in residential area = $(4 + 13 \cdot 3 + 8)$ min $= 25.3$ min or 26 min.
3. Travel time from garage to CBD terminal (or reverse) = time required to travel 1 mi at 15 mph = 4 min.

Vehicle and driver assignments are fairly straightforward in this case, since, according to the specifications, additional equipment and operators must be supplied exclusively for the express service. These assignments are given in column 1 of Table C-2. Estimates of the output measures of service that are needed for cost analysis are derived from the system design. Table C-2 shows the estimates of vehicle-miles and vehicle-hours of equipment operation and man-hours of operator service to be paid.

Cost Analysis

The cost of providing the express bus service, as specified, includes all the major categories of expenditure. The analysis for each is discussed separately.

Cost of Guideways and Related Facilities

On the basis of an engineering study, it was decided that

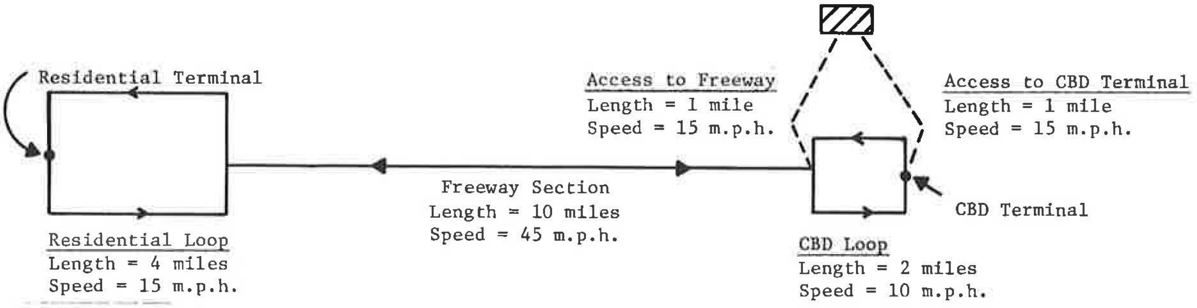


Figure C-1. Route layout of express bus service for commuters.

TABLE C-1

SCHEDULE OF EXPRESS BUS SERVICE

A. A.M. SCHEDULE

Bus and Driver No.	Leave or Arrive Garage	Leave Residential Terminal	Arrive CBD Terminal	Arrive Residential Terminal
1	L 6:34	7:00	7:28	7:56
2	L 6:54	7:20	7:48	8:16
3	L 7:14	7:40	8:08	8:36
1		8:00	8:28	8:56
2	A 8:52	8:20	8:48	
3	A 9:12	8:40	9:08	
1	A 9:32	9:00	9:28	

B. P.M. SCHEDULE

Bus and Driver No.	Leave or Arrive Garage	Leave Residential Terminal	Arrive CBD Terminal	Arrive Residential Terminal
1	L 3:34	4:00	4:28	4:56
2	L 3:54	4:20	4:48	5:16
3	L 4:14	4:40	5:08	5:36
1		5:00	5:28	5:56
2	A 5:52	5:20	5:48	
3	A 6:12	5:40	6:08	
1	A 6:32	6:00	6:28	

TABLE C-2

ESTIMATES OF OUTPUT MEASURES FOR EXPRESS BUS SERVICE

A. VEHICLE-MILES OF OPERATION

	For A.M. hours		For P.M. hours		
Bus No.	In-Service	Deadhead	In-Service	Deadhead	Total
1	65	14	65	14	158
2	39	14	39	14	67
3	39	14	39	14	67
				TOTAL	292

B. VEHICLE-HOURS AND OPERATOR PAY HOURS

	Vehicle/Platform Hours			
Driving No.	A.M. Hours	P.M. Hours	Total	Pay Hours
1	3.0	3.0	6.0	8.0
2	2.0	2.0	4.0	8.0
3	2.0	2.0	4.0	8.0
			TOTAL =14.0	TOTAL =24.0

the exclusive lane for the express service will be provided by constructing a busway along the median of a freeway. Of course, if express service was provided in mixed traffic or on an existing roadway, the costs would be different. The busway will accommodate one-way movement in the peak direction. The reverse movement in the off-peak direction will take place along the freeway lanes. Assuming a 24-ft pavement with 8-ft shoulders on each side, it is estimated that the guideway will cost approximately $2.5 million per mile, including the cost of special access ramps. Thus, the initial cost for the 10-mile section is $25 million, assuming 10 percent interest rate and 40-year service life:

1. Annual Cost = $25,000,000 (*CR* - 10% - 40 yr) = $25,000,000 × 0.10226 = $2,556,500.
2. Considering 250 days of operation per year, daily cost = $2,556,500 ÷ 250 = $10,226.

The busway will not be used by this particular express route alone. The minimum number of bus trips needed to justify a busway usually is considered to be in the range of 40 to 60 per hour in one direction during the peak hours. In this case, the planner estimates that there would be 50 bus trips per hour on the busway in the peak direction, and thus a total of 200 bus trips will be accommodated by this busway during the four peak hours in the morning and afternoon of each operating day. Therefore, the daily cost for the busway that may be allocated to this express route providing 14 trips per day is $10,226 × 14/200 = $715.82.

It should be pointed out that the busway may be used by carpools and vanpools during the peak hours and for other special purposes during off-peak hours. However, because in this particular case the primary purpose for constructing the busway is for the use of express buses during peak hours and because the other uses are not clearly defined, the cost is not allocated to other possible users.

Cost of Equipment

According to the specifications, none of the already available buses may be used for this service. Therefore, three new buses must be purchased. However, the specifications also indicate that these buses will be used for other purposes; so the cost can be allocated to the express service in proportion to usage.

Assuming that the initial cost of a new 51-passenger bus is $80,000 and that its service life is 12 years at the end of which it will have a salvage value, the present worth of which is $16,000, annual cost = $64,000 × (*CR* - 10% - 12 yr) = $64,000 × 0.1505 = $9,393/year.

Considering 250 days of operation per year and 12 hours of use of each bus per day, the hourly cost for equipment is $9,393 ÷ 3,000 hours = $3.13 per hour. Thus the daily cost for equipment for 14.0 vehicle-hours of operation is $3.13 per hour × 14.0 hours = $43.82.

Operating Cost

The operating cost of transit services is grouped into four broad categories:

1. Out-of-pocket vehicle operating cost (excluding operator's wage).
2. Direct maintenance cost.
3. Operator's wage.
4. Other operating costs.

Of these categories, only the first three are considered relevant to this analysis. Considering that the express service is a small addition to an existing system, many costs related to system operation and administration will not be affected by the additional service. Using unit costs appropriate for the particular system being analyzed, the operating costs are estimated as follows:

1. Out-of-pocket vehicle operating cost = 292 vehicle-miles × $0.15 per vehicle-mile = $43.80.
2. Direct maintenance cost = 292 vehicle-miles × $0.20 per vehicle-mile = $58.40.
3. Operator's wage = 24.0 pay-hours × $8.00 per hour = $192.00.

