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Estimating Patronage for Community Transit Services

October 1984

UMTA TECHNICAL ASSISTANCE PROGRAM

Estimating Patronage for Community Transit Services

Final Report
October 1984

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Prepared for
Federal Highway Administration
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U.S. Department of Transportation
Washington, D.C. 20590

Distributed in Cooperation with
Technology Sharing Program
Office of the Secretary of Transportation
Washington, D.C. 20590

DOT-I-85-21

FORWARD

In many urban areas, travel within and between neighborhoods and suburban areas is not well served by fixed route transit. Community-based transit and paratransit services may provide a promising alternative to conventional public transit in serving local travel in these areas. The establishment of such services typically requires an assessment of financial feasibility, which in turn requires sound estimates of ridership and revenues.

This handbook pulls together several existing (and some enhanced) estimation techniques that are applicable in planning community transit services. Several simple techniques are presented for preliminary planning stages or for situations in which exact estimates are not required. More sophisticated techniques also are included for the more detailed estimates required for the later stages of some planning studies. The techniques are illustrated, and case studies are presented that illustrate their combined application in different planning situtations.

Additional copies of this report are available from the National Technical Information Service (NTIS), Springfield, Virginia 22161.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF ILLUSTRATIONS

PAGE

FIGURES

TABLES

CHAPTER 1: SCOPE OF THE HANDBOOK

1.1 Introduction to the Community Transit Concept

In most urban areas, trips from city and suburban neighborhoods to the central business district and other major commercial centers are adequately served by regular bus routes and rail transit lines. Travel within and between neighborhoods, however, is only coincidentally served by these line-haul transit routes, and many short distance trips would require circuitous travel and one or more transfers if made on radially-oriented transit networks. Trips involving multiple destinations or the carriage of packages are particularly awkward on conventional fixed-route transit systems.

Alternatives to conventional public transit may be considered for a number of reasons. One common situation is a replacement for conventional transit in an effort to reduce operating costs. In recent years, increasing financial pressures have caused regional transit authorities to reassess their systems and to cut back on routes and services that fall at the low end of the performance spectrum. Whether the performance evaluation involves productivity measures such as passengers per vehicle hour, or cost-effectiveness measures such as operating ratio, those routes that perform most poorly are likely to reflect one or more of the following conditions:

- Key travel destinations from the route's service area are not directly served.
- Bus stops are beyond a comfortable walk for many potential patrons.
- Residential densities are too low to support regular route service.
- Almost all travelers from the route's service area have autos available for their trips.

If the first two conditions are the cause of a route's poor performance, realignment may solve the problem. In many situations, however, travel patterns may be so dispersed that no routing will meet service standards, or the physical layout of streets will not allow large buses to be operated over potentially good routings. In these cases, and in cases where the last two conditions are true, community transit may provide a good replacement for regular route service.

Community transit service also may be considered as a supplement to regular route service or as a means of extending transit service into new areas. Small vehicles operating over neighborhood streets can serve as feeders to rapid rail or express bus stations, or to regular bus routes, in addition to providing direct service for local trips. A new or supplementary community transit service might be considered under one or more of the following conditions:

- o Service warrants or coverage policy calls for transit service in an area where dispersed travel, street geometry or other factors appear to rule out regular routes.
- o Street layout and/or low residential densities make regular route feeders to a new rail or express bus station impractical or infeasible.
- o Community officials or citizen groups perceive a disparity between their current transit service and their contributions to cover regional transit deficits, or wish to provide a good alternative to auto travel for local trips.

1.2 Community Transit Service Options

Community transit typically is operated with small vehicles such as mini-buses, vans or even sedans. The service may be provided by a taxi or transit operator, by a municipal agency, or by a private operator under contract to a city, town or transit agency. When operated directly by a transit property, community transit services usually require lower wage scales if cost recovery or operating ratio standards are to be met.[1]

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1 San Diego, for example, has negotiated a separate job classification with a substantially lower wage scale for some of their suburban services.

The principal community transit service options involve the routing of vehicles and the points at which passengers may board and alight. Vehicles may be confined to designated routes, operate in sectors or service bands, or travel throughout the community. They may be allowed to stop for passengers at signed stops, any point along a route, or any point requested in advance. These options may be combined into specific service "modes", including some hybrids offering more than one option. The following modes are being operated or considered for operation[1]:

- <u>fixed routes</u>, usually focused at one or two key points to allow convenient transfers.

  route options: - linear
  - 1 way loop
  - 2 way loop

  stop options: - signed stops (bus)
  - any point (jitney)

- <u>routing determined by service requests</u>

  route options: - unconstrained (many-to-many)

  - depart from a central point at fixed times (cycled many-to-one)

  - set by standing requests (subscription)

  stop options: - any point (doorstep)
  - signed stops (checkpoint)

- <u>hybrid services</u>, where a "route" is expanded laterally to form a service band or sector:

  options: - serve all signed stops along route plus requests for any side points beyond a comfortable walking distance (doorstep deviation)

  - serve all signed stops along route plus requests for all signed site points (checkpoint deviation)

  - serve any requested signed point (checkpoint only)

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1 The names in parenthesis are standard designations for service modes used throughout this report.

The modes are shown schematically in Figure 1-1.

Although community transit may include a fixed-route schedule service in some cases, it may be distinguished from conventional transit by one or more of the following characteristics:

- small vehicles instead of full size buses
- operation by a town or private contractor rather than a regional transit authority
- intra- (or adjacent) community orientation rather than regional orientation towards the central business district (CBD).

In some situations, a community transit system may be designed to serve a particularly large service area. In this case, the service area may be divided into a number of zones or sectors. Service among the various zones must then be coordinated to accomodate travel between sectors. This can be accomplished by designating transfer points, preferably at major destinations such as shopping centers, town centers, or rail or express bus stations. Service to each zone or sector can be operated so vehicles meet at the transfer point at regular intervals; these operations are commonly referred to as cycled or pulse systems.

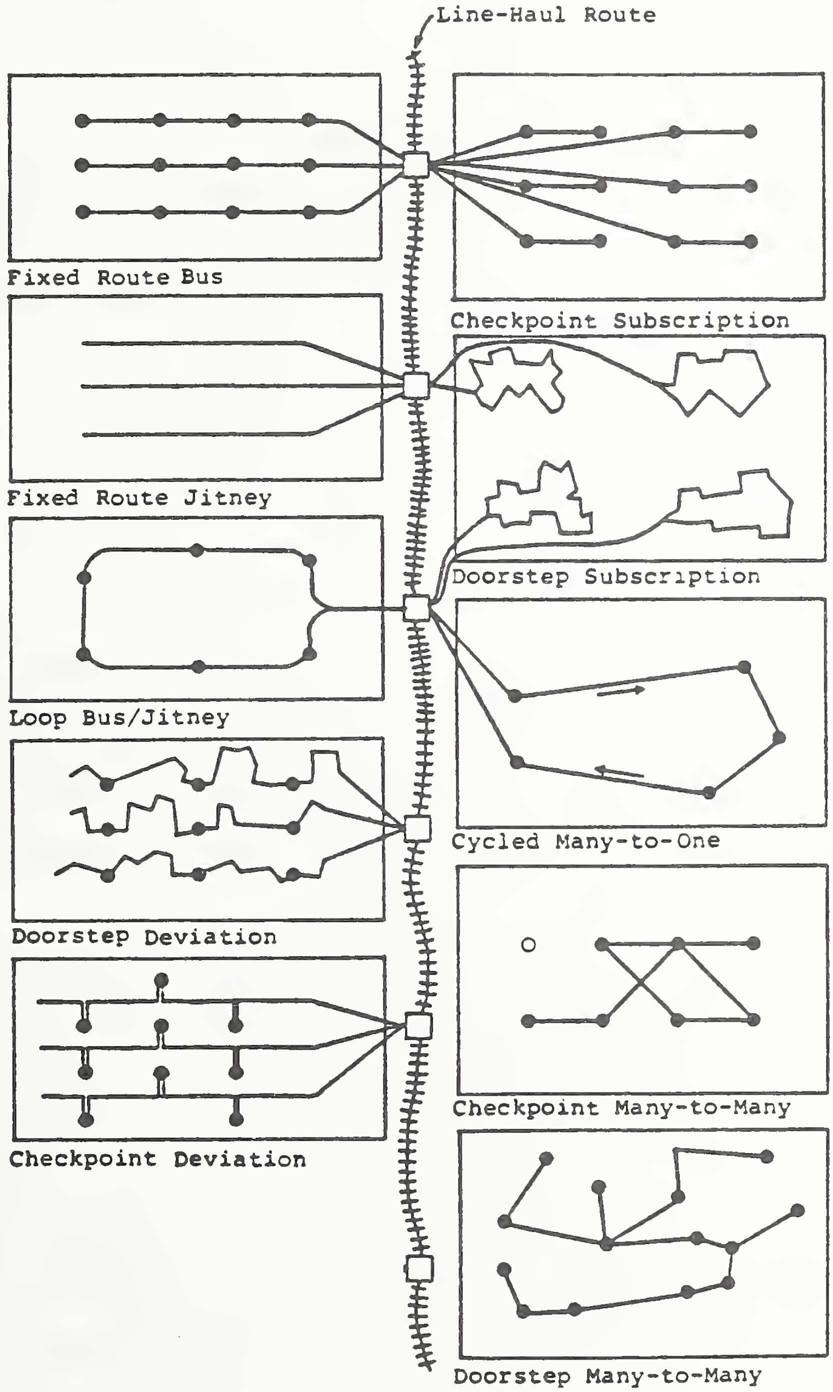
The service features that set community transit modes apart from conventional transit (and affect their patronage) include:

- reduced walking (through door-to-door service or vehicles that can operate on residential streets)
- waiting at home (through telephone requests for doorstep service)
- standing service requests (e.g., a 7:10 pick-up every weekday morning)
- premium fare options (e.g., for door-to-door service)
- increased ride time variance (due to variable routing of vehicles).

The extent to which these features are proposed for a service (and the ease of estimating the service levels experienced by potential users) will determine the applicability of different types of patronage estimation methods in analyzing a proposed community transit service.

Figure 1-1:

COMMUNITY TRANSIT MODES



Source (1)

1.3 Purpose and Organization of the Handbook

This Handbook is designed to provide guidance in estimating patronage for community-based transit services that could be implemented to replace or supplement regular route service, or to provide transit service in communities having none. The planning approach and techniques it presents and illustrates are applicable to feasibility studies, screening analyses and detailed service planning activities for new and replacement services in a variety of urban, suburban and small city settings. Planners at transit properties, city and town agencies, metropolitan planning agencies, and state transportation offices responsible for providing local assistance will find the Handbook useful in supporting their efforts to design and implement feasible and effective community transit services.

Chapter 2 discusses the decisions made in designing and evaluating a proposed community transit service, describes the role of ridership estimates in these decisions, and presents approaches to analyzing proposed services in different situations. Alternative methods for estimating ridership are discussed, along with their applicability in different planning situations.

Chapter 3 presents and illustrates the simpler techniques that may be used in preliminary planning stages or in situations where exact estimates are not required. Techniques that provide the level of sophistication that may be required in the later stages of some planning efforts are presented in Chapter 4. Three case studies, presented in Chapter 5, show the use of both types of techniques in different planning situations.

The Handbook pulls together existing estimation techniques into a single document and provides guidance on when and how each should be used. In some instances, existing techniques have been enhanced where it became clear in the course of preparing the Handbook that important gaps existed. For situations that indicate a need to invoke relatively sophisticated techniques such as the application of equilibrium models, the Handbook discusses applicability, data requirements, what resources are required to run the models (including where to locate software, hardware compatibility, and typical computer resource requirements), and provides reference to more detailed documentation.

CHAPTER 2: SELECTING A PLANNING APPROACH

2.1 The Framework for Planning Community Transit Services

Ridership on a new or modified community transit service may depend on a variety of factors. Some of these are design and operational decisions made by an agency in the course of planning and implementing the service, such as providing doorstep service options, and setting frequency and fare levels. Conversely, estimates of ridership are useful in making many design and operational decisions, such as determining an appropriate vehicle size or estimating driver and fleet requirements. Because of this interaction, ridership estimation should be approached as an integral part of planning for community transit services, not as a separate activity.

A decision-oriented approach to planning a wide range of short-range transportation improvements is presented and illustrated in NCHRP Report 263 (2). The approach focuses planning efforts, including estimation, on the development of implementable actions that solve identified problems (such as a transit route operating below regional cost recovery standards) and/or accomplish specific planning objectives (such as providing transit service within a half-mile of all residents in a medium-density, suburban community). It is readily adaptable to community transit service planning, and is used in this chapter as a framework for presenting ridership estimation techniques and discussing their applicability in different planning situations.

The key steps in the NCHRP 263 approach that will help an agency plan a workable community transit system are as follows:

1. assess conditions in the community that will affect the service's operation and use, the transportation problems or inadequacies the service is intended to resolve, and the resources available for implementing and operating the service.

2. establish important factors (e.g., coverage and costs) and corresponding criteria to be used in making design and operational decisions and/or in judging the merits of a proposed service.

3. identify specific performance or impact measures (e.g., annual operating costs) needed to support the decisions and assessments.

4. design an efficient analysis plan for estimating and applying these measures.

5. select appropriate estimation techniques for carrying out the analysis.

6. apply the plan to develop a recommended service design in sufficient detail for implementation, and to support any review and approval processes required prior to implementation.

None of these steps requires complex procedures. They simply act as guidelines to organize an agency's approach to developing a community transit service that will be both effective and feasible.

This Handbook focuses on steps 2 through 5, particularly as they relate to ridership estimation. Section 2.2 identifies the major decisions made by an agency in planning and implementing a community transit service, and discusses the role of ridership and other factors in these decisions. The section also identifies other performance or impact measures (such as ridership and capital and operating costs) that might be used in a feasibility or service planning study, and lists the factors that influence their values. The general relationship among the various factors and measures is presented and discussed in Section 2.3 from the perspective of their estimation and application in an analysis. The discussion leads to a general approach to design and analysis.

Section 2.4 presents different ridership estimation techniques that are applicable to community transit service planning, and discusses different procedures for their application. Section 2.5 presents four sample analysis plans that are based on the general approach. The plans have differing levels of sophistication, and rely on differing degrees of specification and estimation. The section also provides guidance in selecting appropriate analysis plans and techniques for different planning situations.

2.2 Design and Evaluation Decisions

The planning of a community transit service typically entails a series of decisions about its design and operation, the key decision areas or issues being the following:

- Travel Markets -- the area and travel to be served (e.g., neighborhoods, employment sites and shopping, medical and recreational facilities to be included in the service area, transit lines to be fed, and days and hours of operation)

- Service Configuration -- the appropriate layout of the service (e.g., service type, location of transfer points, stop or checkpoint spacing, and routing or sector designation)

- Service Operating Policy -- the level of service to be provided (e.g. days and hours of operation, service frequency, direct service vs. transfer, and fare structure)

- Service Capacity/Supply -- the equipment and personnel required for service operation (e.g. vehicle size, number of vehicles, drivers, dispatchers and call-takers, communications equipment, and computers)

Table 2-1 lists the principal design decisions associated with each of these four issues, and presents the various factors that typically influence each decision. The factors in Table 2-1 can be grouped into four categories:

- characteristics of the service area and its inhabitants

- various feasibility, adequacy and acceptability factors that reflect policy considerations.

- other design and operational decisions.

- service performance characteristics or impacts that are, at least in part, consequences of design and operational decisions.

Factors in the first category are important in service planning, for they often constrain the design and operation of a service and limit its potential effectiveness. In most cases, these factors are fixed in the short-range and beyond the influence of the agency. The second category contains policy factors that, while often exogenous to a specific service planning study, can be adapted to the local situation. These factors primarily are used in a broader level of decision-making, i.e. the overall assessment or evaluation of a proposed service. They typically address the following issues:

- operational feasibility (e.g., the ability of vehicles to negotiate proposed routings, and the ability of the system to handle peak loads)

- service adequacy (e.g., the meeting of mandated or desirable frequency, wait time, mobility and/or speed levels)

- financial feasibility (e.g., maintaining costs within expected capital and operating budgets, and meeting cost recovery and/or productivity levels necessary for regional or state funding)

- community acceptance (e.g., the appearance of vehicles on residential streets and the absence of fumes and noise)

In long-range planning, many of these issues are addressed after design decisions have been made and analyzed. In community transit service and other short-range planning, however, design and evaluation decisions need not (and should not) be made independently. Instead, most of these evaluation criteria can be addressed by a service planner within the design process, hence their inclusion in Table 2-1. An example would be to exclude a low density neighborhood from the service area on the basis of the extensive backhauling needed to route vehicles through its disconnected streets and cul-de-sacs (e.g., operational feasibility problems).

The remaining categories contain factors that are integral to service design and analysis. The third contains decisions that are listed in Table 2-1, while the fourth contains system performance characteristics and impacts that in part result from those decisions. Measures of these latter factors often are needed to support both design and evaluation decisions, although they need not be rigorously derived in many analyses. Table 2-2 lists service measures that commonly supplement the decision measures (listed in Table 2-1) in analyzing a proposed community transit service, or are useful in preparing decision and evaluation measures.

- Service Quality -- the level of service provided from the user's perspective (e.g., wait or response time, and ride time)

- Use -- expected ridership

- Supply -- aggregate measures of the service provided (e.g., vehicle miles)

Table 2-1:

FACTORS INFLUENCING DESIGN DECISIONS

ISSUES	DECISIONS	FACTORS
Travel Markets	o neighborhoods to be served	- ridership generation potential (residential density, auto availability, income, age distribution)
		- vehicle routing feasibility (turning radii, street connectivity)
	o destinations to be served	- ridership attraction potential (of shopping centers, office parks, medical facilities, etc.)
	o line-haul routes to be fed	- ridership attraction potential (destinations served by route, current route ridership)
	o days or hours of operation	- ridership potential (operating hours of major destinations, temporal distribution of current person-trips from neighborhoods)
		- staffing feasibility (work hours, overtime provisions)
Service Configuration	o service type	- locations (concentration) of travel destinations
		- residential density
		- street patterns
		- desirability of doorstep service (age distribution, trip purposes)
		- financial feasibility (capital and operating costs)

Table 2-1 (continued):

FACTORS INFLUENCING DESIGN DECISIONS

ISSUES	DECISIONS	FACTORS
Service Configuration (continued)	o stop or check-point spacing	- residential density
		- provision of doorstep service
	o location of transfer centers	- trip attraction potential line-haul station or stop, destination for local trips)
		- operational feasibility (space for vehicles and waiting riders, access routes that avoid major congestion)
	o number and location of routes or service sectors	- vehicle routing feasibility (turning radii, street patterns and connectivity)
		- schedule maintenance (round trip running time, service frequency)
		- financial feasibility (ridership density, productivity or load factor)
Service Operating Policy	o service frequency (route-based) service)	- coordination with line-haul service
		- ridership density
		- operational feasibility (route length or sector size, round trip running time, fleet size)
	o fare structure	- financial feasibility (cost recovery, acceptable subsidy levels)
		- service policy (current transit and taxi fares, ridership or mobility objectives)

Table 2-1 (continued):

FACTORS INFLUENCING DESIGN DECISIONS

ISSUES	DECISIONS	FACTORS
Equipment and Staff Requirements	o vehicle size	- operational feasibility (street widths, turning radii, vertical clearances)
		- community acceptance (appearance on streets, fumes)
		- peak rider loads
	o number of vehicles (route-based services)	- number of routes or sectors
		- service frequency
		- round trip running time
	o number of vehicles (demand-responsive service)	- desired or acceptable response time
		- service area size
		- ridership
	o number of drivers	- fleet size
		- days and hours of operation
		- work rules
	o number of dis-patchers	- service type
		- fleet size
		- days and hours of operation
		- work rules
	o number of call-takers	- service type
		- doorstep requests (volume and time distribution)
		- work rules

Table 2-2:

FACTORS INFLUENCING PERFORMANCE AND IMPACT MEASURES

ISSUES	MEASURES	FACTORS
Service Quality	o wait time (non-doorstep service)	- service frequency
		- schedule adherence and dispatch reliability
	o response time (doorstep)	- vehicle density (service area size, fleet size)
		- ridership density
	o walk time	- stop or checkpoint spacing
	o ride time	- trip length distribution (location of destinations)
		- trip circuity (route location, transfer requirement, frequency of doorstep pick-ups and drop-offs, service type)
		- operating speed (auto speeds, frequency of stops)
	o travel cost	- fare structure
		- trip and traveller characteristics
	o travel impedance	- weighted sum of travel time and cost components
Use	o ridership	- residential population and density
		- socio-economic characteristics (age, income, auto availability)
		- service quality (wait or response time, walk time, ride time, travel cost, travel impedance)

Table 2-2 (continued):

FACTORS INFLUENCING PERFORMANCE AND IMPACT MEASURES

ISSUES	MEASURES	FACTORS
Service Supply	o vehicle-hours in service	- days and hours of operation - number of vehicles in service
	o vehicle-miles in service (route-based)	- number of routes or sectors - service frequency - average route length, including deviations for doorstep service
	o vehicle-miles in service (demand-responsive)	- service area size - number of vehicles in service - ridership - trip length
Cost	o capital cost	- vehicle requirements (number, size) - equipment requirements (service type, number of dispatchers and call-takers)
	o operating and maintenance costs	- staffing requirements - wage rates - number of vehicles - vehicle-miles in service - equipment (amount and type of communications, dispatching and scheduling equipment)
	o revenues	- ridership - fare structure

- Cost -- the costs of providing the service (e.g., capital cost of vehicles and communications equipment) and the revenues received.