Thus the total operating cost is estimated to be $294.20 per day.

Summary

As noted in Table C-3, the total daily cost of providing the proposed express bus service can be found by summing up the various components. These add up to $1,053.84 per day. This cost now can be compared with the estimated revenue for the purpose of a feasibility analysis.

The disaggregate structure of the cost estimation procedure will permit adjustments to be made if it is decided to change the specifications. For example, if it is determined that the express service can be provided with buses that are already available, the item for the cost of equipment depreciation may be ignored. On the other hand, certain types of changes will require revisions in the computations. For instance, if it is decided to explore the alternative of running the express buses with mixed traffic along the regular freeway lanes, the planner not only may ignore the cost for guideways, but also may have to adjust scheduling since travel time for the buses along the freeway would be different. However, the planner would know exactly where and how these changes should be incorporated because of the open structure of the procedure.

COST ANALYSIS EXAMPLE FOR A CONVENTIONAL BUS SERVICE

Scenario

The planning agency wants to implement bus service between the CBD and a major shopping center in a suburb. The planning agency feels that the service would attract many commuters and that it would provide urban residents access to the suburban shopping center, enhancing their employment and shopping opportunities. The Transit Authority of an urban area wants a precise estimate of the cost of providing the service before agreeing to implement the proposal.

Specifications for Service

The market analysis and other studies provide the following information related to the proposed service:

1. The bus service should be of a conventional nature with frequent stops. However, the route should be as direct as possible and use the major arterial roadway connecting the CBD with the shopping center.

2. The bus service should be provided for approximately 15 hours. The first bus trip should leave the shopping center at 6 a.m. and the last trip should leave the CBD at 9:00 p.m.

3. The headway should be approximately 20 minutes during the two peak periods of 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m.

4. Buses for the service are already available.

5. None of the present drivers can be utilized for this service and the additional drivers to be hired have to be guaranteed a minimum of 8 hours of service. The maximum spread time without premium pay is 12 hours. The premium pay is 1½ times the regular wage for all hours in excess of 8 platform hours. The spread premium pay is an extra amount at the rate of one-half the regular hourly wage for all hours after the 12-hour spread.

System Design

The first step in system design is to lay out the route and prepare a headway table. The planner accomplishes these tasks as shown in Figure C-2 and Table C-4, respectively, based on the following estimates of travel times:

1. Travel time for a one-way trip between the shopping center and CBD terminal in peak direction during peak hours = 52 minutes; and in off-peak direction during peak hours and both directions during off-peak hours = 40 minutes.

2. Travel time from garage to shopping center (or reverse) = 39 minutes.

3. Travel time from garage to CBD terminal (or reverse) = 4 minutes.

Vehicle and driver assignments were complicated by the requirement of different headways during peak and off-peak hours. Driver assignment, or run-cutting, needs careful analysis because the planner must strive to minimize pay-hours. The stipulations of the labor contract must be recognized in the run-cutting process to avoid premium pay as well as pay without work. The run-cutting shown in Table C-5 was done manually by a trial and error procedure. The estimates of the output measures of service that are needed for cost analysis are given in Tables C-6 and C-7.

TABLE C-3

DAILY COST SUMMARY FOR EXPRESS BUS SERVICE

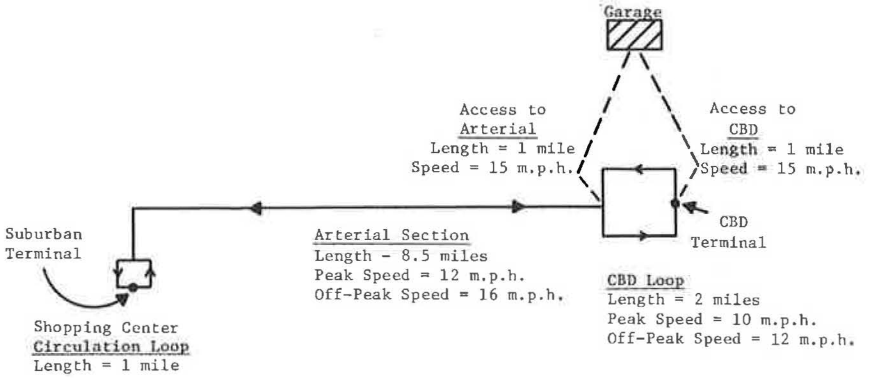
Busway		$715.82/day*
Equipment		43.82/day
Operating Cost		
Out-of-Pocket Vehicle Opt.	43.80	
Maintenance	58.40	
Labor	192.00	294.20/day
TOTAL		$1053.84

*If express service was provided in mixed traffic or on existing roadway, the cost would be different.

Cost Analysis

The cost of providing the new direct bus service between the CBD and suburban shopping center includes neither the cost of guideways nor capital expenditures for new equipment. Of course, there will be some guideway related expenses for such items as bus stop signs, but they will be ignored for this example exercise. Thus, the operating cost in this case is the only major item that needs a detailed analysis.

Of the various items within the category of operating cost, the out-of-pocket vehicle operating cost, direct maintenance cost, and operator's wage are most relevant for this case. Because the proposed service is an addition to an existing system for which administrative and operational personnel are already available, transportation operations, scheduling and general administration, etc. are likely to be absorbed by the current system. However, in the case of a small transit system, especially when the operating agency is already understaffed, the addition of a new regular route may require additional manpower. The



Peak and Off-Peak
Speed = 10 m.p.h.

Assumption: Peak speed used for travel during peak hours in the peak direction only.

Figure C-2. Route layout of conventional bus service.

TABLE C-4

SCHEDULE OF CONVENTIONAL BUS SERVICE

Bus No.	Leave or Arrive Garage	Leave Shopping Center	Arrive CBD Terminal	Arrive Shopping Center
1	L 5:21 a.m.	6:00	6:40	7:20
2	L 5:51	6:30	7:10	7:50
3	L 6:21	7:00 Peak	7:52	8:32
1		7:20 Peak	8:12	8:52
4	L 7:01	7:40 Peak	8:32	9:12
2	A 8:56	8:00 Peak	8:52	
5	L 7:41	8:20 Peak	9:12	9:52
3	A 9:36	8:40 Peak	9:32	
1		9:00	9:40	10:20
4		9:30	10:10	10:50
5		10:00	10:40	11:20
1		10:30	11:10	11:50
4		11:00	11:40	12:20
5		11:30	12:10 p.m.	12:50
1		12:00 noon	12:40	1:20
4		12:30	1:10	1:50
5		1:00	1:40	2:20
1		1:30	2:10	2:50
4		2:00	2:40	3:20
5		2:30	3:10	3:50
1		3:00	3:40	4:20
4		3:20	4:00 Peak	4:52
2	L 4:16		4:20 Peak	5:12
5		4:00	4:40 Peak	5:32
1	A 6:31	4:20	5:00 Peak	5:52
3	L 5:16		5:20 Peak	6:12
4	A 7:11	5:00	5:40 Peak	6:32
2		5:20	6:00	6:40
5		5:50	6:30	7:10
3		6:20	7:00	7:40
2		6:50	7:30	8:10
5	A 9:19	7:20	8:00	8:40
3	A 9:49	7:50	8:30	9:10
2	A 10:19	8:20	9:00	9:40

planner must examine the specific situation carefully and decide whether to ignore the item of "other" operating cost or not. For the purpose of this analysis, the "other" operating costs will be ignored. The costs are estimated as follows:

1. Out-of-pocket vehicle operating cost = 749 vehicle-miles × \$0.15 per vehicle-mile = \$112.35.
2. Direct maintenance cost = 749 vehicle-miles × \$0.20 per vehicle-mile = \$149.80.
3. Operator's wage = 70.87 pay-hours × \$8.00 per hour = \$566.96.

Summary

As noted in Table C-8, the total operating cost is estimated to be \$829.11 per day. Total operating cost in this case accounts for all additional expenditures to be incurred by the transit authority in providing the new service. The marginal or incremental approach used for cost estimation ignored the cost of equipment depreciation because the buses already were depreciated, and it did not allocate a portion of the "other" operating costs to the new service. This approach may be questioned from a pure cost accounting standpoint, but it is appropriate for the planning context of this particular case.

COST ANALYSIS EXAMPLE FOR A DEMAND RESPONSIVE SERVICE

Scenario

The planning agency in a medium size urban area is examining the feasibility of providing transit service during off-peak hours in a low density residential area so that the local residents (housewives, elderly persons, and children) can have access to a shopping center, a community center, and the terminal of a line-haul bus route located at the shopping center. The transit planner has been asked to estimate the cost of providing a dial-a-ride service. In addition, the planner has been asked to explore the costs of two alternative suppliers for the service—the city-owned transit company and a private operator.

Specification for Service

A market opportunity analysis (MOA) was performed for a dial-a-ride service in the selected area, and it helped determine the potential demand as well as certain desirable attributes of the service that are listed as follows:

1. The service is needed for a 7-hour period between 9:00 a.m. and 4:00 p.m. on weekdays.
2. The average demand for service = 20 passenger trips per 1,000 persons per day. During this 7-hour period, there is no significant peaking of demand.
3. The level of service does not need to be high and a wait time of 30 minutes, or a total time from phone call to delivery at destination of 45 minutes, would be acceptable and consistent with the estimated demand rate.
4. No additional shelters need be provided because those in the shopping center and the community center can be utilized by the dial-a-ride patrons.
5. The vehicles (vans and/or limousines) for providing

the dial-a-ride service have to be purchased by the city-owned transit company. The radio communication system for the regular fixed-route system of the transit company can be utilized for the dial-a-ride service, and there would be no additional cost for dispatching except for radio equipment in the vehicles.

6. A few drivers of the transit company have idle hours during the off-peak period and may be available at no additional cost. One operator is available between 9:00 a.m. and 1:00 p.m., and another is available between 12:00 noon and 4:00 p.m. Any drivers added for the service would have to be guaranteed a minimum of 8 hours of service according to the labor contract.

System Design

A step-by-step procedure for estimating the vehicle requirement, vehicle-hours, and pay-hours for operators is outlined in the following:

1. Characteristics of service area and service.
   P = Population = 10,000
   A = Area = 6 sq mi
   R = Hourly demand = $20 \times 10 \div 7 = 29$ requests per hour (Assuming conservatively that each passenger trip generates one request)
   T = Total time from phone call to delivery = 45 min
   S = Vehicle speed = 15 mph

2. Operating strategy for dial-a-ride service. Many-to-few service will be provided between home and two focal points—shopping center and community center.

3. Number of vehicles. The number of vehicles required to serve the anticipated demand may be estimated by two methods. Both are used for a comparison of the results and an assessment of their reasonableness, the difference, if any.

   a. Using a formula developed at MIT (see App. B), number of vehicles for many-to-many service = $(0.86A + 0.092R) \div [ST/32.4(A)^{1/2} - 1]^{1/2} = 7.83 \div (8.5 - 1)^{1/2} = 7.83 \div 2.74 = 2.86$. Number of vehicles for many-to-few service $\approx$ 85 percent of vehicle requirement for many-to-many services = $0.85 \times 2.86 = 2.4 \approx 2$ vehicles.

   b. Maximum vehicle productivity based on experience in several urban areas with many-to-few service = 12 trips per hour (for medium level of service). Therefore, the number of vehicles required = $29 \div 12 = 2.4$.

The estimates based on both procedures are compatible and appear to be reasonable.

4. Vehicle-miles and vehicle-hours of service.
   a. In-service vehicle-hours per day = 2 vehicles $\times$ 7 hours = 14 vehicle-hours.
   b. Assuming a speed of 15 mph, daily in-service vehicle-miles of operation = $14 \times 15 = 210$. Deadhead vehicle-miles = 20. Total vehicle-miles = 230.

5. Man-hours of service and pay-hours.
   a. Man-hours of service = 14 man-hours = (7

TABLE C-5

UNIT OPERATING SCHEDULE AND DRIVER ASSIGNMENT

Vehicle	Leave Garage	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD	Res.	CBD		~~Return~~ Garage
1	4 5:21	6:00	6:40	7:20	8:12	9:00	9:40	10:30	1 11:10	12:00	12:40	1:30	2:10	3:00	3:40	4:20	5:00	5:52					6:31
2	7 5:51	6:30	7:10	8:00	8:52	Garage 8:56								8 Garage 4:16	4:20	5:20	6:00	6:50	7:30	8:20	9:00	9:40	10:19
3	6 6:21	7:00	7:52	8:40	9:32	Garage 9:36								7 Garage 5:16	5:20	6:20	7:00	7:50	8:30	9:10			9:49
4	2 7:01	7:40	8:32	9:30	10:10	11:00	11:40	12:30	1:10	2:00	6 2:40	3:20	4:00	5:00	5:40	6:32							7:11
5	5 7:41	8:20	9:12	10:00	10:40	11:30	12:10	1:00	3 1:40	2:30	3:10	4:00	4:40	5:50	6:30	7:20	8:00	8:40					9:19

Note: 4 denotes a run number. Each run is assigned to one driver.

TABLE C-6

VEHICLE MILES OF OPERATION

Bus No.	Number of Round Trips	In-Service Mileage	Deadhead Mileage	Total Mileage
1	8	160	21	181
2	5	100	23	123
3	4	80	23	103
4	7	140	21	161
5	8	160	21	181
Totals	32	640	109	749

man-hours on one vehicle and 7 man-hours on the second vehicle).

b. According to the specifications, 7 consecutive hours service can be provided by two idle operators and they can be assigned to one vehicle. For operating the other vehicle, however, an additional driver must be hired and will have to be paid for a minimum of 8 hours. Thus, the number of pay-hours = 8.