2.3 A General Approach to Estimation and Analysis

As indicated in Tables 2-1 and 2-2, there are underlying interactions among many of the decision, performance and impact measures potentially used in design, analysis and evaluation. While not all of these need to be explicitly considered in most cases, the planner needs to be sufficiently aware of them to avoid making inconsistent or incorrect assumptions (e.g. that ridership on a proposed service will be the same as ridership on a similar service in a higher density community, or that a service can be modified to provide doorstep service to most riders without increasing fleet size or decreasing frequency).

The interactions among major categories of measures are summarized in Figure 2-1. The solid arrows in the figures indicate basic, functional relationships, while the dashed arrows show interactions due to operational and financial feasibility assessments made in the course of an analysis or evaluation. The main points illustrated in the figure are as follows:

- An agency's actions are limited to measures listed in the "service configuration/policy" and "capacity/supply" boxes. While service quality, ridership, cost and revenue measures may be extremely important in design and evaluation, they can only be modified indirectly through changes in service configuration, operating policy and/or supply/capacity.

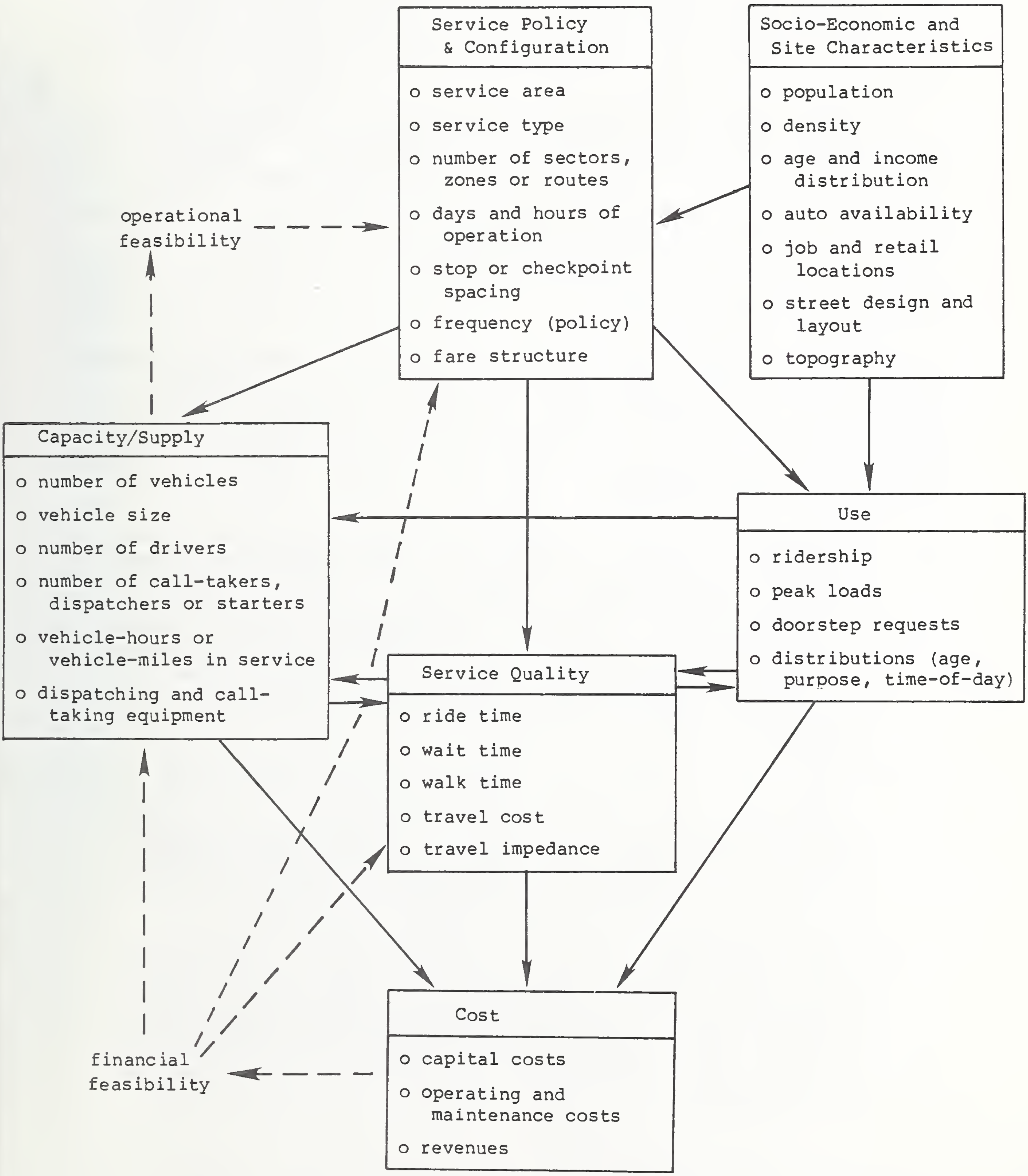
- Land use and socio-economic characteristics cannot be significantly affected by community transit service. These measures, however, are very influential in determining ridership and the operational feasibility of a service.

- The most difficult set of interactions to deal with in analysis are those among measure of capacity/supply, service quality and use. This is particularly true of demand-responsive services, where wait and ride time often are dependent on the number of riders.

- Cost and revenue measures, while key to assessing the financial feasibility of a proposed service, can be readily derived once use, capacity/supply and service quality measures have been estimated. They need not be estimated for every service design option that is examined, but can be calculated for those alternatives that produce values that are within acceptable ranges for the other measures.

Figure 2-1:

ANALYTIC APPROACH TO PLANNING COMMUNITY TRANSIT



These key points, and the relationships shown in Figure 2-1, can be applied to develop efficient analysis plans for different situations. Four sample plans are presented and discussed in Section 2.5 to show how the planner's objectives determine the correct planning approach and ridership estimation technique.

The next section provides a general overview of the basic techniques available for estimation of ridership on unconventional community transit services. In the last section of Chapter 2, the whole planning process will be tied together by showing how the planner's objectives determine the correct planning approach and ridership estimation technique.

2.4 Ridership Estimation Methods

Several techniques are available to estimate ridership on proposed community transit services, and some of them are presented in Chapters 3 and 4 of this manual. The techniques can be grouped into five categories; the basic features of these categories and their applicability in different planning situations are discussed below:

- Analogy -- The use of ridership levels attained on similar services in similar locations is the simplest estimation technique. Data from a single system or from compilation or synthesis based on several systems may be used, with or without adjustments to reflect differences between site characteristics. The method also is useful in complementing or verifying estimates obtained from analytic methods, because the prediction of impacts outside the range of observed results is an indication that errors or oversights may have occurred in an analysis.

- Elasticity -- Changes in ridership can be estimated using elasticities, which measure proportional changes in ridership resulting from proportional changes in service quality or supply measures such as fare, ride time, wait time and vehicle-miles in service. Elasticities have been derived from observed changes in transit and paratransit operations, and estimated in the course of calibrating ridership and mode choice models.

- Direct Estimation -- Ridership data from existing services have been synthesized into graphs, equations, nomographs and similar techniques that can be applied to estimate ridership on a proposed service. Estimates prepared using these techniques may be used directly, or adjusted using analogs or elasticities to account for differences in community or service characteristics.

- Mode Choice -- Ridership on proposed feeder services can be estimated using mode-choice models, provided that total travel from the service area to the line-haul route being fed can be measured or estimated. These models typically estimate the shares of travel using feeder transit, private auto and walk modes to access rail or express bus services.

- Equilibrium Models -- Direct estimation equations or mode-choice techniques can be imbedded in an analytical procedure that also estimates the service quality resulting from the estimated ridership. These supply and demand models are iteratively applied until their results converge.

Many of the techniques in the above categories can be applied in different ways depending on available information and resources, and on the intended use of the results. Aside from the obvious choice of manual vs. computerized application, the choices include:

- Segmentation -- Varying levels of detail or segmentation can be used in applying many methods; these include preparing separate ridership estimates for different trip purposes or times of day, or distinguishing among different segments of the population. While too much detail will result in unnecessary analysis, too little may obscure important differences among users' perceptions of the service and their propensity to use it.

- Pivot-point or Ratio of Change -- Methods other than elasticities also can be applied to estimate changes in ridership. In a pivot-point appliation, the ridership estimation technique selected for the analysis would be applied to both the proposed service and to an existing service in the same or similar area to obtain an estimate of proportional change. The estimated change is then applied to scale observed ridership for use in analyzing the proposed service. The pivot-point procedure is designed to minimize model errors, because it reduces the effects of differences between the analysis site and the communities and services used in calibrating the technique.

- Sensitivity Testing -- A service planner may have legitimate doubts about the accuracy of ridership estimates developed using any of the above techniques, or be uncertain of the service quality and other estimates used in applying the techniques. Sensitivity testing is a useful procedure for dealing with these uncertainties, and usually is easier and cheaper than attempting to develop a better estimate of the uncertain condition. The planner essentially determines the likely range of each uncertain parameter, systematically applies the estimation technique using two to four values that cover each parameter's range, and thus determines a likely range of ridership for use in the analysis. If the range is small, the planner can confidently proceed with implementation. If the range is large, the procedure will highlight the factors causing the variation allowing additional planning efforts to be directed at their resolution.

The choice of an appropriate method and application procedure depends on the specific problem, the intended use of the results, and the information base and other resources. Limited data, planning budgets, time, staff availability, skills and experience, and access to computers all place restrictions on the methods and procedures that can be applied. These restrictions usually are clear, although the best approaches to dealing with them may not be.

The accuracy and detail of ridership estimates should be keyed to the design and operational decisions they will influence, otherwise the analyst may end up with incompatible or unnecessarily exact estimates. Several factors influence the required detail and accuracy; these include:

- Size of likely impact -- Small changes in ridership are difficult to predict with confidence, because they are often smaller than the errors inherent in both the estimation procedure and the observed data. For example, ridership counts on an existing service may be accurate to only ±10 percent, so changes resulting from small changes in service may be difficult to estimate, or to detect once the change has been implemented.

- Sensitivity of design features -- Capacity measures and other design features vary in sensitivity to estimated volumes as a result of their integral nature. A rough estimate of patronage, for example, might indicate that two buses were required for a suburban feeder service. If this number would not change even with a 40 percent lower or higher patronage estimate, the initial estimate is quite adequate for determining vehicle requirements.

- Ability to fine-tune -- Many aspects of a community transit service can be modified after implementation when direct measurements of ridership and other service parameters can be made. While most agencies will want to minimize the extent of these modifications to maintain their professional credibility with the public, some reduction in estimation accuracy is appropriate in designing these services.

The method descriptions and case studies in the chapters that follow expand and illustrate these points. The next section provides general guidance in applying different ridership estimation techniques in planning community transit services.

2.5 Sample Analysis Plans and Their Applicability

The general analysis approach illustrated in Figure 2-1 can be adapted to different planning situations that call for different techniques and application procedures. Four distinct plans are shown in Figures 2-2 through 2-5, and discussed below. The main difference among them is the way in which the relationships among measures of supply/capacity, service quality, and use (See Figure 2-1) are explicitly addressed in the analysis. The dashed boxes in the figures enclose measures that would be specified in an analysis, either as a result of stated policy objectives, the use of analogies, or the setting of a likely range of values. Other measures in the plans would then be estimated or derived from these specified measures as required for making design and evaluation decisions.

Plan #1 is most appropriate in the following situations:

- o when the objective is to determine the lowest possible cost for which a new service with predetermined service standards and ridership response can be introduced;
- o when the objective is to determine whether existing service can be replaced with a different service configuration that would offer comparable service standards and ridership response at less cost.

In Plan #1 (see Figure 2-2), measures of use (e.g., ridership) and service quality (as required) are specified by the analyst. The balance between measures in these categories, and their compatability with specified service configuration and policy measures, typically is accomplished by relying on operational data from similar services in similar communities. Capacity/supply and cost/revenue measures are then estimated using analogies, equations, or simple models.

Plan # 2 utilizes the elasticity methodolgy of ridership estimation. It may be more appropriate to use Plan 2 in lieu of Plan # 1 in the following situations:

- o when a new service is being contemplated and the planner's objective is to determine what ridership, supply, and cost are likely to result from setting predetermined service levels. Plan # 2 is used if ridership is treated as a (planning) output rather than a (policy objective) input.

- when service changes that involve an increase or decrease in service quality are being considered.

In Plan #2 (see Figure 2-3), only the service quality variables are set (or calculated) to be compatible with service configuation and policy variables. Ridership is then estimated, along with the (changes in) capacity/supply required to meet the expected ridership at the proposed service levels. This plan often is used to estimate the change in ridership resulting from proposed changes in service quality. When it is used to estimate ridership on a new service, the elasticity factors must be used to adjust ridership observed in similar locations elsewhere.

Plans 1 and 2 can be used at the initial feasibility stage for any community transit planning scenario. Plan # 3 may be used in lieu of Plan 2 if additional accuracy is desired for a subsequent step to screen selected options. Plan 3 (see Figure 2-4) differs from Plan 2 in that capacity supply variables are set first and used as a basis for setting or calculating compatible service quality variables. (To some degree, this depends upon an initial feasibility assessment having concluded that the capacity/supply measures being chosen are reasonable.) Ridership is then estimated, typically using sample equations, nomographs or similar models.

In Plan #4 (see Figure 2-5), only the service configuration and policy variables and key capacity/supply measures (e.g., number of vehicles) are set. A series of equations or other models are then applied in an iterative manner to estimate service quality, ridership and other capacity/supply measures. Because of the inherent complexity of iterative models, Plan #4 is normally used only at the detailed planning stage.

Table 2-3 provides a summary of how the analysis plans, and different techniques described in the previous section, might be applied to analyze service replacement and modification in different planning situations. Table 2-4 provides similar guidance for the planning of new services.

Figure 2-2:

SAMPLE ANALYSIS PLAN #1

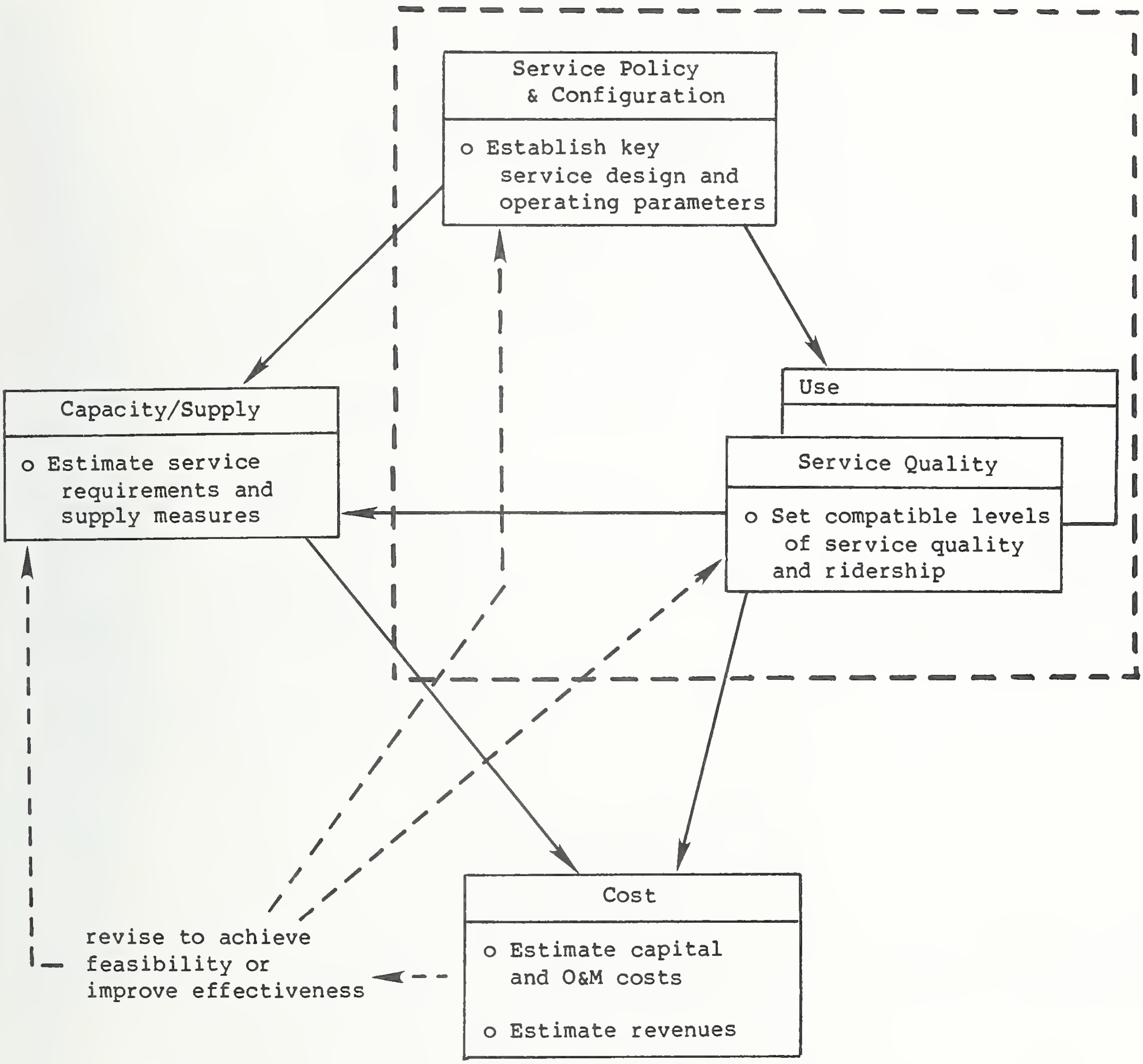


Figure 2-3:

SAMPLE ANALYSIS PLAN #2

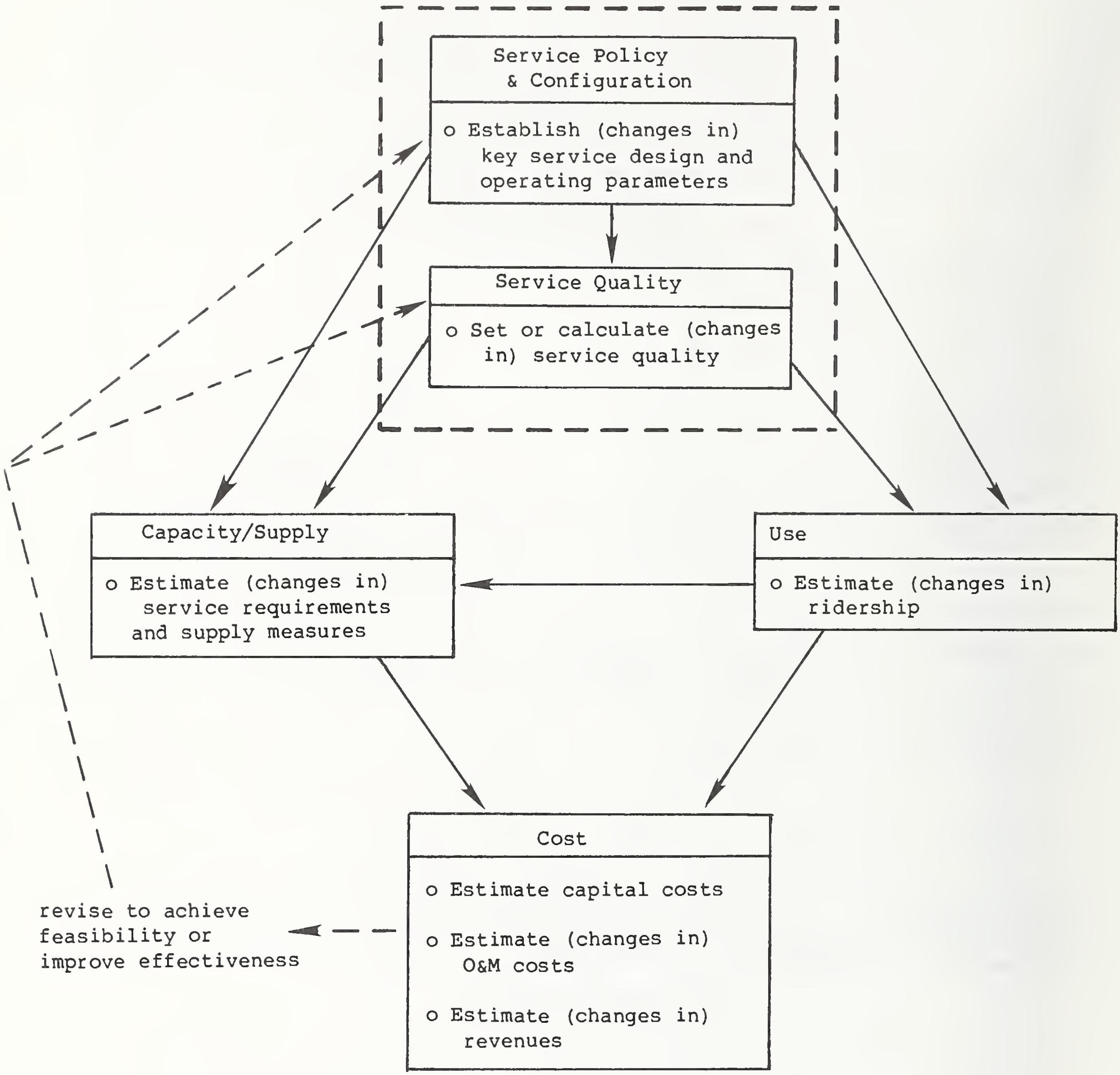


Figure 2-4:

SAMPLE ANALYSIS PLAN #3

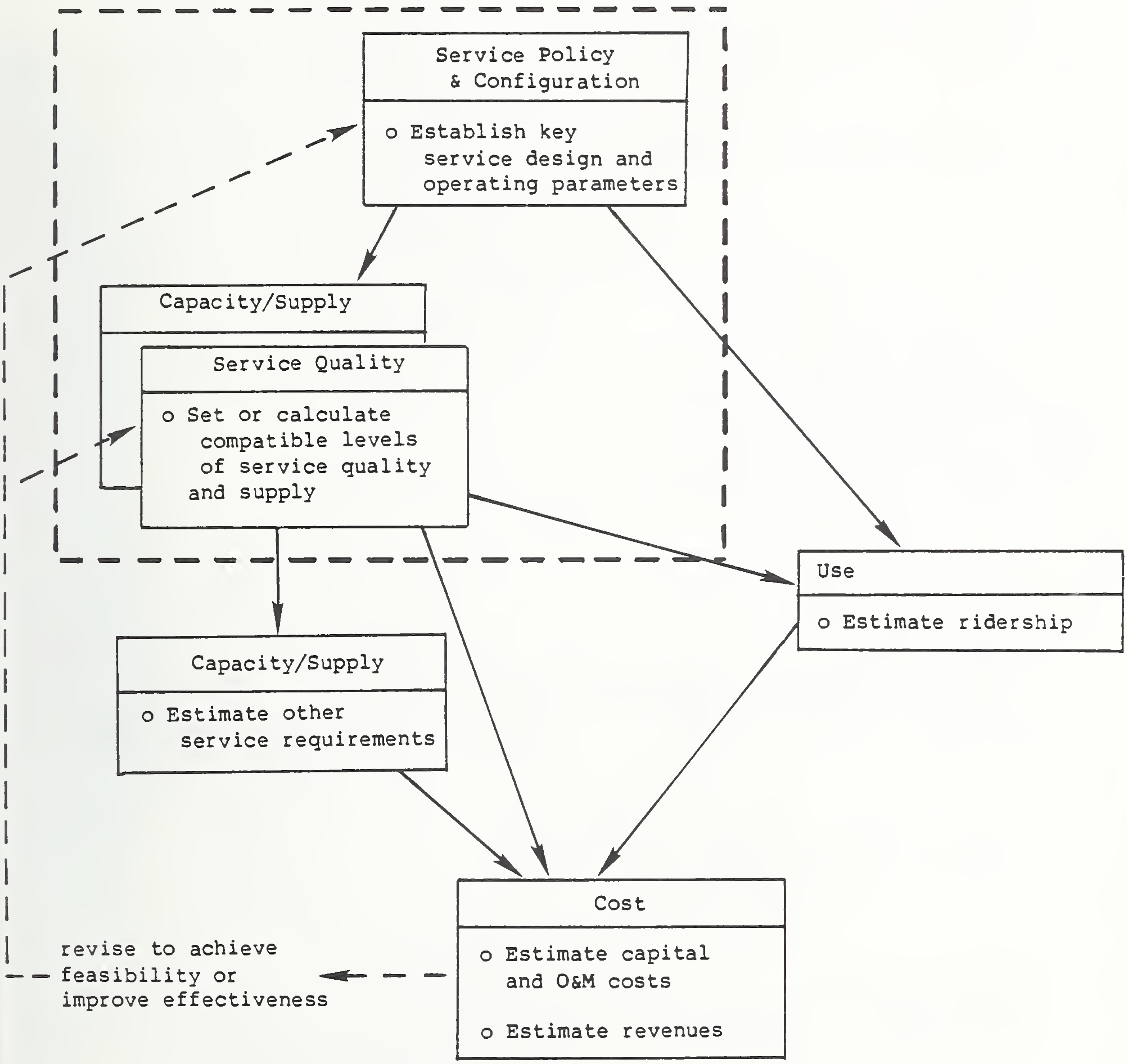


Figure 2-5:

SAMPLE ANALYSIS PLAN #4

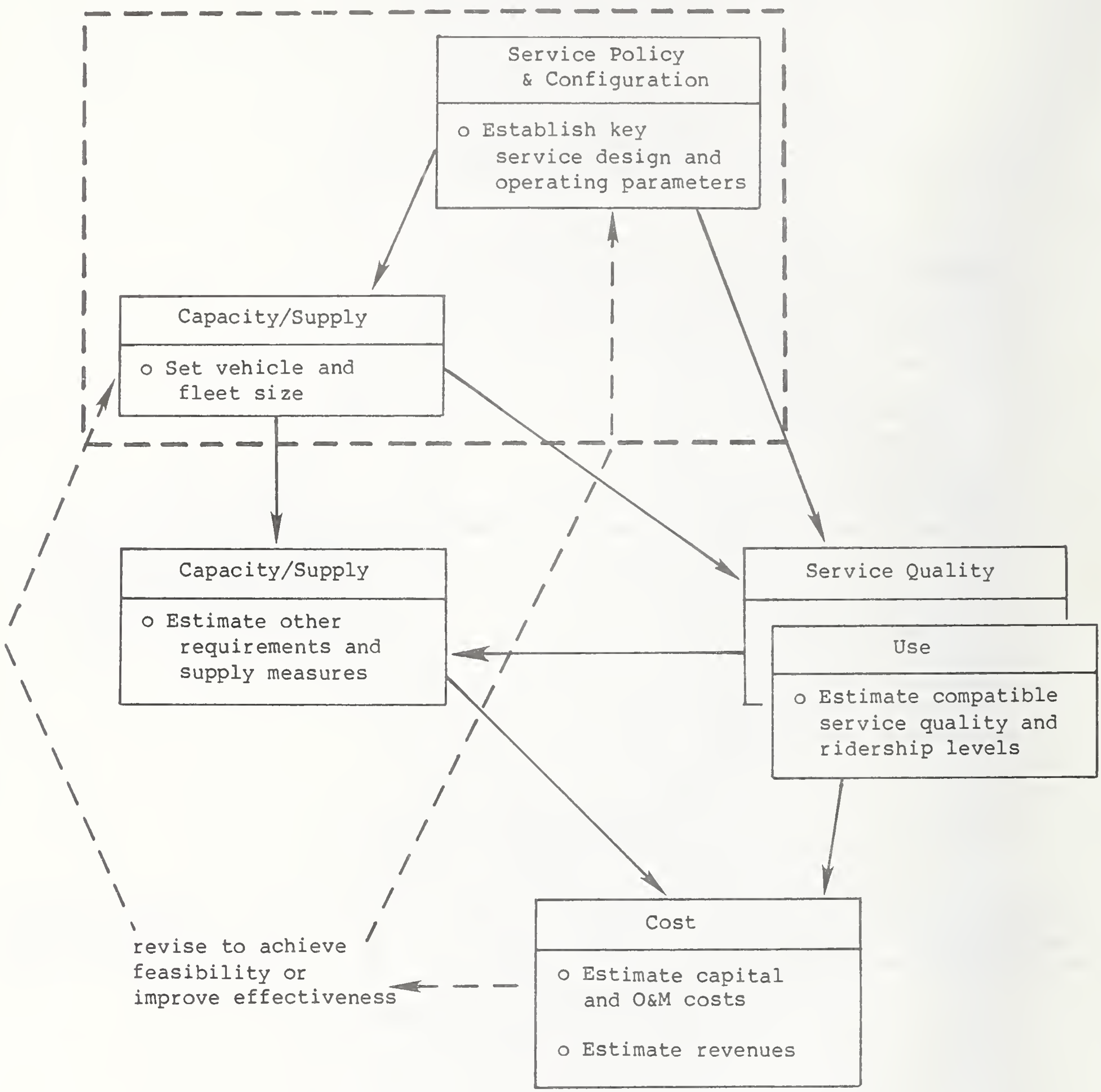


Table 2-3:

APPLICABILITY OF ANALYSIS PLANS TO SERVICE REPLACEMENT AND MODIFICATION

Objective of Service Change	Initial Feasibility	Screening of Options	Detailed Planning
o Offer same service quality at lower cost	Use plan #1 with existing or slightly adjusted ridership	→	→
o Offer reduced service at lower cost	Use Plan #2, applying elasticities to estimate ridership loss in appropriate markets	→	→
		- or - Use plan #3, with the pivot-point application of a direct estimation or mode-choice model to estimate ridership loss in appropriate markets	→
o Offer increased service at same cost	Use Plan #2, applying elasticities to estimate ridership gain in approprate markets	→	→
		- or - Use Plan #3, applying elasticities to estimate ridership gain in appropriate markets	→
o Offer increased service at higher cost	Use Plan #2, applying elasticities to estimate ridership gain in appropriate markets	→	
		- or - Use Plan #3, applying elasticities to estimate ridership gain in appropriate markets	→

Table 2-4:

APPLICABILITY OF ANALYSIS PLANS TO NEW SERVICES

Objective of New Service	Initial Feasibility	Screening of Options	Detailed Planning
o Meet service standards at least cost	Use Plan #1 with ridership from similar services in similar locations	→	→
		- or - Use Plan #3, applying direct estimation or mode-choice models to estimate ridership	→
o Offer high quality service	Use Plan #2, applying elasticities to adjust ridership observed in similar locations	→	→
		- or - Use Plan #3, applying a mode-choice or direct estimation model (perhaps supplemented by elasticities) to estimate ridership	→
			- or - Use Plan #4, applying an equilibrium model to estimate ridership

CHAPTER 3: PREPARING "BALL-PARK" PATRONAGE ESTIMATES

An agency interested in assessing the feasibility of community transit, or in screening potential system sizes and operating strategies, needs only an approximate estimate of potential ridership. This information can be obtained using one of the types of techniques presented in this chapter. The first technique, covered in Section 3.1, is the use of ridership observed on services in similar areas. The second, presented in Section 3.2, is the use of simple models to estimate ridership. The third, covered in Section 3.3, is the application of elasticities to existing ridership in a service area to estimate the impact of service substitution.

3.1 Ridership Analogs

Ridership observed on similar systems in similar locations can provide a reasonable estimate of ridership on a proposed community transit service. Ridership, operation, and demographic data have been complied by other researchers (3, 4, 5) and by state agencies (6). Data from these sources, as well as selected data collected from state and local agencies, are presented in Appendix A and summarized below for use in ridership estimation. These data are primarily applicable in the following situations:

- o estimating a likely range of ridership for a proposed service,
- o assessing the reasonableness of an estimate produced using a more detailed procedure.

Summary of Available Data

Ridership, operational, and demographic data for community transit services have been complied from available published sources and telephone conversations with operators and state agencies. These data are presented in Appendix A for close to one hundred demand-responsive and fixed-route systems serving small cities or neighborhoods or suburbs of larger cities. Systems serving areas under 10,000 population or systems which are all-rural or county-wide are not included. The appendix contains data on service area population and area, service type, ridership, service levels, vehicles, and fares as well as socio-economic data from the 1980 U.S. Census. The data are for varying years due to the variety of sources and the fact that many of the systems are no longer in existence. Appendix A may be used to locate areas with population, area, and/or other attributes similar to those of the area under study. The ridership for these sample areas can be used as a ball-park estimate, or can be refined using elasticities or other procedures.

Table 3-1 summarizes the data in Appendix A. It shows weekday and annual riderhip per capita and per square mile, and annual ridership per vehicle-hour and per vehicle-mile. Separate summaries are shown for the following settings:

- free-standing small cities
- circulator services in suburbs and neighborhoods of larger cities
- feeder services in larger urban areas.

The table shows, among other things, that feeder services tend to have the highest ridership, while circulator services in free-standing cities attract on average more riders than those in suburban or neighborhood settings.

In addition to average values, the table shows the range of values and statistical measures of variability. These measures clearly show large differences among services within each category, indicating the limited applicability of average observed ridership in estimating ridership for proposed systems. Nonetheless, the information in the table can be used to obtain rough bounds on potential ridership.

Figures 3-1 through 3-3 plot ridership as a function of population for the three service categories summarized in Table 3-1. In these figures, a "B" indicates a bus operation while a "T" indicates shared-ride taxi service. Figures 3-4 through 3-6 are similar, but plot ridership per square mile as a function of population per square mile.

Table 3-1:

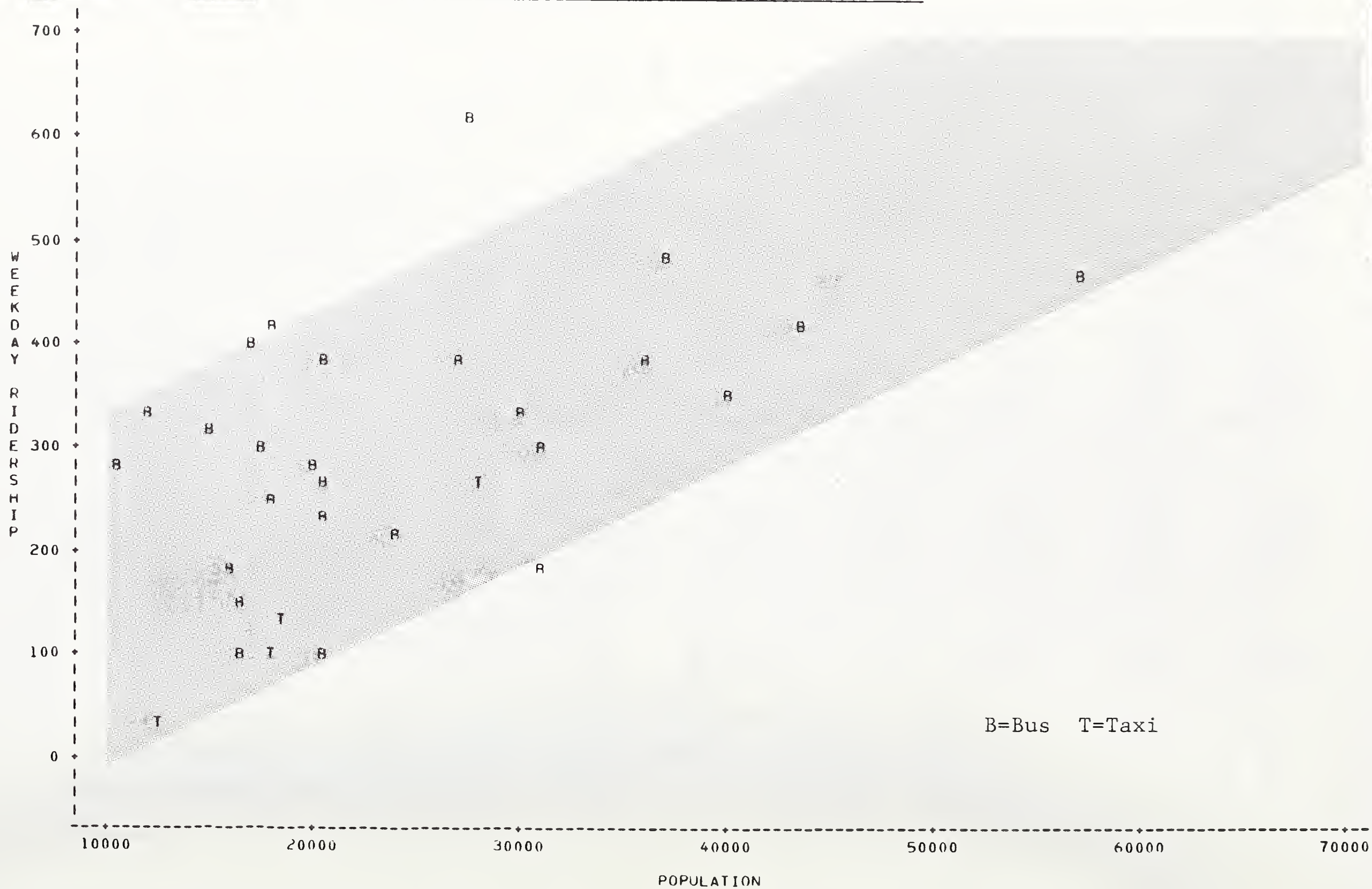
SUMMARY OF OBSERVED RIDERSHIP

STATISTICS FOR RIDERSHIP VARIABLES
BY TYPE OF SYSTEM

	N	MEAN	STANDARD DEVIATION	C.V.	STD ERROR OF MEAN	MINIMUM VALUE	MAXIMUM VALUE
NEIGHBORHOOD/SUBURBAN CIRCULATOR SYSTEMS							
ANNUAL TRIPS PER SQUARE MILE	36	7468.2088	7885.1806	105.583	1314.1968	761.4599	43573.5294
WEEKDAY TRIPS PER SQUARE MILE	35	30.3673	25.3414	83.449	4.2835	2.9927	119.7059
ANNUAL RIDERSHIP PER CAPITA	36	1.4917	1.1549	77.420	0.1925	0.2999	6.1601
WEEKDAY RIDERSHIP PER CAPITA	35	0.0058	0.0040	68.295	0.0007	0.0010	0.0169
ANNUAL RIDERSHIP PER VEHICLE-HOUR	29	5.9287	1.7236	29.073	0.3201	2.8647	10.0900
ANNUAL RIDERSHIP PER VEHICLE-MILE	24	0.4565	0.1759	38.540	0.0359	0.2233	0.7800
NEIGHBORHOOD/SUBURBAN FEEDER SYSTEMS							
ANNUAL TRIPS PER SQUARE MILE	12	47364.2859	35982.0616	75.969	10387.1265	10732.2353	114387.0000
WEEKDAY TRIPS PER SQUARE MILE	14	183.0773	136.4547	74.534	36.4690	2.0000	393.5860
ANNUAL RIDERSHIP PER CAPITA	12	10.4877	6.3117	60.181	1.8220	0.8973	22.8774
WEEKDAY RIDERSHIP PER CAPITA	14	0.0396	0.0230	58.145	0.0062	0.0008	0.0733
ANNUAL RIDERSHIP PER VEHICLE-HOUR	8	9.7340	2.0578	21.141	0.7276	5.7656	12.0815
ANNUAL RIDERSHIP PER VEHICLE-MILE	6	0.9655	0.3388	35.093	0.1383	0.4341	1.3889
SMALL CITY CIRCULATOR SYSTEMS							
ANNUAL TRIPS PER SQUARE MILE	35	8120.4642	5595.0697	68.901	945.7394	523.7086	22172.9091
WEEKDAY TRIPS PER SQUARE MILE	32	35.4307	22.3164	62.986	3.9450	2.0530	83.3333
ANNUAL RIDERSHIP PER CAPITA	37	3.5931	1.9956	55.539	0.3281	0.6251	8.2302
WEEKDAY RIDERSHIP PER CAPITA	33	0.0139	0.0075	54.244	0.0013	0.0025	0.0317
ANNUAL RIDERSHIP PER VEHICLE-HOUR	31	6.6760	2.1997	32.950	0.3951	2.8528	12.0200
ANNUAL RIDERSHIP PER VEHICLE-MILE	31	0.4858	0.1453	29.911	0.0261	0.2234	0.8308

Figure 3-1:

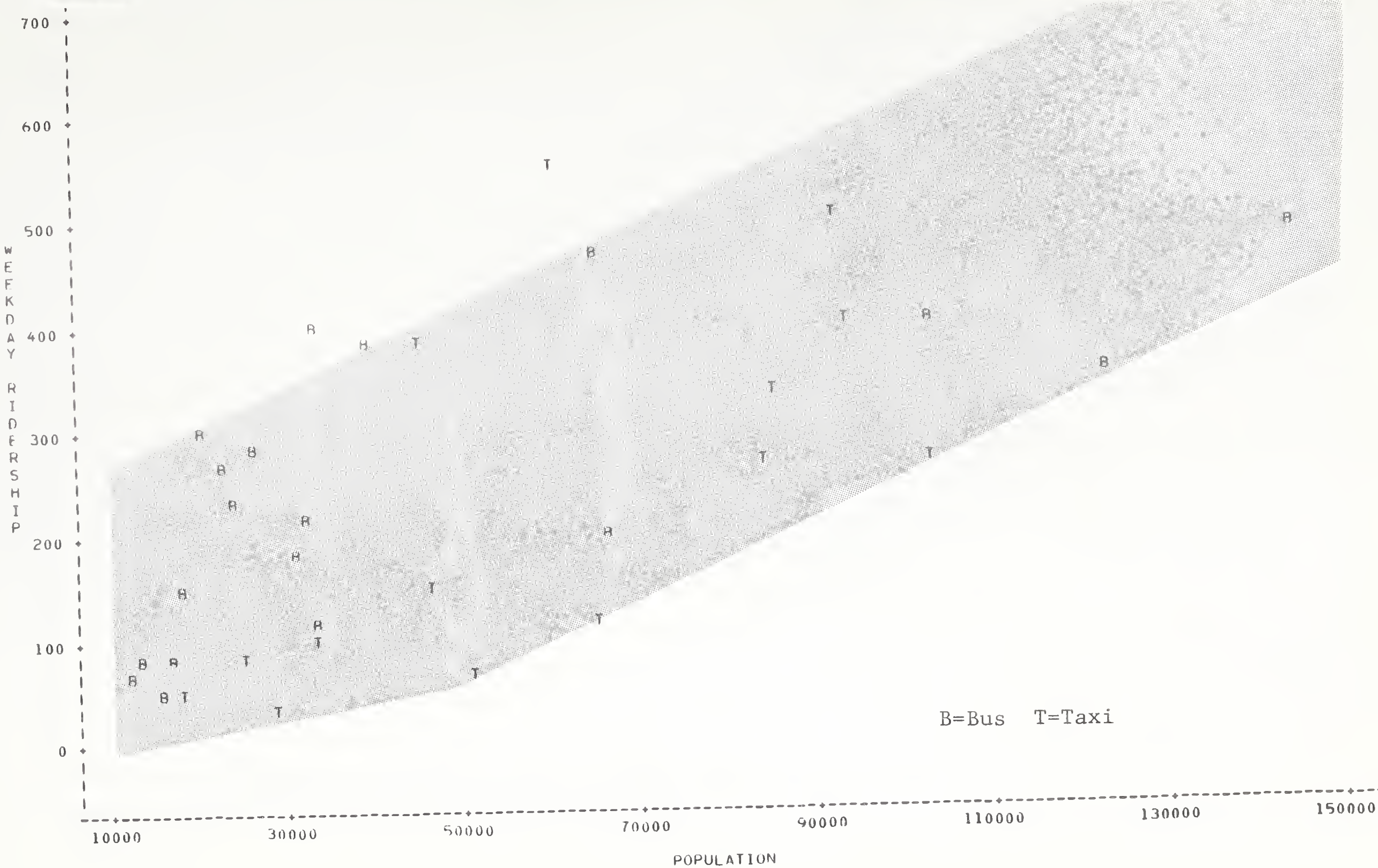
WEEKDAY RIDERSHIP AS A FUNCTION OF POPULATION, SMALL CITIES



NOTE: 12 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

Figure 3-2:

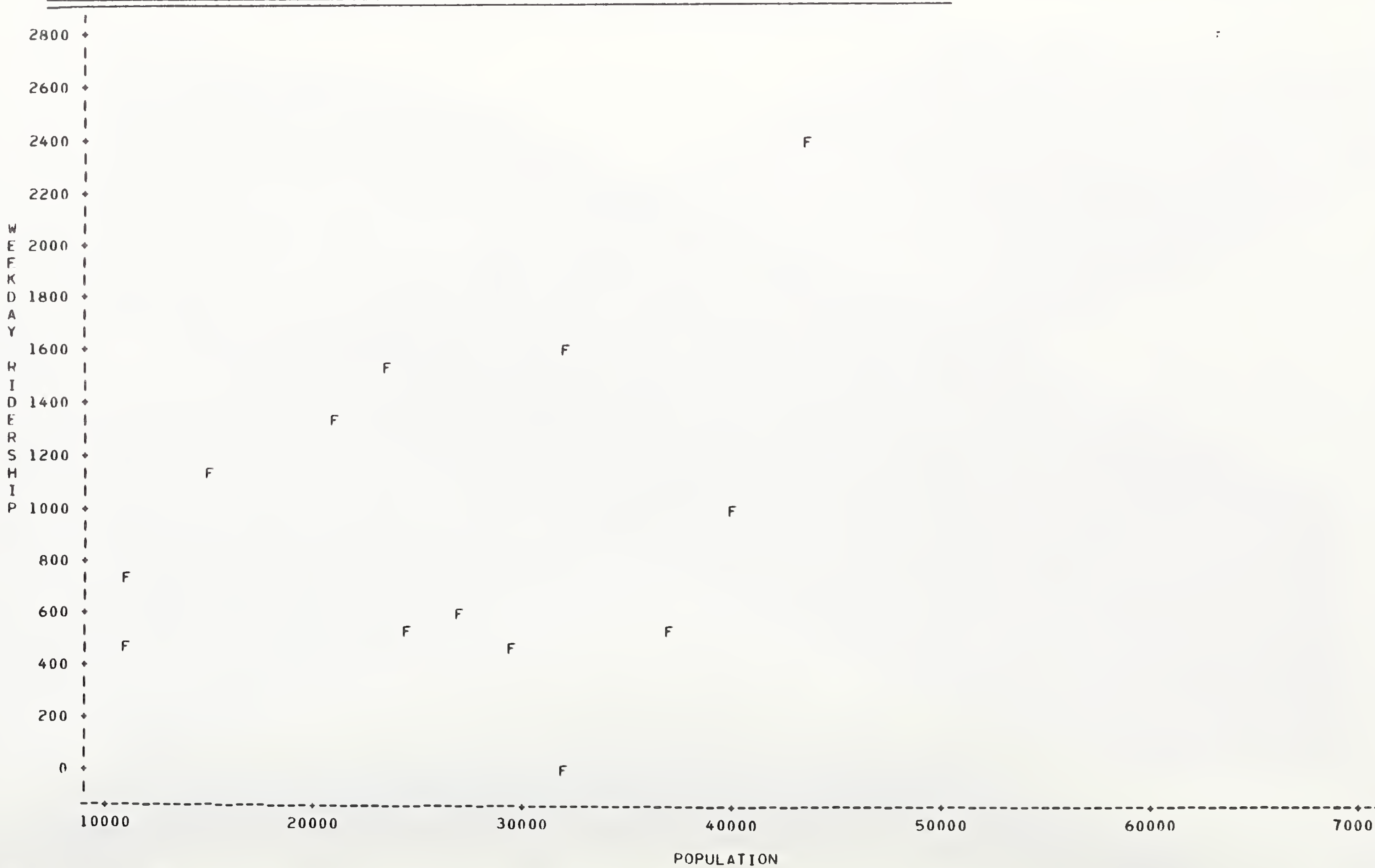
WEEKDAY RIDERSHIP AS A FUNCTION OF POPULATION, SUBURBAN CIRCULATORS



NOTE: 8 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

Figure 3-3:

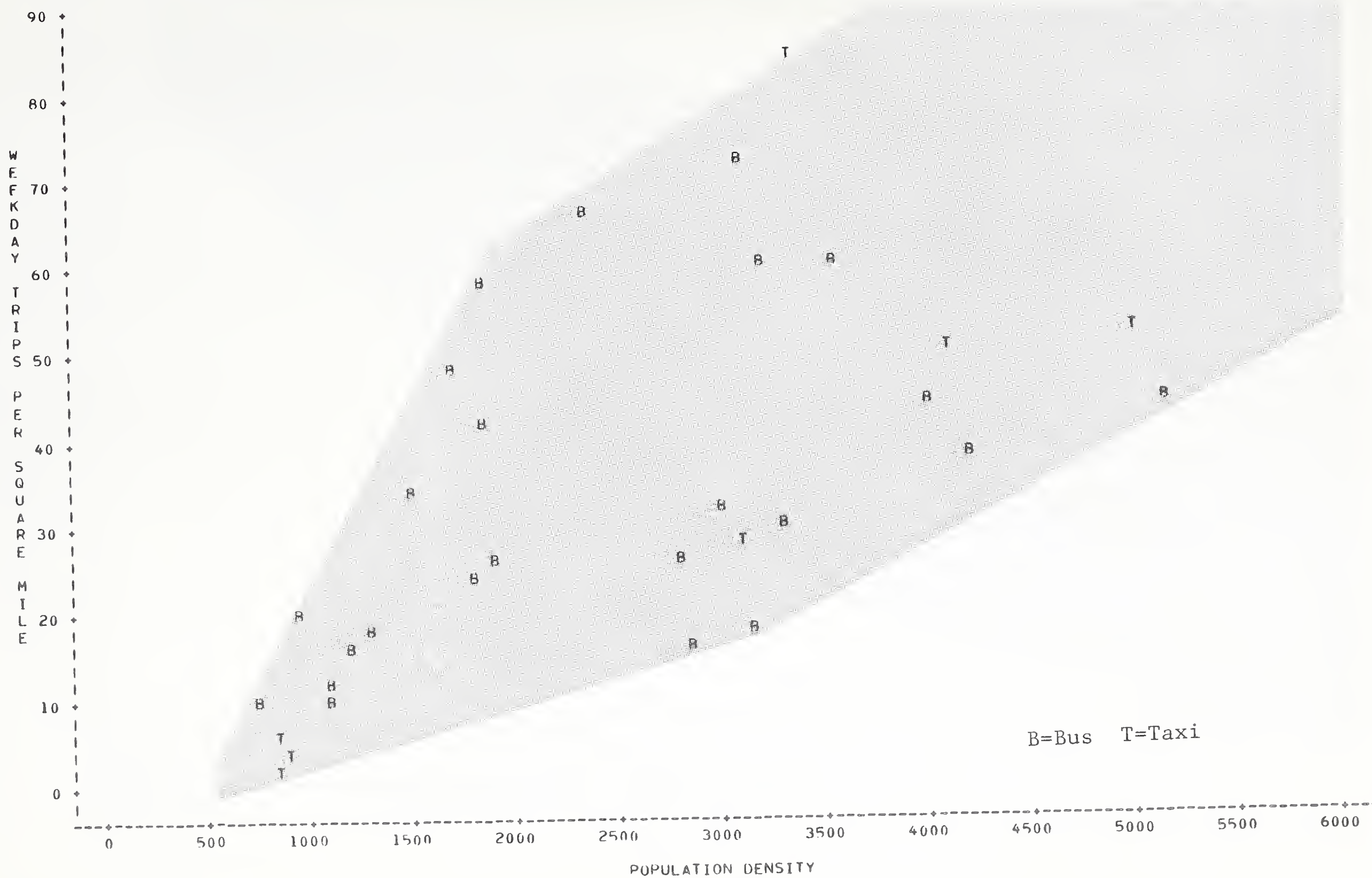
WEEKDAY RIDERSHIP AS A FUNCTION OF POPULATION, FEEDERS



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

Figure 3-4:

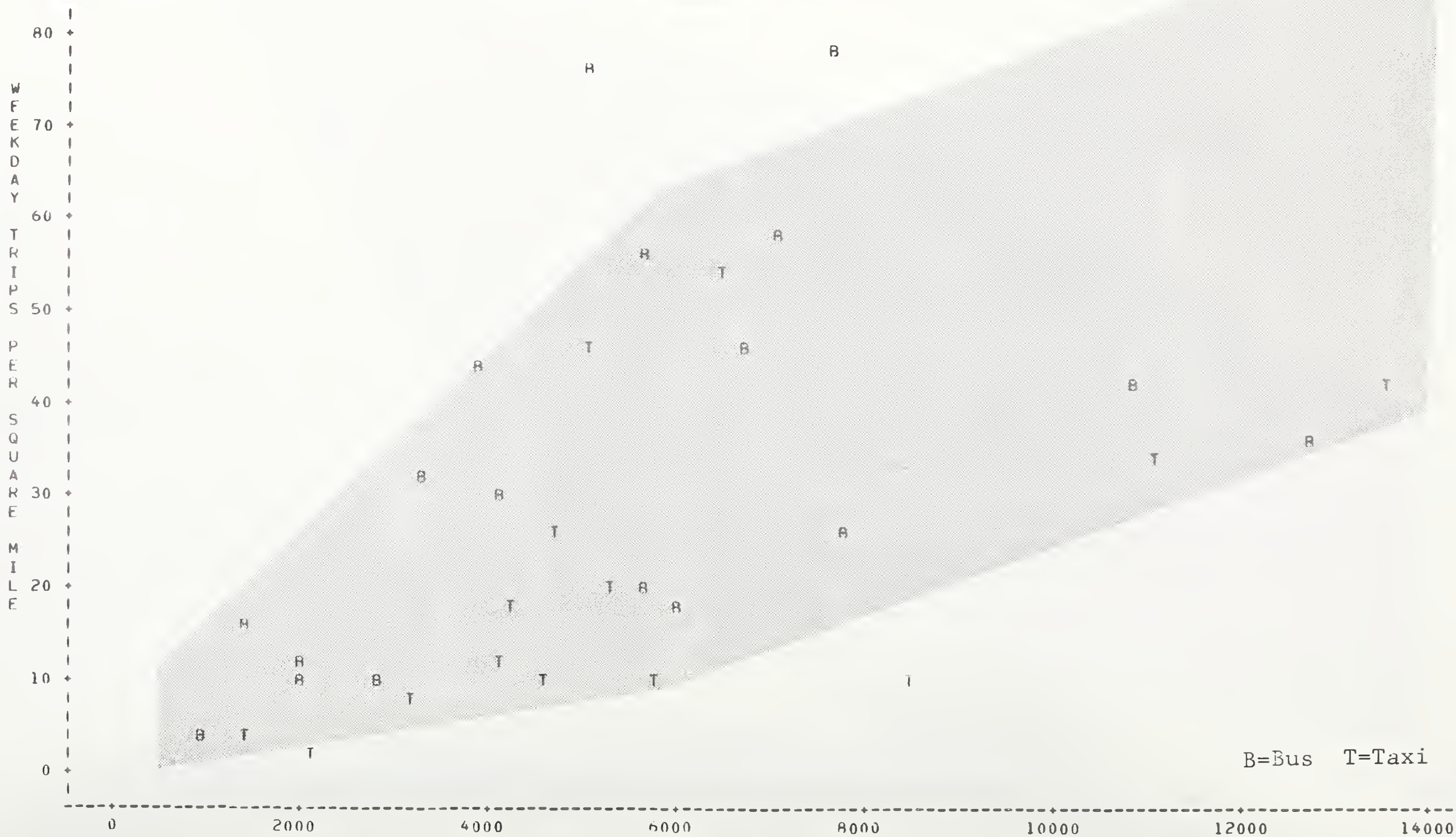
WEEKDAY RIDERS PER SQUARE MILE AS A FUNCTION OF POPULATION DENSITY, SMALL CITIES



NOTE: 10 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 1 OBS HIDDEN

Figure 3-5:

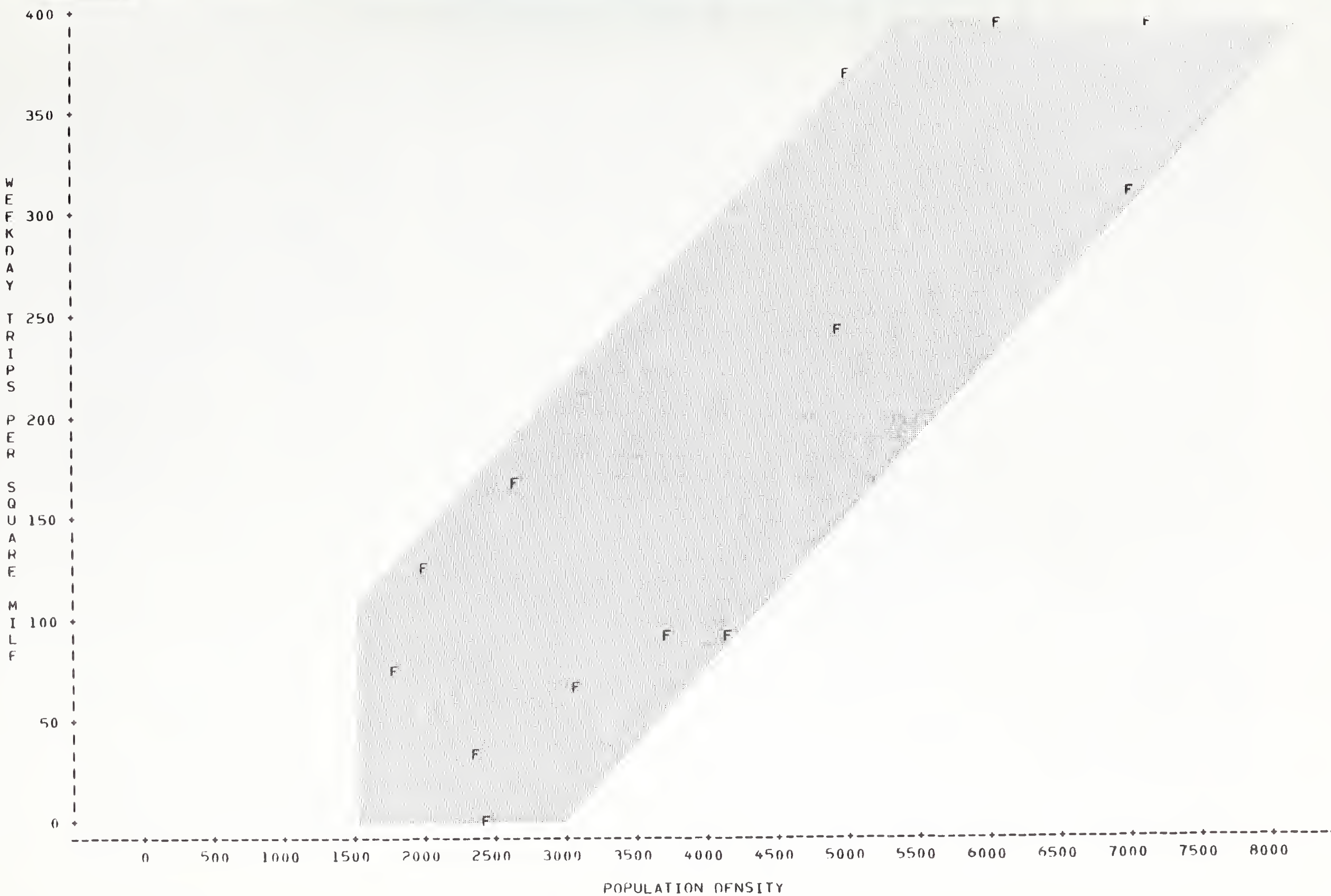
WEEKDAY RIDERS PER SQUARE MILE AS A FUNCTION OF POPULATION DENSITY, SUBURBAN CIRCULATORS



NOTE: 8 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 1 OBS HIDDEN

Figure 3-6:

WEEKDAY RIDERS PER SQUARE MILE AS A FUNCTION OF POPULATION DENSITY, FEEDERS



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

The shaded bands shown in the figures indicate the ranges in which most systems fall. Although they are wide, they do show a tendency for ridership to increase with population and density. Other researchers (e.g., 3) have developed similar plots which combine different types of services, and consequently show a greater spread of data points.