Cost Analysis for Public Operation

According to the specifications there will be no cost for guideways and related fixed facilities. The costs for equipment and operations are estimated as follows:

1. Cost for equipment. The equipment includes two vans equipped with radio and fare boxes:

a. Cost for two vans at $12,000 each = $24,000. Radio equipment for vehicles at $1,500 each = $3,000. Fare boxes at $500 each = $1,000. Total = $28,000.

b. Assuming 6-year life of equipment with no salvage value and 10% interest rate, the cost = annual cost for equipment = $28,000 (*CR* — 10% — 6 yr) = $28,000 × 0.2296 = $6,428.80.

c. Assuming 250 days of operation per year, the cost for equipment per day = annual cost ÷ 250 = $6,428.80 ÷ 250 = $25.72.

2. Operating cost. The operating cost in this case includes out-of-pocket operating cost, direct maintenance cost, and driver wages. According to the specifications, other operating costs including those for dispatching and scheduling can be absorbed by the existing operation without additional expenditures:

a. Out-of-pocket operating cost and direct maintenance cost at $0.15 per vehicle-mile = 230 × 0.15 = $34.50.

b. Drivers wages = pay-hours × wage rate = 8 × $8.00 = $64.00.

c. Total daily operating cost = $98.50.

Thus the total cost of providing the dial-a-ride service by the city-owned transit company = $124.22 per day (Table C-9).

Cost Analysis for Private Operation

The cost of private operation can be estimated accurately by actually taking bids from private operators who are capable and willing to provide the service. Therefore, the first step would be to identify appropriate suppliers. In the case of a small-scale service, it is highly unlikely that a private operator would be willing to start a new operation exclusively for this purpose. However, operators currently engaged in demand responsive services with small vehicles, such as taxicab companies, might be interested in providing this service. Therefore, the planner can contact a few selected taxicab operators, identifying those willing to provide the service at $10.00 per hour. Thus, the daily cost to be incurred by the city to provide the service through a private operator = $10.00 × 7 hours = $70.00.

Summary and Comments

The planner has two options for providing the dial-a-ride service in a residential area. The cost of providing the service by the city-owned transit company is $124.22 per

TABLE C-7

DRIVER RUN SUMMARY

Run No.	Work Time Period[1]	Platform Hour	Overtime Hour[2]	Spread Premium Hour[3]	Total Equivalent Pay Hour
1	10:51 - 6:46	7:55	0	0	8.00
2	6:46 - 2:59	8:13	0.22	0	8.43
3	1:21 - 9:34	8:13	0.22	0	8.43
4	5:06 - 11:29	6:23	0	0	8.00
5	5:21-7:26, 7:26-1:59	8:38	0.63	0	9.27
6	2:21-5:59, 6:06-9:51	7:23	0	0	8.0
7	4:57-10:04, 5:36-9:11	8:42	0.7	4.47	11.64
8	4:01 - 10:34	8:33	0.55	0	9.10
					70.87

1. Work time period covers 15 minutes before bus run starts and 15 minutes after bus run ends, plus 4 minutes of commuter time to and from CBD when drivers start or end their run at that location.

2. Overtime hour is the time in excess of 8 platform hours for which the rate is 1½ times the regular rate.

3. Spread premium hour is the time in excess of 12 hours of spread time. A driver is paid an extra amount at the rate of one-half the regular hourly wage for these hours.

day, while that of hiring a taxicab company to provide the service is $70.00 per day. The main reason for the difference in cost in this case is that the city-owned operation will have to purchase new vehicles to provide this service, whereas the rate quoted by the taxicab operators appears to indicate that they would be able to accommodate this added demand with their existing fleet.

Another item of cost that may make a significant difference between public and private operation is the wage rate of operators. Usually, the wage rate of drivers in a unionized public operation is higher than that paid by private operators who employ many part-time drivers. In this specific case, however, the wage-related cost for the public operation was not higher because of the availability of two idle operators from the existing fixed-route system.

The planner should point out to the transit authority or the appropriate decision-making group that the cost estimates for the two types of operations (public and private) may not be directly comparable because the type of vehicle used may differ and the quality of service also may differ in terms of reliability. A satisfactory mechanism for revenue recovery will have to be devised in the case of the private operation.

TABLE C-8

DAILY COST FOR CONVENTIONAL BUS SERVICE

Busway		None
Equipment		None - Assumed to be Fully Depreciated
Operating Cost		
Out-of-Pocket Vehicle Opt.	112.35	
Maintenance	149.80	
Labor	566.96	
	$829.11	

TABLE C-9

DAILY COST FOR DEMAND RESPONSIVE SERVICE (PUBLIC OPERATION)

Equipment		
Vans		$25.72
Operating Costs		
Out-of-Pocket Vehicle Operation and Maintenance	34.50	
Labor	64.00	
TOTAL		98.50
		$124.22/day

COST ANALYSIS EXAMPLES FOR RIDESHARE SERVICE

Scenario A

A middle income subdivision, where many individuals (400) who work for the major employer in the downtown area reside, is located 15 miles from the CBD. The employer has expressed an interest in promoting ridesharing as an energy conservation program and to avoid providing free downtown parking for employees. No transit service currently serves the subdivision.

Present vehicle occupancies are 1.3 person/vehicle, with little incentive for ridesharing (no formal promotion, no incentive packages, relatively low and stable gasoline prices, tight but sufficient parking). Informal contacts suggest 25 to 35 employees might seriously consider ridesharing. Should the employer encourage carpools through priority parking for carpoolers and provide an in-company match board or should the employer initiate a rideshare van or bus program?

Specifications for Service A

1. Assume 30 persons are seriously interested in ridesharing, and carpools will assume to have an average auto occupancy of 3.2 persons/vehicle. Driving responsibilities are to be rotated, and the commuter car is not to be sold. Out-of-pocket savings are half of total operating costs = $0.158/2. Also include $1.50/day for parking.

2. Fifteen-seat vans will be provided and are expected to achieve an average occupancy of 10 persons/van. Vans will incur 15 percent increased VMT due to pickup in residential area. Vans will cost $250/mo. plus $0.10/mile to operate. It is also assumed van fares will be set to provide break-even operations.

3. A standard 50-seat bus will be requested from the transit company. Since no additional peak-hour service is available, a driver will be hired just to provide the express service and the driver will be paid 10 hours per day, two hours of which are considered overtime. The driver will start and end all trips at the garage.

4. Annual bus operating costs are as follows:
    a. Vehicle operating costs = $0.15/mi.
    b. Maintenance costs = $0.20/mi.
    c. Operator wages = $8.00/hr.
    d. Full depreciation (at 12 years, 250 day/yr, 12 hr/day) = $3.13/hr.
    e. Insurance and management costs are minor and are not included.
    f. Bus is not stored in CBD area, but is returned to the garage 2 mi from the CBD.
    g. Fare = $0.60/ride.
    h. VMT will increase 25 percent for circulation in residential areas.