When drawing analogies from the tables and figures in this section and from Appendix A, note that such analogies are only for ball-park estimates. The similarities and dissimilarities between the sample communities and the community for which a system is being planned must be carefully considered before drawing any conclusions. It is best just to consider the ranges of ridership in similar communities rather than trying to predict actual ridership. If more exact figures are required other methods of ridership estimation should be used.

Example Application

An outlying suburb, 20 square miles in area with a population of 27,000 (1350 per square mile) is served only a by a single line-haul transit route to the central city. The town is considering implementing a community transit service for local circulation purposes. Using Figure 3-2 it can be seen that services in communities this size typically attract ridership in the range of 40 to 350 riders per weekday, or using Figure 3-5, 2 to 18 weekday riders per square mile (i.e., 40 to 360 over the 20 square miles). This is a very wide range, but in assessing the feasibility of a service (or in its initial planning) an agency should consider the implications of operating at different ridership levels over this large a range.

To try to narrow this range, a planner could use Appendix A or other compilations (e.g., 3) to identify services in simlar settings. Using the appendix, it can be seen that Claremont and Corona (California) have populations and densities similar to the suburb under study. The ridership in these two areas, however, ranges from only 76 per weekday in Claremont to over 400 in Corona. The other information in the appendix, such as level of other transit service, hours of service, and socio-economic data, can then be compared to the suburb under study to possibly narrow the range of estimated ridership. Noting that Claremont has some existing local transit while Corona does not, a planner may expect ridership on the proposed system to be in the high end of the range. The planner may also wish to revise his estimates based on a comparison of the socio-economic data for the suburb with that of Claremont and Corona noting the differing income and age distributions of the two cities. These estimates, however, will still be only ball-park figures and will only yield an approximate range. If further refining of estimates is required then more accurate methods of refinement, such as elasticities, must be used.

3.2 Direct Estimation Techniques

One of the limitations of analogs is that they give little indication of the interaction among different factors affecting ridership. Sample plots for different types of service, such as those presented in Section 3.1, indicate a few of these interactions, but clearly show a lot of unexplained variation among existing services. To remedy this situation, researchers have attempted to develop models that predict community transit ridership using a variety of land use, socio-economic, supply, and service quality factors. These models, and some developed specifically for this handbook, are discussed below. They can be applied in the following situations:

- o estimating ridership for a new service
- o estimating ridership for a replacement service where a major change in service is planned.

Available Techniques

An early effort to develop direct estimation models was performed by researchers at Mitre (7). Using data from 16 paratransit services, they calibrated the following equations:

$$R = -238.9 + 0.072D + 23.3V + 0.161PSH \qquad r^2 = 0.99$$
$$RPP = 0.00793 - 0.01638FA + 0.00012PS + 0.0000036D \qquad = 0.92$$
$$RPM = -5.19 + 0.06D + 1.6V - 145.4FA \qquad = 0.87$$
$$RPH = 22.6 + 0.0009P + 0.187PS - 72.0FA \qquad = 0.94$$

where:

R = average daily ridership
RPP = average daily ridership divided by service area population
RPM = average daily ridership divided by service area size (in square miles)
RPH = average daily ridership divided by number of daily hours of operation

P = population of service area
D = density, or population per square mile
V = average number of daily operating vehicles in system
H = average number of operating hours per day
PS = average daily seats in operation
PSH = (PS) (H)
FA = average fare (in dollars)

Despite their high r^2 values and the inclusion of service and supply variables, these models are of limited use. They are very sensitive to fare, which combined with their linear form can yield predictions of negative ridership. The constant terms in all equations are high in relation to typical values of the dependent variable, and all but the last equation have an odd mix of density and absolute variables.

The fourth equation was transformed into a nomograph to simplify its use as a planning technique. This nomograph, shown in Figure 3-7, indicates the ranges of data used in developing the model. Any application of the model also should be limited to this range.

More recently, a model was calibrated by researchers at the University of Illinois (8) using data from 33 systems. The model development, which followed a review of the Mitre equations and other models, produced the following equation:

$$\log y = 1.16 + 0.23 \log V_1 - 0.17 \log V_2 - 0.54 \log V_3 + 0.72 \log V_4 + .57 V_5 \qquad r^2 = .56$$

where:

y = ridership per hour

V_1 = population of the service area

V_2 = area (square miles)

V_3 = number of hours of operation

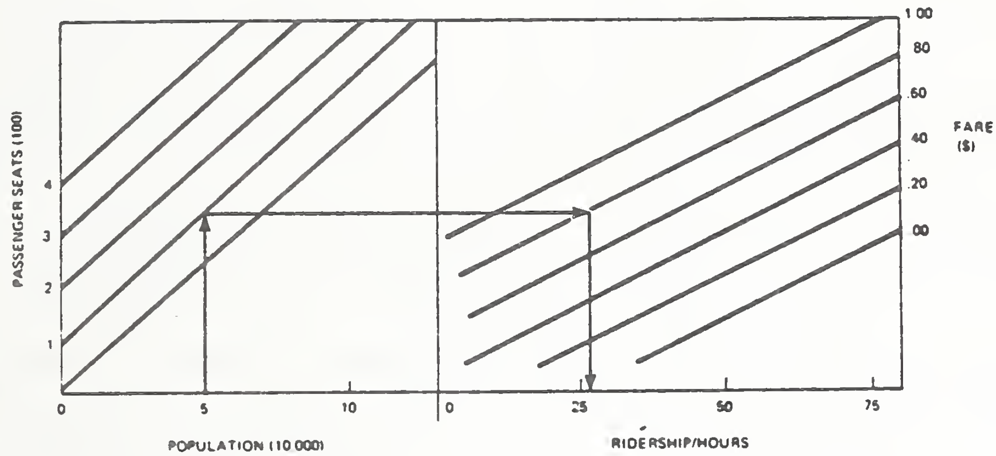
V_4 = number of vehicles

V_5 = 0 if the system is many-to-many
= 1 if otherwise

The negative coefficient on hours of service appears odd at first glance, but the equation produces increased daily ridership as hours of service increase. The model apparently has not been validated or used in service planning, but

Figure 3-7:

MITRE NOMOGRAPH FOR RIDERSHIP ESTIMATION



Source (7)

it appears to be well-specified and potentially useful. The low R^2, however, indicates that additional explanatory variables are needed.

Expanded Models

Data on 98 community transit services, presented in Appendix A, were used to develop improved direct estimation procedures. The improvement effort focussed on distinguishing among different types of services, retaining or expanding service quality variables, and adding socio-economic characteristics.

The size of the data base allowed its separation into the three categories used for presenting ridership summaries in Section 3.1. Separate equations were developed for each category, as this proved better than a single equation with service category variables. Models, presented below, were calibrated for estimating ridership on circulation services in free-standing communities and in suburbs and neighborhoods of larger cities. Attempts to develop similar models for feeder services were not successful.

Two models were calibrated (using log-linear regression) for estimating ridership on services in free-standing small cities. The first estimates average weekday ridership per square mile, while the second estimates average weekly ridership per square mile. The equations are as follows:

$$\text{WDYRDEN} = .950 * \left[\frac{\text{POP}}{\text{AREA}}\right]^{.463} * \left[\frac{\text{FLEET}}{\text{AREA}}\right]^{.598} * \exp\left(-.47 * \text{SRTAXI} + .034 * \text{NOAUTO} - .016 * \text{OVER64}\right)$$

$$\text{WKYRDEN} = 9.47 * \left[\frac{\text{POP}}{\text{AREA}}\right]^{.387} * \left[\frac{\text{FLEET}}{\text{AREA}}\right]^{.619} * \exp\left(-.46 * \text{SRTAXI} + .036 * \text{NOAUTO} - .018 * \text{OVER64}\right)$$

where:

WDYRDEN = average weekday ridership per square mile

WKYRDEN = average weekly ridership per square mile

POP = population of the service area

AREA = size of the service area (in square miles)

FLEET = number of community transit vehicles

SRTAXI = 1 (if shared-ride taxi is planned)
= 0 (otherwise)

NOAUTO = percent of households without an automobile

OVER64 = percent of population over 64 years of age

The equations are based on data for 28 systems. All coefficients in the equations are significant at 5%; the r^2 measures (for the equation form that is shown) are .77 and .84, respectively. Variables which were examined but not found significant at 10% included fare (adjusted to constant 1983 dollars), the fraction of the population under 19 years of age, hours of service, and various income and auto ownership variables.

Population density in the calibration data ranged from 700 to 8000 people per square mile, while vehicles per square mile ranged from 1/15 to 7. The fraction of households without autos ranged from 2% to 18%, while the fraction of elderly in the population ranged from 0.2% to 48%.

Similar equations were calibrated for estimating average weekday and weekly ridership on suburban circulation systems, as follows:

$$WDYRDEN = 3.87 * \left[\frac{POP}{AREA}\right]^{.256} * \left[\frac{FLEET}{AREA}\right]^{.770}$$

$$WKYRDEN = 6.04 * \left[\frac{POP}{AREA}\right]^{.246} * \left[\frac{FLEET}{AREA}\right]^{.721} * (WKYHRS)^{.320}$$

where:

WKYHRS = hours of service per week.

The equations are based on 32 and 30 observations, respectively. All coefficients are significant at 10%; the r^2 measures (for the equation form that is shown) are .79 and .87, respectively. Again, other variables were examined but not found significant at 10%.

Population density in the calibration data ranged from 900 to 19000 people per square mile, while fleet density ranged from 1/14 to 6 vehicles per square mile. Weekly service hours ranged from 30 to 168.

These equations will perform best when applied to areas well within the ranges specified above. When applying these equations to areas near the ends of the ranges, other techniques, such as analogies, should also be used .

Example Application

A small city of 15,000 people is considering contracting with the local taxi operator to provide shared-ride service within the city limits (a 6 square mile service area). The taxi operator currently uses 8 vehicles. 10% of households in town are without autos, and approximately 15% of the population is elderly.

The town planner, applying the equations presented, estimates the following ridership:

weekday: $.950 * (2{,}500)^{.463} * (1.33)^{.598} * \exp(-.47 + .034 * 10 -.016 * 5)$
$= .950 * 37.4 * 1.19 * .69$
$= 29$

weekly: $9.47 * (2{,}500)^{.387} + (1.33)^{.619} * \exp(-.46 + .036 * 10 - 0.18 * 15)$
$= 9.47 * 20.7 * 1.19 * .69$
$= 161$

3.3 Elasticities

An elasticity is a measure of the proportional change in ridership resulting from a proportional change in fare, service quality or supply. As an example, an elasticity of 0.5 with respect to vehicle-miles of transit service operated indicates that a 10% increase in vehicle-miles can be expected to produce a 5% increase in ridership.

Elasticities have been derived from observed changes in ridership on community and regular route transit services and systems, and estimated from cross-sectional data during the development of mode choice and other estimation models. They are applicable in the following situations:

- o estimating ridership for a replacement service that will result in only moderate changes in service quality.
- o adjusting analogies to account for differences in service or operation.
- o estimating ridership response to proposed changes to an existing community transit service.

Available Techniques

Elasticities derived from observed ridership changes are reported in several sources and may be applicable in estimating ridership on community services. These values generally have been calculated using one of the following equations:

<u>shrinkage ratio</u>:

$$E_m = \frac{M_b}{V_b} \times \frac{(V_a - V_b)}{(M_a - M_b)} \qquad (3\text{-}1a)$$

<u>logarithmic arc</u>:

$$E_m = \frac{\log (V)_b - \log (V_a)}{\log (M_b) - \log (M_a)} \qquad (3\text{-}1b)$$

<u>midpoint arc</u>:

$$E_m = \frac{(M_b + M_a)}{(V_b + V_a)} \times \frac{(V_a - V_b)}{(M_a - M_b)} \qquad (3\text{-}1c)$$

where:

E_m = elasticity of ridership with respect to service measure m

V_b = ridership before the change

V_a = ridership after the change

M_b = service level or fare before the change

M_a = service level or fare after the change

Before applying an elasticity, the user should learn how it was derived. The first of these forms, while simple to calculate, produces values that are highly dependent on the "before" values and the direction of change. The second and third forms produce elasticities that are more stable and presumably applicable over a greater range of conditions and changes; the values they produce are similar and can be used interchangeably. The use of the midpoint and logarithmic forms are strongly recommended for this and other reasons (see References 9 and 10). Elasticities derived from calibrated models also are similar to these forms.

Arc elasticities drawn from References 9 and 10 are shown in Tables 3-2 and 3-3 to illustrate the types of elasticities that have been derived from ridership responses to changes in fares and various service quality measures,

Table 3-2:

TYPICAL FARE ELASTICITIES

Charactertistic[1]	Elasticity[2]	# of Cases
Fare		
Peak	-0.09 ± 0.04	4
Off-peak	-0.31 ± 0.16	8
All-hours*	-0.56 ± 0.28	14
Increase	-0.32 + 0.13	19
Decrease	-0.37 ± 0.11	9
CBD fare free zone	-0.52 ± 0.13	3
Senior citizen discounts	-0.27 ± 0.19	12
Small city and suburban	-0.39 ± 0.22	8
Demand-responsive (includes paratransit and shared-ride taxi)	-0.43 ± 0.24	6

Sources: (9, 10, 11)

1 Bus only, unless otherwise noted.

2 Mean value ± standard deviation, where available.

* Starred elasticities are based on nonexperimental data, e.g., data that do not reflect an actual fare change.

Table 3-3:

TYPICAL SERVICE ELASTICITIES

Characteristic[1]	Elasticity[2]	# of Cases
Vehicle-miles		
Systemwide	+0.66 ± 0.26	6
Systemwide*	+0.78 ± 0.32	9
Headway		
Peak, weekday	-0.37 ± 0.19	3
Off-peak, weekday	-0.46 ± 0.26	9
Weekends	-0.38 ± 0.17	4
Less than 10 minutes	-0.22 ± 0.10	7
More than 50 minutes	-0.58 ± 0.19	10
Small city of suburban	-0.48 ± 0.28	8
Total Travel Time		
Peak*	-1.03 ± 0.13	2
All hours*	-0.92 ± 0.37	2
In-vehicle or Ride Time		
Peak	-0.29 ± 0.13	9
Off-peak	-0.83	1
Peak*	-0.68 ± 0.32	7
Non-work trip*	-0.12	1
(Composite) Out-of-Vehicle Time		
All hours (bus and rapid rail)*	-0.59 ± 0.15	3
Walk time		
Peak*	-0.26	1
Off-peak*	-0.14	1
Wait time		
Peak (bus and rapid rail)*	-0.20 ± 0.07	4
Off-peak (bus and rapid rail)*	-0.21	1
Transfer time		
Peak (bus and rapid rail)*	-0.40 ± 0.18	3
Number of transfers		
Off-peak	-0.59	1

Sources: (9, 10, 11)

1 Bus only, unless otherwise noted.

2 Mean value ± standard deviation, where available.

* Starred elasticities are based on nonexperimental data, e.g., data that do not reflect an acutal service change.

respectively. The tables provide a good summary of available elasticities, and show the range and variability of observed and estimated ridership responses.

An elasticity from the tables (or another source) is applied to estimated ridership using one of the following equations:

<u>any change</u>:

$$V_a = V_b \times \left[\frac{M_a}{M_b} \right]^{E_m} \tag{3-2a}$$

<u>small changes</u>:

$$V_a = V_b \times \left\{ 1 + E_m \times \left[\frac{M_a}{M_b} - 1 \right] \right\} \tag{3-2b}$$

If more than one fare or service measure change is contemplated, these equations can be expanded as follows:

$$V_a = V_b \times EFAC_1 \times EFAC_2 \times \ldots\ldots \tag{3-3}$$

where: $EFAC_1$ = the expression enclosed in brackets in equation 3-2a or 2b calculated for a specific fare or service measure being changed

The application of elasticities in planning community transit services, unfortunately, is not straightforward for a number of reasons. First, the elasticities in the tables and other sources are based on fare and service levels, and changes in these levels, observed during the 1960's and 1970's. As a result, they should be used with caution in estimating responses to conditions that will vary radically from conditions typical of those decades. Mayworm (<u>12</u>), for example, discussed evidence that fare elasticities will become increasingly negative as fare levels and the importance of fare in a traveller's overall impedance (i.e., a weighted sum of fare and various travel time components) increases.

Second, many of the elasticities presented for measure such as walk and ride time are derived from model calibrations (as denoted by asterisks in the tables). These elasticities need to be used with caution, for they capture differences among travellers in different parts of a region (e.g., people with no need for transit service choosing to live in an area with little service, and vice versa) and coding conventions used in preparing UTPS or similar networks (such as the placement of boarding nodes and procedures used for estimating average walk time from a zone) as well as transit service differences.

One way of dealing with this uncertainty of applicability is to use the standard deviations shown in the tables to derive a conservative estimate of an elasticity, as follows:

$$E_c = E_m + CFAC * SDEV \qquad (3-4)$$

where: E_c = conservative elasticity, to be used in equation 3-2 instead of E_m.