Cost Analysis A

1. Carpools. Assuming carpools are attractive for 25 to 35 (use 30 as average) employees with an average auto occupancy of 3.2 persons/carpool, determine the resulting cost.
    a. Autos eliminated from CBD = 30/1.3 = 23
    Less vehicles used for carpooling 30/3.2 = 10
    Net reduction for CBD parking 13 autos.
    b. Annual VMT = 10 autos × 15 mi/day × 2 × 250 days/yr = 75,000 VMT/yr.

c. Annual user cost $= \frac{(\$0.158)}{2}$ (75,000 VMT/yr) + ($1.50/day) (250 day/yr) (10) = $9675/yr.

2. Vanpools. Assuming vanpools were established for the 30 employees interested in ridesharing and with an average van occupancy of 10 persons/van, determine the resulting costs.

   a. Autos eliminated from CBD = 30/1.3 = 23 autos
      Vans required = 30/10 = 3 vans
      Net reduction for CBD parking = 20 autos.
   b. Annual VMT = 3 × 15 × 2 × 250 × 1.15 = 25,875 VMT/yr.
   c. Annual user cost = 25,875 VMT/yr ($0.10/mi) + (3) 250 (12) = $11,587/yr.

3. Buspool

   a. Buses required = 30/50 = 1 bus.
   b. Annual bus VMT =
      revenue service = 1 bus × 15 mi × 2 trips/day × 250 days/yr × 1.25
      deadheading = 1 bus × 15 mi × 2 trips/day × 250 days/yr
      access to garage = 1 bus × 2 mi × 2 trips/day × 250 days/yr
      = 17,875 VMT/yr.
   c. Bus annual cost = 17,875 VMT/yr ($0.35/mi) + $8.00/hr (8 hr/day) 250 days/yr + $8.00/hr (1.5) (2 hr) 250 days/yr + $3.13 (10 hr/day) (250 days/yr) = $36,080.
   d. To offset the operating cost revenue collected would be $0.60/ride × 2 trips/day × 30 persons/day × 250 days/yr = $9,000.

Summary A

The results from the three options are summarized in Table C-10 and indicate that both the vanpools and express bus are less efficient than carpooling in reducing user costs. Cost estimates for user savings through vanpooling and buspooling are conservative because it is assumed that carpools members rely on shared driving and no payments will exchange hands. If a private vehicle could be sold because of the vanpool or buspool, the resulting user savings would be greater for these two rideshare modes. Unfortunately, operating the express bus results in a large monetary loss to the public bus company. Most of this loss can be attributed to the corresponding difficulty in locating base work for the drivers and equipment. The most efficient program would then be vanpooling, assuming that the employer is willing to become involved in coordinating a vanpool program.

Scenario B

Because of increased energy costs and a sharp reduction in downtown parking due to new office building construction, the potential market for ridesharing has increased to 180 riders per day. What are the prospects for an employee based program?

Specification for Service B

1. The same situation is evident as stated in the previous scenario, except that the bus company can provide a driver and bus with base period work. Thirty percent of the driver's time and 25 percent of the equipment will be charged against the express service. A distance of 2 miles will be required to return the bus to the garage or to its next assignment, and deadheading will still be required.

Cost Analysis B

1. Carpools

   a. Autos eliminated from CBD = 180/1.3 = 130 autos
      less vehicles used for carpooling = 180/3.2 = 56 autos
      Net reduction = 82 autos.
   b. Annual VMT = 56 autos × 15 mi/day × 2 × 250 days/yr = 420,000 VMT/yr.
   c. Annual user cost $= 420{,}000 \left(\frac{0.158}{2} \right)$ + 1.50 (250) (56) = $54,180/yr.

2. Vanpools

   a. Autos eliminated from CBD = 180/1.3 = 138 autos.
   b. Vans required = 180/10 = 18 vans.
   c. Annual VMT = 18 × 15 × 2 × 250 × 1.15 = 155,250 VMT/yr.
   d. Annual van costs = (0.10) (155,250 VMT/yr) + 250 (12) (18)1 = $69,525/yr.

3. Buspool

   a. Buses required = 180/50 = 4 buses.
   b. Annual bus VMT =
      revenue service = 4 × 15 × 2 × 250 × 1.25
      deadheading = 4 × 15 × 2 × 250
      garage access = 4 × 2 × 2 × 250
      Total = 71,500 VMT/yr.
   c. Annual bus operating cost = 71,500 ($0.35/mi) + (8.00) (8) + ($8.00) (1.5) (2) (0.30) (250) (4) + 3.13 (0.25) (12) (250) (4) = $25,025 + 26,400 + 9,390 = 60,815/yr.
   d. Bus revenue = 0.60 (180) (2) (250) = $54,000/yr.

Summary B

As noted in Table C-11, the buspool becomes competitive with the carpool, although the transit company would realize a slight loss from the express service. This loss might be justified in part by achieving other community objectives, such as energy conservation.

Scenario C

To avoid full-time labor costs and deadheading miles, the employer is exploring the option of attracting a private operator who would charter a bus using part-time drivers who also are employed at the employment site. The drivers could earn $5.00/hour with no fringe benefits and secure free transportation. A fare of $0.50 per ride would

TABLE C-10

SUMMARY OF RIDESHARE ANALYSIS A

	Carpooling	Vanpooling	Buspooling
Autos Removed from CBD	13	20	23
Annual User Cost	$ 9,675/yr	$11,587/yr	$ 9,000/yr
Transit Co. Cost (Opt. Cost less Revenue)	-	-	$27,080/yr
Employer Cost	Minor - few direct expenditures--some coordination assistance expected match based on ridesharing survey < $9,000	Major--must see that vans are purchased, maintained, operated. Also must administer program if costs are set to break even	Little, some help required in coordinating and promoting bus service.

TABLE C-11

SUMMARY OF RIDESHARE ANALYSIS B

	Carpooling	Vanpooling	Buspooling
Autos removed from CBD	82	120	138
Annual User Cost	$54,180/yr.	$69,525/yr.	$54,000/yr.
Transit Co. Cost (Opt. Cost less Revenue)	-	-	$ 6,815/yr.
Employer Cost	Minor - Coordination	Major - Employer Agrees to operate 18 vans ana coordinate programs. Program starts to reach a size where it can be efficiently administered by an employer.	Minor - Coordination

be charged. Driving responsibility requires 2 hours per day. Smaller, school bus vehicles with 42 seats will be procured from the private bus company. Bus costs are $0.14 per mile with a fixed cost of $200 per month.

Cost Analysis C

1. Buses required = 180/42 = 5 buses.
2. Annual bus VMT = 5 × 2 × 15 × 1.25 × 250 = 46,875 VMT/yr.
3. Annual bus costs = $46,875 (0.14) + $5.00 (2) (250) (5) + $200 (12) (5) = $6,562 + 12,500 + 12,000 = $31,062.
4. Revenue = 0.50 (250) (2) (180) = $45,000.

Summary C

Using a private bus with moonlighting drivers can yield the greatest user savings and the fewest vehicles being stored in the CBD area. In addition, the private bus operator could receive a return of almost $14,000 per year for chartering the buses.

Scenario D

There is presently express bus service with four buses serving the subdivision in the morning and evening peak periods. A major hospital or office complex was constructed due west of the subdivision. If the bus schedules could be coordinated to attract 75 percent reverse commuting, determine the resulting cost and impact (variation of scenario B). Access to the office complex requires an additional 2 miles of bus travel per trip, but no additional time.

Cost Analysis D

1. Buses required = 4.
2. Annual bus VMT = 71,500 + 2 (2) 250 (4) = 75,500 VMT/yr.
3. Annual bus costs = 25,025 + 26,400 + 9,390 = 60,815/yr.
4. Annual bus revenue =
   peak direction = 180 × 0.60 × 2 (250)
   = 54,000
   reverse direction = 135 × 0.60 × 2 (250)
   = 40,500
   Total = 94,500.

Summary D

With the additional reverse flow express bus riders, service for the CBD employees would remain the same, but revenue collected by the bus company would increase. With this situation the public bus company could operate the express service at a small profit ($94,500 — 60,815 = $33,685).

Scenario E

The public bus company can only provide three express buses, leading to overcrowded conditions on the buses. The employer is investigating the option of requesting that the bus company provide a fourth bus or rely on promoting three vans (variation of scenario B).

Cost Analysis E

1. Bus option. Addition of one bus, assuming 100 percent commitment to express service, no compensating work available.
   a. Annual bus VMT =
      reverse service = 15 × 2 × 250 × 1.25
      deadheading = 15 × 2 × 250
      garage access = 1 × 2 × 250 × 2
      Total = 17,875 VMT/yr.
   b. Annual bus cost = 17,875 (0.35) + (8.00 (8) + 8.00 (1.5) (2) (1.00 (250)) + 3.12 (1.00) (12) (250) = $37,650/yr.
2. Van option.
   a. Annual van VMT = (1.15) × 3 × (15) × (2) × (250) = 25,875 VMT/yr.
   b. Annual van cost = 3($250) × (12) + 25,875 × ($0.10/m) = $9000 + 2,588 = $11,588/yr.

Summary E

As noted, it would be more expensive to provide express bus service, particularly if compensatory work cannot be supplied. The vanpooling option would relieve the situation more economically.

Scenario F

Twenty-five senior citizens per day are interested in special service to a neighborhood shopping center between the hours of 10 a.m. and 2 p.m. The bus driver and vehicle are already available from the commuter service. Would it be more economical to provide two vans from a social service agency or provide a public bus? The trip distance is 5 one-way miles, with 3 miles deadheading for the bus and 2 miles for the van. A fare of $0.30 per ride could be charged for the service.

Cost Analysis F

1. Bus option. Provision of one bus, assuming driver and vehicle were already available.
   a. Annual bus VMT =
      service = 5 × 2 × 250 = 2,500
      deadheading = 3 × 2 × 250 = 1,500
      Total = 4,000 VMT/yr.
   b. Annual bus cost = 4000 (0.35) + 0 labor + 0 equipment = $1,400.
2. Van option. Provision of two vans, assuming driver costs are absorbed by the social service agency, but one new van needs to be purchased by the agency.
   a. Annual van VMT =
      service = 2 × 2 × 2 × 250
      deadheading = 2 × 2 × 2 × 250
      Total = 8,000 VMT/yr.
   b. Annual costs = (8,000 VMT) × ($0.10/mi) + 150 × (1) × (12) = $2,600.

Summary F

On an annual basis the public bus would be most economical. If a fare of $0.30 per rider could be collected, the bus company would be providing a valuable community service and breaking even financially (assuming driver and vehicle are already available and paid).

APPENDIX D

DERIVATION OF CAPACITY CURVES

The capacity of a proposed service during a given time period is determined by the number of vehicle trips and the number of passengers per trip that can be carried in each vehicle. The number of vehicle trips corresponding to a given headway can be estimated based on systems design. For transit service in urban areas, the direction of a bus trip is significant for vehicle occupancy characteristics. From a realistic standpoint the bus trips cannot be expected to carry the same number of passengers in both directions, especially during commuting hours. Actually, for an express bus service, rarely are efforts made to provide an equal number of in-service trips in both directions, and the trips that have to be made in the nonpeak direction often are considered deadhead trips. However, in some cases where business employment locations are decentralized, the trips in the nonpeak direction during commuting hours could be utilized to serve the potential market segment of central city dwellers working in the suburbs. For nonexpress service, particularly for service during off-peak hours, it is common to have moderate ridership in both directions, although usually there is an imbalance in the number of riders.

In addition to the directional distribution of travel, the turnover of passengers during a trip may influence the capacity significantly. In the case of an express service, passengers usually board the buses at the start of the trip and no one gets on or off the bus midway along the trip. On the other hand, in nonexpress service, passengers may get on or off at many intermediate stops, thus accommodating larger numbers of passengers without varying the loading standard. Also, capacity of a conventional service tends to increase with trip length since passenger turnover is related to the trip length.

Assumptions concerning directional distribution and loading characteristics used in this analysis are presented as follows:

1. The seating capacity of each bus is 50 and each passenger is assured a seat.
2. For express service for commuting purposes along a busway or a freeway, each bus trip in the peak direction carries a maximum of 50 passengers, and each trip in the nonpeak direction carries a maximum of 10 passengers. (These capacity values imply that there is no turnover of passengers during a trip.) Capacity is not sensitive to the length of express trips.
3. For nonexpress service on a bus lane or in mixed traffic along an arterial roadway, each bus trip in the peak direction carries a maximum of 60 passengers and each trip in the nonpeak direction carries a maximum of 15 passengers. (The capacity value of 60 recognizes the probable turnover of passengers on a local bus route.) These capacity values are applicable for routes of short to medium length, say up to 10 miles, and in the case of longer trips a capacity of 75 passengers in the peak direction and 25 passengers in the nonpeak direction may be assumed.

On the basis of these assumptions about the maximum use of each bus trip, the total passenger carrying capacity of a particular type of service during a given time period can be estimated by determining the number of trips in peak and nonpeak directions. For example, referring to the cost analysis (App. C) example of an express bus service on a busway with 20-minutes headway, the number of bus trips during a 4-hour service period is 22, of which 14 are in the peak direction and 8 in the nonpeak direction. Therefore, the capacity during the 4 hours of service is ($50 \times 14 + 10 \times 8$) or 780 passengers, and the hourly capacity for 20-minutes headway is ($780 \div 4$) or 195 passengers. The same procedure can be used to derive the hourly capacity of any particular type of service for different headways. The capacity values corresponding to the different headways may be plotted, and a curve fitted through them by hand, based on judgment similar to that shown in Figure 14 (Chap. 5). Ideally, several "observations" should be plotted to draw a nonlinear curve. However, for the purpose of identifying the viability space of a transit mode for sketch planning purposes, four observations would be sufficient, provided they cover the range of likely headways appropriate for the service.