E_m = mean elasticity obtained from tables

SDEV = standard deviation of elasticity obtained from tables, with the sign selected to dampen and expected ridership increase and expand an expected decrease.

CFAC = factor reflecting derived confidence level, obtained from the following table:

Confidence Level	CFAC
50%	0.0
70%	0.525
80%	0.842
90%	1.282
95%	1.645
98%	2.054

More importantly, the elasticities presented in the tables largely are based on changes in regular route service, and may not be directly applicable to community transit modes. For example, ridership response to a change in wait time may be less for a dial-a-ride service than for a fixed-route service because patrons can wait at home. With flexible routing and dispatching on request, service quality measures not covered in the tables may become as or more important than the measures traditionally associated with fixed-route service. Examples are variability of wait and ride time and similar measures of service reliability.

Analyses of changes in mode compound some of these problems. For example, when analyzing dial-a-ride as a substitute for fixed-route service, the resulting change from a 5 minute to a 0 minute walk is outside the range of most walk time elasticities, so they are not applicable. Major changes in other service quality measures may cause similar problems. An approach that attempts to overcome these problems is presented below.

Adapting Elasticity Analysis to Community Transit

Community transit analysis may involve changes in fare, ride time, and/or various out-of-vehicle components. Adaptations of elasticity analysis to examine ridership response to these three types of changes are discussed below. Procedures for estimating ride time and various out-of-vehicle times on different community transit modes are presented in Appendix B.

As shown in Table 3-2, fare elasticities for demand-responsive service appear comparable to those for regular-route service in the off-peak and in small cities and suburbs. Because of this similarity, these particular elasticities should be directly applicable in most analyses of community transit. One issue in their application to community transit is the need to distinguish among groups of riders paying different fares, and to separately estimate ridership changes within each group whenever possible. Another is to apply an elasticity to changes in total trip fare when travellers also use other modes in making a trip. For example, a fare increase from 25¢ to 50¢ on a community service is a 100% increase for local trips, but only a 20% increase for trips using the service to access a line-haul route with a $1.00 fare. These market segments will probably respond differently to the increase, and should be analyzed separately.

The observed ride time elasticities in Table 3-3 are based on express bus operations. Despite this, they are generally more in line with the observed headway elasticities than are the ride time elasticities derived from models, i.e., they indicate that riders are less sensitive to changes in ride time than to changes in wait time. For lack of better information, a ride time elasticity of about -0.3 is probably adequate for assessing most community transit options. A potential adjustment to deal with the high variablity of ride time on flexibly routed services is presented in the application section that follows.

The walk and wait time elasticities presented in Table 3-3 are based on a few models, and appear low with respect to other elasticities. In contrast, the transfer and composite out-of-vehicle time elasticities appear reasonable. The most supportable elasticities, however, are those observed for headway changes, which are directly related to wait time and schedule convenience changes. With the exception of the one number-of-transfers elasticity, they are the only elasticities based on observed changes in out-of-vehicle time. The best approach to community transit analysis appears to be to use the headway elasticities shown in Table 3-3 as a basis for analyzing all changes involving more than one component of out-of-vehicle time as well as all changes involving only headway or wait time. The major adaptation is to apply factors to convert all out-of-vehicle time components into comparable measures of fixed-route wait time. A resonable set of factors is as follows:

wait time at stop	1.0
walk time	0.8
response time or wait time at home	0.5

The use of these or similar weights should avoid many of the problems associated with changes in mode, and produce reasonable estimates of the ratio of change in service quality (i.e., M_a/M_b) for use in equation 3-2. As an example of their application, the equivalent wait time (M_b) for a fixed-route rider with a 5-minute walk and a 10-minute wait would be 0.8 * 5 + 1.0 * 10 = 14 minutes.

The mix of out-of-vehicle components also may affect riders' sensitivity to change. A further adaptation to account for this is to scale an elasticity (from either Table 3-3 or equation 3-4) by the ratio for M_b computed with weights to M_b computed without weights. In the above example, the selected elasticity would be multiplied by 14/15 or 0.93 before being used in equation 3-2. This adaptation also allows the procedure to be used when only walk or response time is being changed.

Note that in applying this procedure to analyze hybrid services, riders receiving doorstep service will have a different service level than those walking to a stop. Consequently, ridership changes for these two groups should be estimated separately. This type of market segmentation also can be applied to distinguish among groups of riders traveling at different times of the day, or among groups who walk different distances to a bus stop.

Example Application

As an example, the operator of a small city transit company that operates 300,000 vehicle-miles a year with 12 mini-buses wants an estimate of the ridership increase that would result from adding 3 vehicles to the fleet. The company currently carries 250,000 passengers annually. The average observed vehicle-mile elasticity in Table 3-3 is 0.66. When applied to a service ratio (M_a/M_b) of 1.25, this elasticity yields an estimated ridership increase of about 16% using either equation.

The operator also wants a conservative estimate of revenues, e.g., an estimate that will be exceeded 80% of the time. For this estimate, he selects the appropriate factor (i.e., .842) and applies equation 3-4 to obtain a revised elasticity of 0.44. This value, used in either form of equation 3-2, produces an estimated annual ridership increase of slightly over 10%.

Note that an estimate of ridership also can be produced using a headway elasticity. If the small city elasticity value of -0.48 is applied to the expected 20% reduction in headway (i.e., M_a/M_b = 0.8 in this case), an estimated ridership increase of 11% results, while a conservative headway elasticity of -0.24 yields an estimated increase of 5.6%. For analysis purposes, the operator can safely assume between 20,000 and 30,000 new riders a year if the fleet is expanded.

The operator also is considering a conversion to many-to-one service when the additional vehicles are delivered. The effective headway is not expected to change, because added run time and variability are expected to compensate for the increase in vehicles. The changes from a rider's perspective are expected to be a 10% increase in ride time, the elimination of a walk to the bus stop (averaging 4.5 minutes), waiting at home instead of at the bus stop (currently averaging 10 minutes), and waiting an extra 5 minutes on average to allow for vehicle dispatching. Equations in Appendix B can be used to estimate consistent measures of average ride time on the fixed-route and many-to-one services. These values, assuming an average passenger load of 3, are 5.8 and 7.5 minutes, respectively. The expected change in ridership can be estimated by applying equation 3-3 as follows, using factors and elasticities discussed above:

$$250{,}000 * \left[\frac{7.5}{6.8}\right]^{-0.3} * \left[\frac{.5 * (10 + 5)}{10 + .8 * 4.5}\right]^{-0.48 * .938}$$

$$= 250{,}000 * 0.97 * 1.31 \qquad (3\text{-}5)$$
$$= 318{,}000$$

Riders, however, may perceive a higher than average ride time with the many-to-one service as a result of variability in passenger loads and run times, and the operator suspects that the estimate produced in equation 3-5 may be high as a result. As an attempt to adjust for this effect, a perceived typical load (PTL) can be estimated as follows:

$$PTL = AVGL + FAC * \sqrt{AVGL} \qquad (3\text{-}6)$$

where: AVGL = average vehicle load

FAC = adjustment factor from the confidence level table presented above

In the example, a perceived load could be calculated as 3.0 + .525 * 3.0 = 3.9, i.e., the load exceeded only 30% of the time. The average ride times at this loading level (derived using equations in Appendix B) are 7.0 and 8.6 minutes for fixed-route and many-to-one, respectively. If these values are used in equation 3-5, estimated ridership drops to 308,000.

A conservative estimate of ridership change also can be made for the many-to-one service. In this case, an elasticity of -0.24 is applied to both ride and out-of-vehicle time changes, because it is unlikely that riders would be more sensitive to ride time. This elasticity results in an estimate of about 275,000 riders.

CHAPTER 4: REFINING PATRONAGE ESTIMATES

Ridership estimates produced using procedures presented in Chapter 3 may prove inadequate for planning purposes due to inadequate accuracy or insufficient detail. Other estimation techniques may be applicable in these situations. Summaries of observed ridership characteristics (presented in Section 4.1) can be helpful in developing profiles of expected riders on a proposed service. More formal techniques that can be applied to provide more detailed, and potentially more accurate, estimates are feeder mode choice models (described in Section 4.2), demand-responsive mode choice models (described in Section 4.3), and the joint operation of service quality models (similar to those in Appendix B) and the demand-responsive mode-choice models in a computerized equilibrium model (described in Section 4.4). The beginning of Section 4.2 contains a brief introduction to mode-choice models, and should be read by users unfamiliar with this general technique.

4.1 Ridership Detail

Ridership estimates prepared using the simple techniques in Chapter 3 may prove adequate for determining basic service design parameters. More detailed information on expected ridership, however, often is beneficial in estimating hourly vehicle requirements, required seating capacities, driver requirements, and revenues. Requirements for vehicles, seating capacity and drivers can be estimated using information on ridership by time of day and trip purpose from other community transit systems. Revenue can be estimated using data on ridership by fare category (usually age group) from other systems. Available published data on ridership by time of day, trip purpose and age are listed below and their applicability is discussed.

Available Information

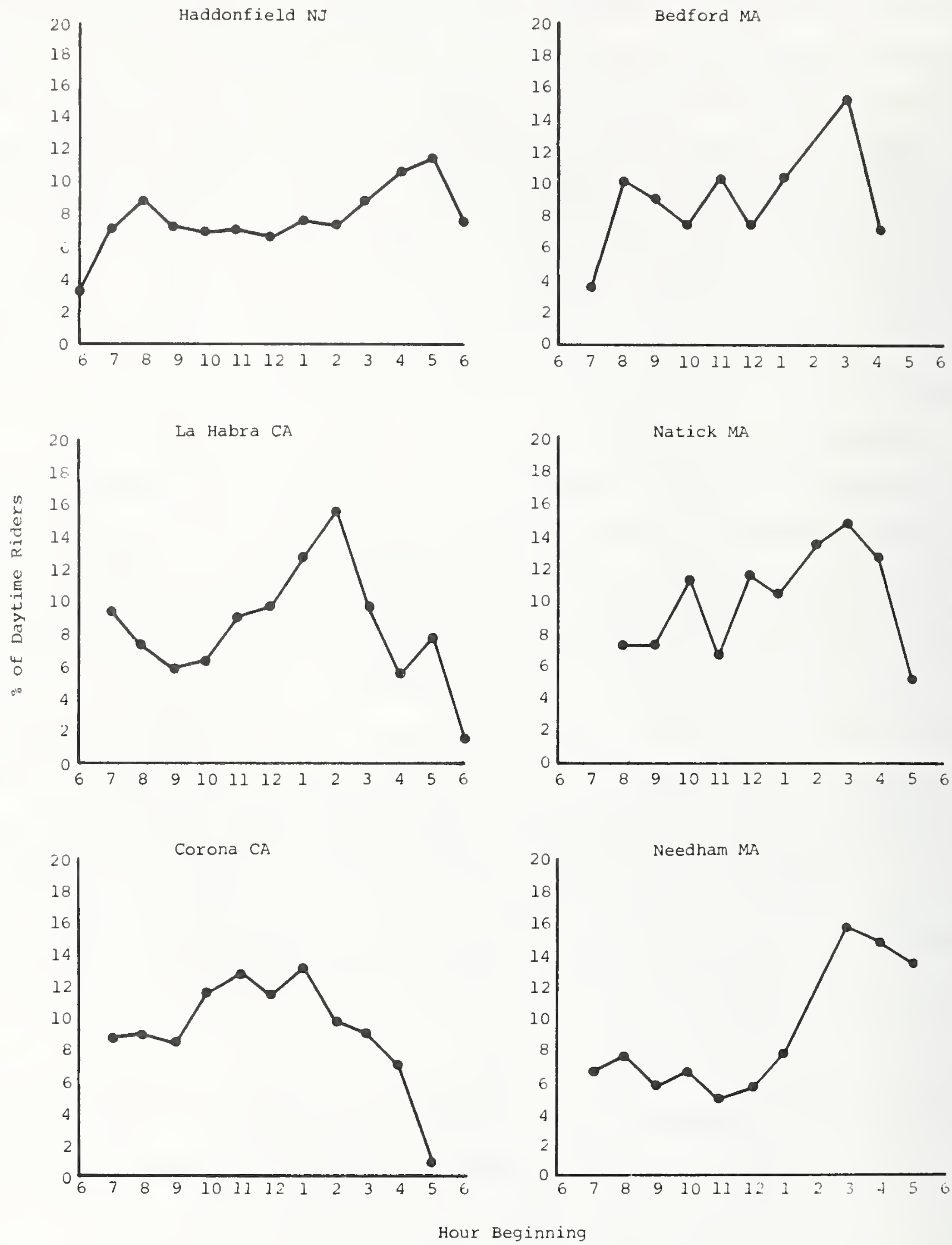
Time of Day - While many demand-responsive systems keep logs of trips served at different times throughout the course of a day, the information is rarely summarized or tabulated. Published data available on ridership by time of day, however, show that ridership can fluctuate significantly during the course of a day. The distribution of trips sometimes is close to that typical of the transit industry as a whole (i.e., two sharp ridership peaks during the morning and evening commuting hours). However, a flatter distribution is more common. There may be peaks during the middle of the day reflecting high usage of the system for shopping or medical trips. Applied Resource Integration Ltd. (13) gives time of day distributions for nine different systems. Five of these, as well as four others, are shown in Figures 4-1 and 4-2. For each of the nine systems, the percent of daytime (6 AM - 7 PM) riders during each hour of the day is shown. Figure 4-1 gives distributions for six suburban systems while Figure 4-2 shows those for three small city systems.

For the suburban systems (see Figure 4-1), only one (Haddonfield, N.J.), shows a ridership distribution resembling that of a traditional transit system (although it is somewhat flatter). Peaks occur between 8-9 AM and 5-6 PM. This appears to be due to the fact that Haddonfield is the only system shown that partially acts as a feeder to line-haul transit (i.e., the PATCO high-speed rail line to Philadelphia). The other systems serve an almost entirely local function and show less traditional peaking behavior. Those systems all show a large peak sometime between 1 PM and 4 PM and often a smaller peak sometime between 10 AM and noon with little to no peaking during normal commuting hours. For the small city systems shown (see Figure 4-2), however, the traditional double peak is somewhat more apparent in two of the three systems, although the PM peak appears earlier than might be expected for most commuters. The two figures show that the pattern of ridership throughout the day can vary significantly from system to system, depending in part on the markets and trip purposes served.

Trip Purpose - The distribution of trips throughout the day appears to be best explained by trip purpose (13). Unfortunately, information on community transit service ridership by trip purpose is scarce and is only available where studies have been conducted which involve rider surveys. Such surveys were taken in five of the nine cities shown in Figures 4-1 and 4-2. Trip purpose information for these and three other systems are shown in Table 4-1.

Figure 4-1:

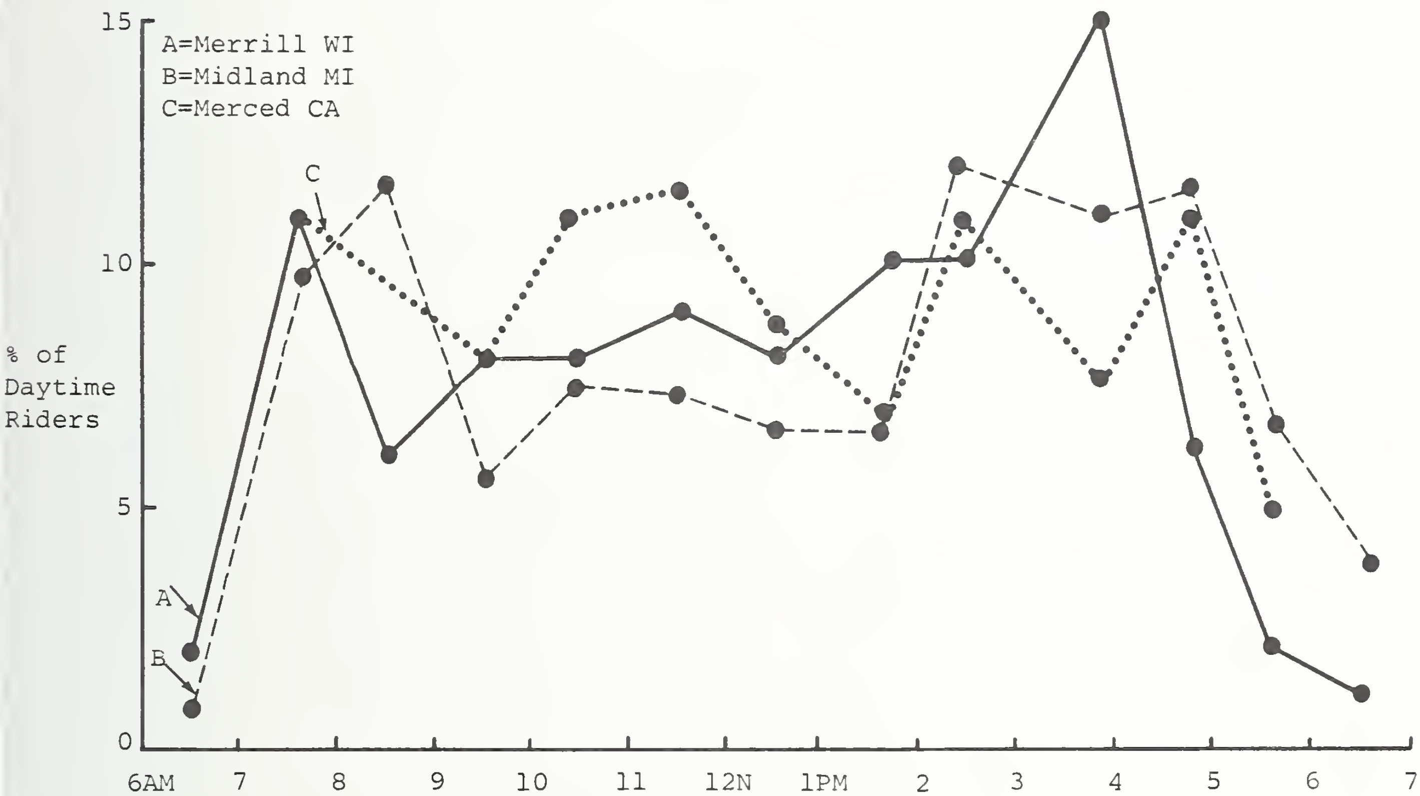
DAILY RIDERSHIP PROFILES ON SUBURBAN SYSTEMS



Sources (13,14,15)

Figure 4-2:

DAILY RIDERSHIP PROFILES ON SMALL CITY SYSTEMS



Sources (13)

Table 4.1:

TRIP PURPOSE (%) OF RIDERS ON SELECTED SYSTEMS

	Bedford MA	Natick MA	Needham MA	Haddonfield NJ**	Merrill WI	Watts-LA CA	Fairfield CA	Batavia NY
Work	16	27	13.0	34-44	15	31.1	18	21.1
Shopping	40	38	13.0	29-39	28	11.1	20	26.3
School	0	16	22.0	2- 6	13	14.4	4	28.9
Recreation	20	1	7.6	4-8 (Recreation and Social)	2	20.0	20	1.3 (Recreation and Social)
Social	7	4	7.6		11	*	*	
Medical	*	4	19.6	14-20 (Medical, Personal and Other)	*	23.3	15	21.8 (Medical, Personal and Other)
Personal	*	4	14.1		39	*	*	
Other	15	4	2.2		13	*	29	
No Answer	*	*	*	*	12	*	*	*

* Not asked on Survey

** Values are from two different surveys

Sources: (13, 14, 16, 17)

A comparison of the trip purpose information and the time of day distributions above does show some correlation. The system with the highest percentage of work trips, Haddonfield, shows the highest hourly ridership during traditional commuting hours. Natick, Bedford and Haddonfield all show a large percentage of shopping trips and a high mid-afternoon ridership, while Needham, which shows a lower percentage of shopping trips, shows a large percentage of school trips which possibly contribute to the significantly higher ridership after 2 PM in that city. As can be seen from the above comparisons, general relationships appear to exist between trip purpose and ridership distribution by time of day, although the available data are far too sparse for any formal relationships to be drawn.