APPENDIX E

RIDESHARE COST RELATIONSHIPS

CARPOOLING

Carpooling costs are determined in relation to the cost of operating a private automobile. It is difficult to establish a generalized operating cost value for a private vehicle, because costs will vary with the type of vehicle, prevailing gasoline and repair costs, annual use of the vehicle (commuting vs. noncommuting), type of financing, decisions about when to replace the vehicle and appropriate local tolls, taxes, and parking charges. (It is not surprising that large variations in cost can be obtained. For example, the FHWA estimates the first-year cost of operating a standard automobile is 18.73 cents/mile, while Hertz computes the cost as 26.01 cents/mile (*E-3*).) Further, the economic advantages of carpooling depend not only on reduced vehicle use (direct out-of-pocket variable cost savings) but also on reduced fixed costs, such as insurance and depreciation discounts due to reduced vehicle use. Where a second (for commuting only) car could be sold, the savings would include out-of-pocket as well as fixed costs. Although not documented, there are situations where the family car, no longer being used for commuting purposes, could result in substantially increased cost due to increased family utilization of the vehicle during the day (*E-1, E-2*).

The most complete cost information available for operating a private automobile is contained in periodic studies by the Federal Highway Administration (FHWA) since the 1950s. The most recent study (1976) provides the cost breakdown (presented in Table E-1) for 10 years and 100,000 mi of private vehicle operation (*E-1*). (Over the life of a car the variance in operating costs tend to stabilize. For example, the Hertz cost estimate for operations of a standard auto over 10 years and 100,000 miles of use was estimated at 19.32 cents/mile—not much different from the FHWA figures (*E-3*).)

The FHWA cost estimate does not include financing costs or interest lost from savings withdrawn to make cash

TABLE E-1

AUTOMOBILE OPERATING COSTS—BASES FOR ESTIMATES

<table>
<tr><th>ITEM</th><th>STANDARD SIZE AUTOMOBILE</th><th>COMPACT SIZE AUTOMOBILE</th><th>SUBCOMPACT SIZE AUTOMOBILE</th></tr>
<tr><td>Automobile Description</td><td>1976 model 4-door sedan
Equipped with: V-8 engine, automatic transmission, power steering and brakes, air conditioning, tinted glass, radio, clock, white stripe radial tires, wheel covers, remote control left-hand mirror, and body protective moulding.
Purchase price - $4,899.</td><td>1976 model 2-door sedan
Equipped with: 6 cylinder engine, automatic transmission, power steering and brakes, radio, vinyl top, wheel covers, tinted glass, remote control left-hand mirror, and body protective moulding.
Purchase price - $3,865.</td><td>1976 model 2-door sedan
Equipped with: standard equipment plus radio, wheel covers, and body protective moulding.
Purchase price - $3,224.</td></tr>
<tr><td>Repairs and Maintenance</td><td colspan="3">Includes routine maintenance such as lubrications, repacking wheel bearings, flushing cooling system, and aiming headlamps; replacement of minor parts such as spark plugs, fan belts, radiator hoses, distributor cap, fuel filter, and pollution control equipment; minor repairs such as brake jobs, water pump, carburetor overhaul, and universal joints; and major repairs such as a complete "valve job." Costs were calculated using 1976 parts prices and a $13.50 per hour labor rate.</td></tr>
<tr><td>Replacement Tires</td><td colspan="3">It was assumed that 3 new regular tires and 4 new snow tires would be purchased during the lives of the standard and subcompact size cars, and 7 new regular tires and 4 new snow tires would be purchased during the life of the compact car.</td></tr>
<tr><td>Accessories</td><td colspan="3">It was assumed that extra wheels and floor mats would be purchased the first year, seat covers the sixth year, and miscellaneous items totaling $2.65 each year.</td></tr>
<tr><td>Gasoline</td><td>Consumption rate of 15 miles per gallon and a gasoline price of 60.9 cents per gallon including taxes were used.</td><td>Consumption rate of 21 miles per gallon and a gasoline price of 60.9 cents per gallon including taxes were used.</td><td>Consumption rate of 29 miles per gallon and a gasoline price of 60.9 cents per gallon including taxes were used.</td></tr>
<tr><td>Oil</td><td>Consumption was associated with gasoline consumption at a rate of 1 gallon of oil for every 167 gallons of gasoline. A price of $1.06 per quart was used.</td><td>Consumption was associated with gasoline consumption at a rate of 1 gallon of oil for every 119 gallons of gasoline. A price of $1.06 per quart was used.</td><td>Consumption was associated with gasoline consumption at a rate of 1 gallon of oil for every 95 gallons of gasoline. A price of $1.06 per quart was used.</td></tr>
<tr><td>Insurance</td><td colspan="3">Coverage includes $50,000 combined public liability ($15,000/$30,000 bodily injury, and $5,000 property damage), $2,500 personal injury protection, uninsured motorist coverage, and full comprehensive coverage for the 10-year period. Deductible collision insurance was assumed for the first 5 years ($100 deductible).</td></tr>
<tr><td>Garaging, Parking, and Tolls</td><td colspan="3">Includes monthly charges of $12.00 for garage rental or indirect cost of the owner's garaging facility, and a toll average of $6.88 per year; plus parking fee averages of $70.00 per year for standard size cars, and $60.00 per year for compact and subcompact size cars. Parking fee and toll fee averages were assigned in proportion to annual travel.</td></tr>
<tr><td>Taxes</td><td colspan="3">Includes Federal excise taxes on tires (10 cents per pound), lubricating oil (6 cents per gallon), and gasoline (4 cents per gallon); plus the Maryland Tax on gasoline (9 cents per gallon), titling tax (4 percent of retail price), sales tax (4 percent of retail items), and registration fee ($20.00 for 3,700 pounds or less shipping weight, or $30.00 for vehicles over 3,700 pounds).</td></tr>
</table>

payments for vehicle purchase or down payment. Table E-1 presents the detailed cost data and cost assumptions accompanying the FHWA study. Planners must adjust the costs to their specific locality utilizing local data.

To estimate driving cost the following relationships were applied:

$$TC = [FC + OPC\ (CVM)]\frac{1}{6} \qquad (E\text{-}1)$$

where:
TC = total monthly commuting costs per user;
FC = fixed monthly costs;
OPC = out-of-pocket variable operating cost per mile;
G = group size; and
CVM = commuting vehicle-miles per month.

For the purpose of this study, unit costs per mile of travel were taken from the FHWA study (*E-1*). The cost equation was then modified as:

$$TC = [(\text{unit cost}) \times (CVM)]\frac{1}{6} \qquad (E\text{-}2)$$

where unit cost = fixed and variable costs to operate an automobile per mile.