Age - Age breakdowns, or at least statistics that distinguish senior citizens from other riders, are generally more available than trip time or purpose information. Data from 29 local bus systems in Michigan show that an average of 30% of all riders are senior citizens (18). Age distributions for several other systems are shown in Table 4-2.

The age distribution of transit riders depends primarily on two factors: 1) the likelihood of an individual in a specified age group using the service, and 2) the size of the age group relative to the rest of the population. The first factor may be similar for different cities while the second may vary significantly from community to community. ARI (13) has developed a measure called the "propensity ratio" to allow adjustment for this second factor. The propensity ratio is defined, for each group, as the ratio of the percent of riderhip accounted for by that group to the percent of total population accounted for by that group. The measure is shown for several systems in Table 4-3. Unfortunately, it is difficult to compare the ratio between systems for most age groups because of the differing age ranges in the underlying data. The age group "65 and over", however, was available for most systems allowing for direct comparisons between systems for this group, probably the age group of most concern to planners. For the "65 and over" age group the propensity ratio for the system listed ranges from 1.2 to 1.7 with most lying between 1.35 and 1.65. The mean factor is 1.49, or 1.5 for planning purposes. The standard deviation of 0.18 is only about 12% of the mean, indicating that the factor can be used with as much confidence as most techniques despite the small number of systems on which it is based.

Table 4-2:

AGE DISTRIBUTION ON SELECTED SYSTEMS

Age Group
% of Riders

Irondequoit, NY	under 20		20-44		45-64		65 or over
	9.8		41.2		31.4		17.7
Greece, NY	32.3		35.5		19.4		12.9
Batavia, NY	under 24		24-44				
	38.4		19.2		21.9		20.5
Oneonta, NY	45.6		9.8		19.9		23.0
Haddonfield, NJ	33.0			24-64			13.0
				54.0			
Merrill, WI*	under 19	19-29		30-44		45-64	55.9
	1.6	12.6		12.6		17.3	
Bedford, MA	under 15	16-21	22-39		40-59	60-64	11.0
	26.0	22.0	19.0		22.0	0.0	
Needham, MA	12.8	24.5	13.8		13.8	4.3	30.9
Natick, MA	under 6			12-64			30.0
	34.0			64.0			
Merced, CA	under 21			22-49		50	
	34.0			43.0		23.0	

Sources (13, 14)

*Excludes school trips

Table 4-3:

PROPENSITY RATIO* BY AGE GROUP

Merrill, WI**		18***	18-44	45-64	65+
		.34	.82	.96	1.7
Batavia, NY		24	25-44	45-65	65+
		1.57	.71	.70	1.22
Oneonta, NY		1.21	.92	.81	1.36
Irondequoit, NY		.66	1.15	.87	1.35
Greece, NY		1.73	.72	.78	1.65
Richmond, CA		24	25-44	45-60	60+
		2.19	.56	.26	1.54
Haddonfield, NJ	15	15-19	20-24	25-64	65+
	.20	1.55	2.60	1.13	1.63
Merced, CA		21	21-49	50+	
		1.74	.84	.79	

* the ratio is defined as: $\frac{\text{percent of all riders in age group}}{\text{percent of all persons of that age group}}$

** School trips are excluded from sample.

*** Excludes persons under 14 years of age from the population distribution.

Source (13)

Applying Detailed Ridership Information

Estimating Hourly Ridership - Typically, ridership distributions by time of day for community transit services can be expected to be flatter than those for conventional transit. The time of day at which peak ridership occurs will depend on the trip purposes being served. Systems serving a large number of work trips can expect high ridership during normal commuting hours. A large number of shopping or social/recreational trips will most likely cause high ridership between 2:00 and 5:00 PM. Systems serving school children can expect more riders in the early morning and throughout the mid- and late-afternoon hours.

The types of trip purposes served will be determined primarily by the service hours, land uses in the service area, and connections to transit to other areas. For example, a system will only attract work trips if it operates early enough in the morning and late enough in the afternoon to accommodate workers and either a sufficient number of local residents' jobs are located within the service area or are along line-haul routes fed by the system. In general, although ridership profiles by time of day are given above for several systems, the profile for a given system will have to be estimated by a planner taking into account the characteristics of the proposed system and the characteristics of the service area.

Estimating Revenue - Once total ridership has been projected using one of the methods from Chapter 3 or 4 and the fare structure has been determined, revenue can be projected based on estimates of ridership in each of several fare categories. Fare categories may be defined by age (child, adult, senior) and by payment method (cash, ticket, pre-paid pass). While no data could be found on ridership by payment method, age distributions and propensity ratios similar to those in Tables 4-2 and 4-3 above can be used to estimate ridership by senior citizens. The percentage of the population that are senior citizens can be multiplied by the propensity ratio for that age group to yield the percent of riders expected to be senior citizens.

For example, consider a proposed system where it has been estimated that 20,000 riders will be attracted annually. The population of the city is 14% elderly. An average percentage of elderly riders can be estimated by applying the mean propensity factor of 1.5 to the 14%, yielding an estimate of 21%.

With a fare of 50¢ for senior citizens and $1.00 for all others, annual revenue can be estimated as $17,900. The city also is interested in a conservative estimate of revenues to match its conservative estimate (at 80% confidence) of 16,000 annual riders. For this estimate, it applies a factor of .842 (see Section 3.3) to the standard deviation (0.18), and <u>adds</u> the result to the mean propensity to yield a value of 1.65. A propensity factor of 1.65 yields an estimated elderly ridership of 23%, and annual revenues of $14,200 (from 16,000 riders).

The principal difficulty in this method lies in the lack of information on other fare categories (such as children).

When estimating detailed ridership statistics for community transit systems, formal models generally do not exist and data for drawing analogies are scarce. Even where data are available, analogies are difficult to draw because of the need to match detailed characteristics of services and service areas. While some guidelines have been proposed in this section, information from more systems is needed before reliable techniques can be derived for estimating detailed ridership characteristics.

4.2 Feeder Mode-Choice Models

Mode choice models are designed to estimate the probability of a traveler choosing a particular mode given its service level and/or fare characteristics relative to the characteristics of other available modes. In planning applications, they are applied to homogeneous groups of travelers (i.e., travelers with similar travel options, origins, destinations, departure times, service levels and socio-economic characteristics) to estimate the fractional share of each group's trips that will use each available mode. The total number of trips made by each group must be known, or independently estimated, in order to apply these models.

Several researchers have developed mode-choice models; these are primarily logit models of the following form:

$$P_i = \frac{e^{G(x)_i}}{\sum_{j=1}^{n} e^{G(x)_j}} \qquad (4\text{-}1)$$

where: P_i = probability of choosing mode i

$G(x)_i$ = an equation that expresses the cost, impedance or inconvenience of mode i for a particular type of trip and traveler.

The denominator of equation 4-1 is the sum of the impedance expressions for all modes that can be used (by the type of traveler) for the trip. For example, travelers without access to an auto may have to choose between walking and riding a feeder bus, others may also have the option of being driven while still others may have the option of driving. Consequently, to use mode-choice models, the user needs information on traveler characteristics (such as auto availability) as well as on the service quality of optional modes and total travel.

A few models have been developed that deal explicitly with the choice of mode used for trips from homes to a commuter rail station or an express bus stop. Three such models are presented in this section. These models may not transfer well to other cities, and an example is given of how one of the models was adapted for use in another region. This type of mode-choice model is primarily applicable in the following situation:

- o estimating peak period ridership on a new feeder service where total number of persons making access trips is known or has been estimated.

Available Techniques

Two feeder mode-choice models (19, 20) have been developed using Chicago station access survey data. Both consider only the choice between feeder bus and auto. The first, by Tahir and Sajovec (19), is a binary logit model, which takes the following form:

$$P_{bus} = \frac{e^{G(x)}}{1 + e^{G(x)}} \tag{4-2}$$

In this case, G(x) is an expression of difference in impedance between feeder bus and auto, as follows[1]:

---

1 In the original equation, the time variables were in seconds.

$$G(x) = 2.5 - 0.72\ (TIMDIF) - .0317\ (CSTDIF) - .0455\ (DISTOP) - .036\ (BSHDWY) \quad (4\text{-}3)$$

TIMDIF = total origin to station travel time difference between modes (bus minus auto, in minutes)

CSTDIF = bus fare minus auto operating cost including parking (in cents)

DTSTOP = distance from trip origin to nearest feeder bus stop (in hundreds of feet)

BSHDWY = headway between feeder buses (in minutes)

If an average walk speed of 250 feet per minute is used, the coefficients on BSHDWY and DTSTOP are the approximate equivalents of weights of 2.0 and 2.6 on wait and walk time, respectively, assuming the TIMDIF variable includes these components in addition to in-vehicle time.

The second model based on Chicago data was developed by Liou and Talvitie (20). The model uses the logit form shown in equation 4-1; its impedance functions are as follows:

$$G(x)_{bus} = -0.382\ (BIVT) - 0.441\ (BOVT) \quad (4\text{-}4a)$$

BIVT = ride time on a feeder bus (in minutes)

BOVT = walk time plus wait time for a feeder bus (in minutes)

$$G(x)_{auto} = -0.681\ (PRIVT) - 0.556\ (OPCOST) \quad (4\text{-}4b)$$

PRIVT = auto ride time (in minutes)

OPCOST= auto out-of-pocket cost (e.g., operating cost plus parking fee, in cents)

A model developed for Cleveland by Kuman and Gur (21) estimates shares of four modes: walk, bus, kiss-ride and park-ride. Two approaches were taken in developing the model. The first was to specify a conceptual access model, with many coefficients adapted from previous mode-share studies; its "calibration" was largely the adjustment of constants so that shares observed at existing stations were matched. The second was to modify or recalibrate a set of access, egress and line-haul mode choice models with similar variables and coefficients; these had intitially been calibrated using Chicago survey data.

The impedance functions in the model are as follows:

$$G(x)_{walk} = CWK * (60 * WDIST/WSPEED) \quad (4\text{-}5a)$$

WDIST = distance to station (in miles)
WSPEED = walking speed (in mph)

$$G(x)_{bus} = CBUS + CWK * (60 * WDBUS/WSPEED) + CWT * WAITB + CRD * BIVT + CCS * FARE \quad (4\text{-}5b)$$

WDBUS = distance to feeder bus stop (in miles)
WAITB = wait time for feeder bus (in minutes)
BIVT = ride time on bus (in minutes)
FARE = bus fare (in cents)

$$G(x)_{P/R} = CPR + CWK * WTPRK + CCS * (0.5 * PCOST + OCOST) + CRD * PRIVT \quad (4\text{-}5c)$$

WTPRK = walking time from parking lot to station (in minutes)
PCOST = parking cost (in cents)
OCOST = operating cost (in cents)
PRIVT = ride time (in minutes)

$$G(x)_{K/R} = CKR + CCS * (2 * OCOST) + CRD * KRIVT \quad (4\text{-}5d)$$

KRIVT = ride time (in minutes), including the one-way trip for the passenger and one-way trip of the driver

Values of the coefficients (i.e., CWK, CWT, CRD, CCS, CBUS, CPR and CKR) are given in Table 4-4 for both calibration approaches.

The Baltimore Regional Planning Council (22) recently reviewed access choice models and adapted the preliminary version of the Cleveland model for use in planning bus routes and parking lots along a rail corridor. Three adjustments were made to bring model predictions more in line with access mode choices observes in the Baltimore region, as follows:

1. Park-ride vs. kiss-ride -- The definition of KRIVT in equation 4-5d was changed to include a round-trip for the driver and a one-way trip for the passenger. A survey of park-ride lots showed that the percent of auto access trips that were kiss-ride ranged from 20% to 6% for access trips of 1 to 4 miles instead of the 50% to 30% predicted by the model with the above adjustment. As a result, the value of CKR was changed to -3.6.

2. Walk vs. auto -- An on-board survey of express bus riders was used to test the model's prediction of walk access in relation to auto access. The preliminary model predicted

Table 4-4:

COEFFICIENTS OF CLEVELAND ACCESS MODE MODEL

Variable	Preliminary Model Coefficients	Combined Access/Egress Model Coefficients		
		Work Trips to CBD	Other Work Trips	Other Trips to CBD
walk (CWK)	-0.20	-0.058	-0.03	-0.040
wait (CWT)	-0.20	-0.090	-0.06	-0.030
ride (CRD)	-0.08	-0.025	-0.01	-0.012
cost (CCS)	-0.026	-0.012	-0.01	-0.010
mode constants:				
feeder bus (CBUS)	0.0	0.25	0.42	0.00
park-ride (CPR)	-2.42	-0.36	-0.55	-0.22
kiss-ride (CKR)	-2.32	-0.40	-0.25	-0.26

percentage walking as declining from 90% to 30% as access distance increased from zero to one mile, while survey data indicated a decline from 95% to 15%. An adjustment to the modes' constant terms could not accomplish the desired change in slope.

3. Bus vs. auto -- Estimates of bus use produced by the Cleveland model were compared to estimates produced using Baltimore's O/D mode-choice model, which is sensitive to income as well as the service variables present in the Cleveland model. The value of CBUS in the Cleveland model was changed to -1.0 to bring estimated bus use into the range estimated for low income travelers (using the Baltimore model).

Applying the Models in Planning Community Transit

Any of the feeder models presented above needs to be exercised on a trial basis prior to use, and if possible, validated and/or adjusted using local data. The Baltimore adjustments are a good example of a rough adaptation. A validation that examines a model's applicability to different market segments, however, would be preferable.

As part of this process, guidelines should be set for specifying service quality variables so that realistic estimates will be obtained when the model is applied. Examples are setting average walk times for park-ride lots of different sizes, and preparing a graph of auto in-vehicle time (e.g., as function of distance) that incorporates time spent starting a car, backing out of a driveway, driving over residential streets and finding a parking space at the station. The models were calibrated using either travelers perceptions of service quality or estimates prepared by an analyst. In neither case are the assumptions that went into preparing these estimates well documented, so a user of the models has to construct a reasonable set of assumptions to use in applying the models.

As stated earlier, the user needs to segregate travelers into reasonably homogenous market segments and apply the model to each segment. The availability of modes and differences in service quality typically are the primary factors for defining these market segments.

The possibility of using demand-responsive or hybrid modes for feeder services adds additional complexity to model application. Techniques for estimating service quality measures for several modes are presented in

Appendix B, and can be used to estimate various in-vehicle and out-of-vehicle components for use in the mode-choice models presented above. If doorstep service is being considered, out-of-vehicle components such as response time should be weighted to reflect the convenience of waiting at home. A weight as high as .7 or .8 may be justifiable for peak period trips, however, for schedule delay is probably the most important component of the wait time impedance traditionally used in modelling fixed-route ridership. If schedules are coordinated with the line-haul service, a lower value could be used.

If hybrid services are being analyzed, different market segments should be defined for travelers potentially receiving doorstep service and those who would have to walk to signed stops. Appendix B illustrates a graphical technique for dividing a service area on this basis.

Example Application

A transit agency is helping a suburban community plan a feeder service to a new rapid transit station. Mode share and assignment analyses performed as part of the alternatives analysis indicated that the rapid transit station would attract 300 riders from the community during a two-hour morning peak. Census and planning data on the community, combined with rider surveys taken along another line, indicate the following market segments are reasonable for screening service options and examining feasibility:

Market Segment	Feeder Modes Available: Transit	Kiss-ride	Park-ride	Number of trips
A	X	X	X	150
B	X	X		60
C	X			90

The station is beyond walking distance.

The agency has selected the Baltimore modifications of the Cleveland model for use on the analysis, and estimated the following variables for auto access:

WTPRK = 2 min.
PCOST = 100¢
OCOST = 16.5¢ (@ 6¢ per mile)
PRIVT = 7.5 min.
KRIVT = 19.5 min.

To examine a subscription service that will meet every other train, the agency has prepared the following service measures:

WAITB = 10 min. * 0.8 = 8 min.
BIVT = 15.5 min.
FARE = 50¢

The estimate of BIVT was obtained by applying equations in Appendix B and assuming an average vehicle pick-up of 12 passengers.

These measures produce the following impedance functions (and their experimental transformations used in the logit equation):

Mode	G(x)	$e^{G(x)}$
Subscription feeder	-5.14	.0059
Kiss-ride	-6.02	.0024
Park-ride	-5.15	.0058

The resulting mode share and ridership for each market segment were then calculated using equation 4-1:

Market Segment	Mode Share	Ridership
A	.42	63
B	.71	43
C	1.00	90
Total	(.65)	196

This estimate of ridership results in an average vehicle load of 196/12 or 16.3 riders at the station, higher than the initial assumption of 12 passengers. The average ride time equation in Appendix B was applied to estimate a value of BIVT at the higher load, and the mode split applied again to establish compatible estimates of service quality and ridership. The additional 2 minutes of ride time produced only a slight decrease in estimated ridership (to 187).

The estimate of about 190 riders appeared high to agency staff, and was used as an upper bound. To provide a lower bound or conservative estimate of ridership, the mode share estimated for segment A was applied to all riders, yielding an estimate of about 125 riders, or 10 per vehicle.

4.3 DRT Mode-Choice Models

One set of models has been developed to estimate mode choices when demand-responsive transit service is offered (23, 24). The FORCAST package, which is discussed further in the section on equilibrium models, contains work trip and non-work trip models partially calibrated using data collected on the

Rochester dial-a-ride services. The models have been tested and applied, with adjustments, to analyze stand-alone DRT services and systems that combine dial-a-ride and fixed-route transit.

The models are applicable in the following situation:

- o estimating ridership on a circulation service when total travel in the service are is known or has been estimated.

Available Techniques

The mode-choice models developed for work and non-work trip estimation in the FORCAST model are presented below.

The work trip model is a multinomial logit model of the form shown in equation 4-1. It contains impedance functions for the following modes:

- o auto without passengers
- o shared-ride auto
- o fixed-route bus
- o demand-responsive transit
- o shared-ride taxi
- o exclusive-ride taxi

The variables used in this (and the non-work) model are listed in Table 4-5, and coefficients of the modal impedance functions used in the work trip model are listed in Table 4-6. These tables can be used to construct the model impedance functions. As an example, the impedance function for demand-responsive transit is as follows:

$$G(x)_{DRT} = 2.09 + 0.753\ (1/DIST) - 0.051\ (IVTT)$$
$$-0.228\ (OVIT/DIST) - 0.01\ (OPTC)$$
$$+ 0.2\ (AGE1) - 0.8\ (AGE2) \qquad (4\text{-}6)$$

The non-work trip model also is a multinomial logit model, but is expanded to include choice of destination as well as mode. The impedance functions and coefficients are listed in Table 4-7. Its application, discussed briefly in the equilibrium model section and in detail in reference 24, involves the simulation of the daily trips of sampled individuals. Consequently, the non-work model requires distributions of the length of time individuals spent at home prior to making a trip, at other locations, and at home once a trip has been made. Distributions based on Rochester data are presented in reference 24.