VANPOOL COSTS

Cost accounting will vary between vanpool programs. For purposes of this analysis, representative costs were taken for the two Knoxville van programs summarized in Table E-2. The two programs use different assumptions in establishing depreciation rates and assessing salvage values. In both cases, depreciation includes interest charged on the loan for the van's purchase. The Tennessee Valley Authority (TVA) cost statement also includes a parking charge and administrative handling fee for the TVA credit union (*E-4*). As noted, operating costs can also vary, based on the age of the vehicles and the price paid for gasoline (*E-5*).

The following cost equations were used in preparing the cost estimates:

1. Vanpooling, direct trip from origin to destination:

$$TC = [(FC) + (CVM) \times (OPC)] \times \left[\frac{1}{G}\right] \qquad (E\text{-}3)$$

2. Vanpooling, excess VMT's due to pickup and discharge rides:

$$TC = [(FC) + (OPC) \times (CVM + EVM)] \times \left[\frac{1}{G}\right] \qquad (E\text{-}4)$$

where:
TC = total cost per month per user;
G = group size;
CVM = commuting vehicle-miles per month;
EVM = excess pickup and discharging vehicle-miles per month;
OPC = out-of-pocket variable operating cost per mile;
FC = monthly fixed cost (insurance, depreciation, interest on loan, registration, etc.); and
OPC = out-of-pocket cost to provide as specific services comprised of two components:

a. MAC = mileage associated costs, based on the total miles for providing service

TABLE E-2

EXAMPLE OPERATING COST FOR TWO VANPOOL PROGRAMS IN KNOXVILLE (1977 PRICES)

	Knoxville Commuter Pool (51 vans - City Operated 15 seats)		TVA (21 vans - Employer operated through Credit Unions, 15 seats)	
	Unit Cost	Monthly Charge	Unit Cost	Monthly Charge
Fixed Operating Expense				
Original Cost	7,000.00		7,800.00*	
Salvage Value	-1,500.00		None	
Depreciable Cost @ 4 years		114.58		200.00**
Sales Tax		6.67		
Insurance		31.67		44.00
License		1.54		2.00
Interest 10% loan		36.60		4.00
Credit Union Admn. Fee		-		30.00
TOTAL		191.06		280.00
Variable Cost				
Gas	.060/mile		.070/mile	
Maintenance	.015/mile		.020/mile	
Tires	.015/mile		.020/mile	
Oil	.003/mile			
Misc.***	-		.020/mile	
Parking	-			
TOTAL	.093/mile		.130/mile	

* Range 6,900 (1976) to 7,806 (1977).

	Life cycle	Monthly Principle and Interest
** 15 - 56 daily round trip commuting miles	6 yrs.	$147
57 - 65 daily round trip commuting miles	5 yrs.	168
66 - 78 daily round trip commuting miles	4 yrs.	200
79 and over daily round trip commuting miles	3 yrs.	254

*** Washing and Contingency

and nonrevenue producing deadheading, dollars/mile;

b. LAC = labor associated costs including daily wage, fringe benefits, and supervisory costs. For public operations these costs will depend on work rules specified in contract, dollar/day; for example:
   (1) If there is full utilization of labor across the minimum day, say 8 hours, for 2-hour commuter service, the allocation would be 25 percent of labor.
   (2) If a driver is hired and works for commuter hours without compensating work, the 100 percent labor cost should be charged to commuter service.
   (3) Under certain operating models a paid driver might be retained on an hourly basis to drive the van. Assuming that part-time help is hired at a rate of $5/hour (base rate and fringes) and 30 minutes are provided for miscellaneous duties and deadhead travel (assumes 20 mph for first 5 mi, 30 mph second 5 mi, and 50 mph for remainder of trip), the wage rate for different trip lengths were taken as follows:

Trip Length	Daily Labor Wage
5	$ 7.50
10	9.16
15	10.16
20	11.17
30	13.17
40	15.16
60	17.18

BUSPOOL COSTS

Buspooling costs replicate those of vanpooling with labor and equipment being allocated to the various services based on the availability of compensatory work. A major issue in express bus service is the deadheading mileage required to initiate revenue service. In the provision of express bus service to an office complex from a residential subdivision, deadheading miles per day are shown in Figure E-1 (*E-6*).

In selected instances the transit operator may be able to mitigate the impact of the deadhead miles if other work can be found for the bus in the vicinity of the "ends of the run."

REFERENCES

E-1. LISTON, L., and FIKEN, C., *Cost of Owning and Operating an Automobile.* Office of Highway Planning, Federal Highway Administration, U.S. Department of Transportation (1976).

E-2. TEETER, E., WARDEN, J., and BELOVICZ, M., *Transportation Costs and Benefits of the Car Versus the Bus for the Individual.* Babcock Graduate School of Management, Wake Forest University, Winston-Salem, N.C.

E-3. MOFFITT, D., "How to Figure True Cost of Car Ownership." *Wall Street Journal* (Nov. 15, 1976) p. 44.

E-4. *Vanpooling.* Tennessee Valley Authority (Aug. 1976).

E-5. BEESON, J., *How To Put Together a Vanpool.* Knoxville Commuter Pool (1977).

E-6. DAVIS, F., ET AL., *Increased Transportation Efficiency Through Ridesharing: The Brokerage Approach.* University of Tennessee, Transportation Center (June 1976).

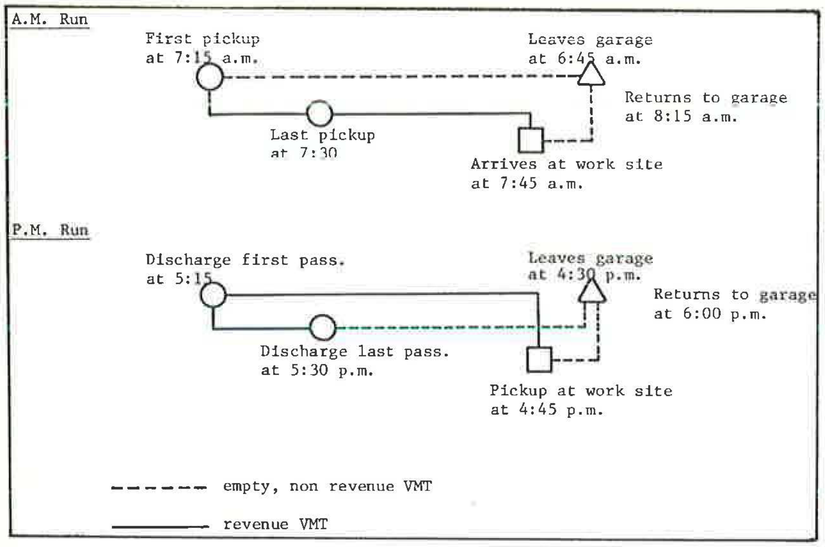


Figure E-1. Express bus deadheading miles.