Table 4-5:

FORCAST MODEL VARIABLES

Variable	Definition
CONST	A mode-specific constant
AALIC	Autos per licensed driver in household
AA16	Autos per household number over 16 years of age
AGE1	1 if under 16 years old, 0 otherwise
AGE2	1 if over 64 years old, 0 otherwise
SEX	1 if male, 0 if female
IVTT	In-vehicle time (in minutes)
OVTT	Out-of-vehicle time (in minutes)
OPTC	Out-of-pocket cost (in cents)
DIST	Distance of trip (in miles)
HOME	1 if destination is home, 0 otherwise
POP	Total population of destination zone
TOTEMP	Total employment of destination zone
AREA	Area of destination zone (in square miles)

Table 4-6:

FORCAST WORK TRIP MODEL COEFFICIENTS

Variable	Applicable Modes*	Coefficient
CONST	ADA	-3.51
	ASR	0.051
	BUS	-0.5
	DRT, SRT	2.09
	ERT	1.09
AALIC	ADA	6.64
	ASR	4.61
IVTT	ALL	-0.051
OVTT/DIST	ALL	-0.228
1/DIST	BUS, DRT, SRT, ERT	0.753
DIST	ASR	-0.272
OPTC	ALL	-0.01
SEX	ADA	3.35
	ASR	2.41
AGE1	DRT, SRT	0.2
	ERT	-0.2
AGE2	DRT, SRT	-0.8
	ERT	0.8

* Mode Key:

ADA	Auto drive alone
ASR	Auto shared ride
BUS	Fixed-route bus
DRT	Any demand-responsive or hybrid transit
SRT	Shared-ride taxi
ERT	Exclusive-ride taxi
ALL	All modes

Table 4-7:

FORCAST NON-WORK TRIP MODEL COEFFICIENTS

Variable	Applicable Modes*	Coefficient: Home Origin	Coefficient: Other Origin
CONST	ADA	-7.22	-3.04
	ASR	-7.34	-2.99
	BUS	-0.50	-0.50
	ERT	-1.10	-0.50
AA16	ADA	7.45	8.61
	ASR	7.58	8.18
(IVTT/OVTT)	ALL	-0.14	-0.057
ln(OPTC)	ALL	-1.48	-0.93
AGE1	DRT, SRT	0.20	0.20
	ERT	-0.20	-0.20
AGE2	DRT, SRT	-0.80	-0.80
	ERT	0.80	0.80
POP/AREA	ALL	-0.77×10^{-4}	-0.25×10^{-5}
TOTEMP/AREA	ALL	0.24×10^{-4}	0.12×10^{-4}
HOME	ALL	--	2.66
ln(AREA)	ALL	1.00	1.00

* Mode Key:

ADA	Auto drive alone
ASR	Auto shared ride
BUS	Fixed-route bus
DRT	Any demand-responsive or hybrid transit
SRT	Shared-ride taxi
ERT	Exclusive ride taxi
ALL	All modes

Adapting Models for Community Transit Planning

The basic models, which were calibrated in an area where the choices were among dial-a-ride and various auto modes, have been expanded in another study (24) to apply to a range of community transit modes and taxi services.

The main issue in their application is market segmentation. In addition to service levels and auto availability, the models (constructed using Tables 4-2 through 4-4) require segments based on the sex and age of travelers. If a zoned service or other complex service designs are contemplated, a large number of market segments may be necessary. As a result, the computerized version discussed in the next section probably should be applied in these cases.

4.4 Equilibrium Models

Demand-responsive transit services differ from fixed route service in many ways. One distinction that has important consequences for planners is that service and patronage levels are far more interdependent. On a fixed route, fixed schedule service, the impact of patronage is small and is limited to minor increases in dwell time at vehicle stops, standing room only for some patrons, and similar impacts. On a demand-responsive or other flexible service, on the other hand, a vehicle's route and travel time may be highly dependent upon the number of passengers. In extreme cases, this can lead to situations such as Santa Clara County, California, where the time required to pick-up and drop-off riders so exceeded expectations that the resulting deterioration of service quality contributed to the collapse of the program.

The advantage of an equilibrium model is that, unlike other models, it explicitly recognizes and responds to the high degreee of interdependency between service quality and ridership. The principal disadvantage is the amount of data and time required for application. As a result, equilibrium models are primarily applicable in the following situation:

- estimating ridership on a new service where a major initial investment is proposed or where simple procedures appear inadequate.

FORCAST Model

The FORCAST model is the principal equilibrium model available for use in planning community transportation service. It can be used to plan area-wide community service, zonal systems, and community services that integrate with regular transit route. It is designed for application in service areas of 10 to 20 square miles, i.e., areas where there will be significant internal travel.

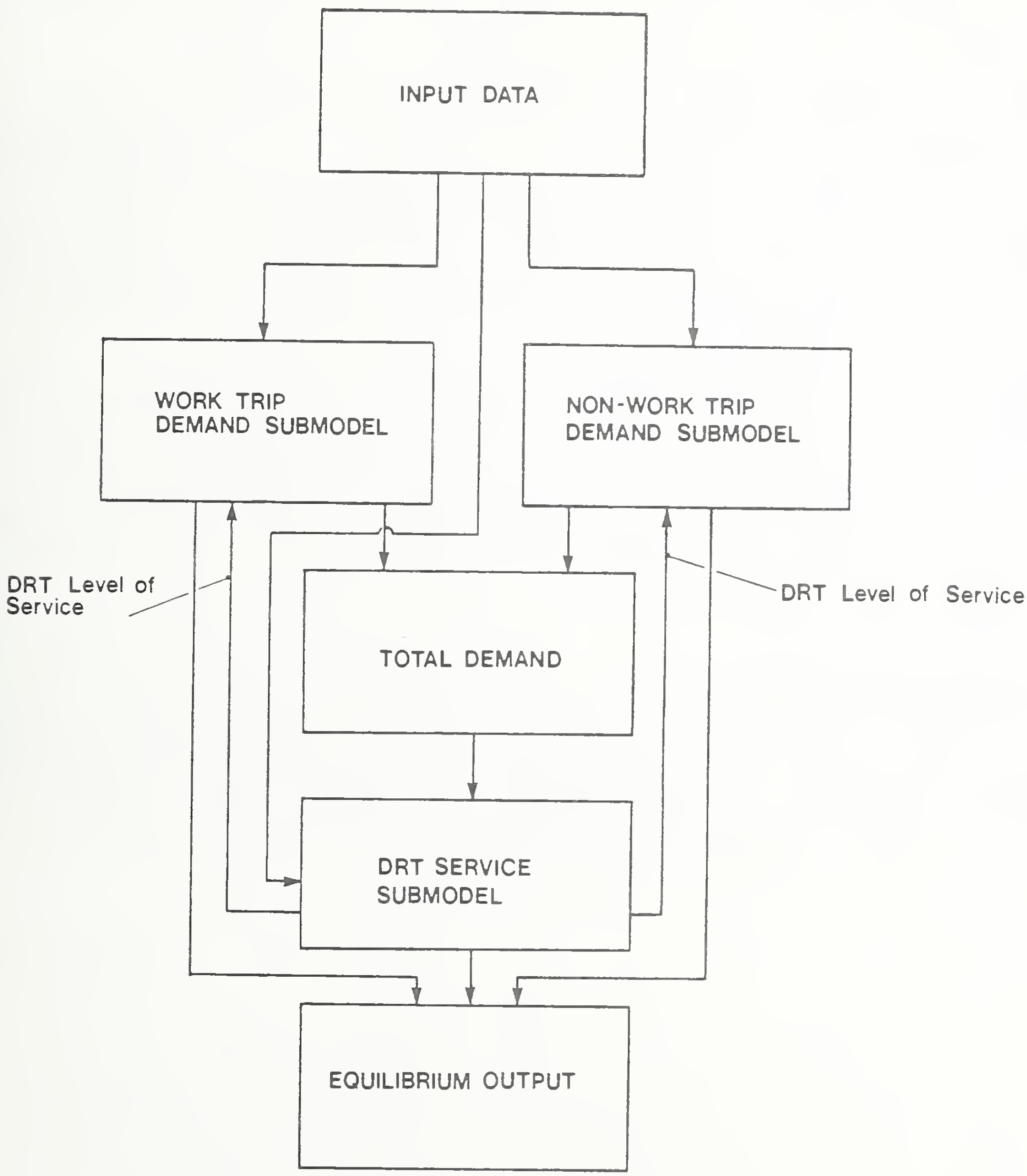
The overall structure of the model, and its data requirements, are presented below to give potential users a better understanding of its capabilities and requirements. Major components of the model are presented elsewhere in this Handbook. Specifically, its mode choice components are discussed in the previous section and service quality models similar to those used in the FORCAST model are presented in Appendix B. Before applying the model, however, the user should obtain reference 24 which contains a detailed model description, calibration and test results, and sample applications. Reference 25 also may be useful; it contains additional examples that include community modes other than dial-a-ride, which is the only mode the initial model (presented in Reference 24) considered.

FORCAST attempts to find an equilibrium between community transit service quality and ridership in each of the operating periods (e.g., midday or PM peak) specified by the analyst. The structure of the non-work model, however, requires that an entire day be analyzed in applying the model if non-work trips are carried by the service. The equilibration framework of the package is shown in Figure 4-3. In each operating period, the two mode-choice models and appropriate service quality models are applied in sequence until convergence criteria set by the user are met.

In each iteration, the work trip mode-choice model presented in Table 4-6 is applied to each origin-destination zone pair in the service area. The model typically is applied with between 10 and 20 zones, each 1 to 2 square miles in area. For each zone pair, separate mode choice estimates are made for each "socio-economic category." The categories are based on three dimensions: auto ownership (0, 1, 2, 3, 4+), household size (1, 2, 3, 4, 5+) and age (16-64, 65+). Single variable distributions supplied in the data are used in an internal procedure to estimate the fraction of workers in each

Figure 4-3:

FORCAST MODEL STRUCTURE



category. Some of the fractions (e.g., 1 person households with 4+ autos) are zero. The value of the variable SEX is set within the program to .4 for the ADA mode and to .36 for the ASR mode.

The non-work trip mode-choice model (see Table 4-7) also is applied in each iteration, but to a random sample of individuals drawn from the service area. The package keeps track of these individuals over the course of the day, and distributions of time between trips are used to determine which individuals travel during the current period.

Services quality models, similar to those presented in Appendix B, are then applied to the service areas as a whole, and average in-vehicle and out-of-vehicle travel times (per mile) on community transit services are estimated for use in the next iteration. The analysis of a period ends either at the end of a set number of iterations or when the percentage change in patronage is below a set value.

The data used by the FORCAST, including the zone structure and period definitions, are listed in Table 4-8. In many analyses, default values contained in the model (e.g., distributions of time between trips) can be used. The major data preparation effort typically will be setting up matrices of zone-to-zone travel times for autos and other modes.

Example Application

FORCAST has been validated using data from two paratransit services near Minneapolis/St. Paul, and applied to analyze community transit services proposed in that area. These efforts are described in Reference 25.

Table 4-8:

FORCAST DATA REQUIREMENTS

a. Zonal data (can vary by operating period):

- coordinates
- area
- population
- employment
- community transit availability

b. Area-wide data:

- hourly distribution of work trips
- number of non-workers over age of 16
- household size distribution
- auto ownership distribution
- percent of population over 64 years of age
- percentage of elderly making work trips
- percentage of population making home-based non-work trips
- on an average day (by age and auto ownership categories)
- average community transit group size (by trip type)
- lengths of stay distributions for non-work model (by age and auto ownership categories)
- airline to street distance conversion factor

c. Operating period data:

- beginning and ending time
- number of community transit vehicles available for service
- average capacity of community transit vehicles
- shared-ride auto occupancy
- initial estimate of community transit ridership
- iteration and convergence controls
- auto operating costs (in cents per mile)
- additional time and cost associated with shared-ride auto passengers

d. Matrix (zone-to-zone) data:

- daily work trips
- in-vehicle travel time (by period and mode: auto, bus, bus with community transit feeder)
- out-of-vehicle travel time (by period and mode: bus, bus with community transit feeder)
- fare (by period and mode: bus, taxi, community transit, bus with community transit feeder)[1]

[1] Taxi fares can also be specified as a fixed fare plus a fare per mile; bus fares can also be specified as a fixed fare.

CHAPTER 5: CASE STUDIES

The ridership estimation techniques in Chapters 3 and 4 are applicable in a wide variety of planning situations. Three examples of their use are presented in this chapter. The examples are set in Norfolk, Virginia; Merrill, Wisconsin; and Baltimore, Maryland. The Norfolk example illustrates planning procedures for the replacement of fixed route service with demand-responsive community transit in a suburban setting and the estimation of ridership changes due to fare changes. The use of direct estimation techniques and elasticities are demonstrated in the case study. The Baltimore example illustrates the planning of feeder services to a new rail station and demonstrates the use of mode choice models. The Merrill example illustrates, using analogies, the planning for an essentially new community transit system in a small city.

Although all three examples represent real situations, the analyses presented were done especially for this handbook using the techniques already presented and do not represent the analyses actually performed in planning the service. In the first two examples a demand-responsive system was implemented and the actual ridership achieved by the new system is presented and compared to the ridership predicted by the estimation techniques.

5.1 Replacing Fixed Route with Demand Responsive Services: Norfolk Maxi-Ride

Background

The Tidewater Transportation District Commission (TTDC) is a government agency which plans, operates, and regulates public transportation services in the Norfolk, Virginia metropolitan area. The district covers 1,092 square miles and has a population of about 800,000. The Commission operates approximately 175 buses on fixed routes, primarily in the more urbanized cities of Norfolk and Portsmouth, but some service is provided in the less urban areas as well. References 26 and 27 document TTDC's experiences.

The idea of shared-ride taxi service in the Norfolk area goes back to 1977. It was originally proposed that some form of demand-responsive transit be implemented in several suburban areas that did not have public transportation services. An initial survey of potential users at suburban activity centers, however, showed little demand potential. Later, in 1979, a shared-ride taxi service was implemented between a suburban area and a shopping mall. Results were disappointing and the service was terminated after seven weeks.

The next attempt at a shared-ride taxi service was in the Deep Creek section of the City of Chesapeake. TTDC had acquired the private bus system operating in the area in 1975. Ridership on the Deep Creek portion of the routes was low and deficit per passenger was increasing. After several service cutbacks the service was terminated in early 1979. Later that year service was reinstated but ridership was lower than ever. In September, 1979 the Deep Creek portion of the bus service was replaced with a demand-responsive shared-ride taxi service with a fare of $1.00 (twice the regular bus fare). The change resulted in substantial cost savings while serving approximately 470 trips per week.

By 1980, TTDC felt that the concept of shared-ride taxi service, which they had dubbed Maxi-Taxi (later changed to Maxi-Ride), was ready for further application. Nine areas were selected. The two areas that will be dealt with in this example are the Ocean View section of Norfolk and the Bower's Hill section of Portsmouth and Chesapeake. In both these areas fixed route services were to be replaced with Maxi-Ride's. The characteristics of these two areas, as well as those of Deep Creek, are shown in Table 5-1.

Initial Planning and Design

The initial problem was to estimate Maxi-Ride ridership in these two areas given the ridership on the existing fixed-route service. The ideal technique for determining ridership on replacement services would be to use elasticities to estimate the change in ridership based on the change in

Table 5-1

CHARACTERISTICS OF MAXI-RIDE SERVICE AREAS

	Population	Area (Sq. Miles)	Population Density (Pop./Sq. Mile)	Monthly Fixed Route Ridership (Aug. 1980)
Deep Creek	19,222	19.06	1001	NA
Bower's Hill	16,427	21.45	766	1586
Ocean View	47,031	7.88	5968	1680

Source (27)

service characteristics when the new system is implemented. The change in fare, and estimated changes in average walk time, average wait time, and average ride time could be inserted into equations 3-2a and 3-3 along with the appropriate elasticities from Table 3-3 and the existing ridership on the fixed-route service. The result would be an estimate of ridership on the new service.

Unfortunately, in both Bower's Hill and Ocean View, no data was available on average walk or ride times on the existing service. An additional complication was that some markets to be served by the proposed service had direct service on existing fixed-routes, while others required transfers and still others were not served at all. For these reasons, the elasticities method of estimating ridership could not be used even for initial feasibility study purposes.

With data on existing services lacking, a planner must treat the proposed services as if they were new services. One method of estimating ridership on new services is through the use of direct estimation models such as those presented in Section 3.2. The models for the suburban circulation systems (page 43) would be most appropriate in the Bower's Hill and Ocean View situations, since these two neighborhoods are part of the greater Norfolk area.

Before applying any direct estimation model, however, a planner should check the ranges of the calibration data to determine whether the equation can be applied to the area in question. The population and density of Ocean View clearly falls within the range specified in Section 3.2 while the density of Bower's Hill, at only 766 people per square mile, is below even the least dense system on which the model was calibrated. Therefore, in the case of Bower's Hill, it may be best to use a different method of ridership estimation.

The equation for estimating weekly ridership per square mile (on page 43) can, however, be applied to the Ocean View situation. The population density and area are obtained from Table 5-1. Since TTDC planned service from 6 a.m. to 7 p.m. six days per week using one vehicle, weekly service hours of 78 and a fleet size of one can be used. These values, when inserted in the model, yield an estimated ridership of 368 riders per week for the Ocean View service. Assuming 4 1/2 weeks per month, this yields an estimated monthly ridership of about 1660.

As noted above, the model cannot be applied for estimating ridership on the Bower's Hill service due to the difference between the Bower's Hill area and the areas on which the model was calibrated. In the absence of an appropriate model, the best technique for estimating ridership would be through the use of analogies. The obvious, closest analogy to Bower's Hill is nearby Deep Creek whose population and density are quite similar to that of Bower's Hill. In January, 1981 the Deep Creek service had a monthly ridership of 1670, or 87 trips per month per 1000 population. This trip rate applied to the Bower's Hill population yields a monthly ridership of about 1430. Since the fares and service levels of the two systems were anticipated to be about the same there is no need to apply elasticities to the estimates to adjust for differing service levels. It should be noted, however, that the lower density of Bower's Hill might result in slightly longer average trip distances and therefore average ride times resulting in slightly lower ridership figures. Therefore, the figure of 1430 riders per week could be regarded as somewhat high.

The Bower's Hill and Ocean View services were implemented in November, 1980 and the ridership achieved for the first 6 months of service is shown in Table 5-2. The ridership for Bower's Hill did not achieve the estimated ridership despite the achievement of those levels in nearby Deep Creek. Ridership in Ocean View started below expected levels but, over the first several months of service, approached the level predicted by the model.

Planning For a Fare Increase

After the services had been in effect for seven months, TTDC decided to enact a system-wide fare increase on July 5, 1981. The fare on the Deep Creek and Bower's Hill Maxi-Rides was to be increased from $1.00 to $1.50. The fare on the Ocean View Maxi-Ride was to double from 50¢ to $1.00.

In order to estimate changes in ridership due to fare changes, elasticities can be used. An elasticity for fare changes on demand-responsive paratransit services can be obtained from Table 3-2. Using this elasticity of -0.43 and the June 1981 ridership shown in Table 5-3, equation 3-2 can be applied to estimate ridership after the changes. The results are shown in Table 5-3. To obtain a range for the estimated ridership, the standard deviation (0.24) given in Table 3-2 can be used. At a confidence level of 90%

Table 5-2

JANUARY - JUNE 1981 MAXI-RIDE RIDERSHIP

	Bower's Hill	Ocean View
Estimated Monthly Ridership	1430[1]	1660[2]
Actual Monthly Ridership		
January	650	1242
February	821	1085
March	691	1223
April	732	1461
May	665	1460
June	738	1617

[1] Using Deep Creek analogy

[2] Using direct estimation model

Source (26)

Table 5-3

MAXI-RIDE RIDERSHIP BEFORE AND AFTER FARE INCREASE

	Deep Creek	Bower's Hill	Ocean View
Fare Increase	$1.00- $1.50	$1.00- $1.50	$0.50- $1.00
Actual Ridership, June 1981	1689	738	1617
Estimated Ridership After Fare Increase	1419	620	1200
Estimated Range After Fare Increase	1250-1610	550-700	970-1490
Actual Ridership[1]			
July 1981	1364	717	1323
August 1981	1331	515	1361

1. Source (26)

this results in an elasticity range of -0.12 to -0.74 (using equation 3-4). The range of estimated ridership using these values is shown in Table 5-3. Also shown in Table 5-3 is the actual ridership that was experienced in July and August after the fare increase. (Further service changes in September and October prevented direct comparisons of actual and estimated ridership after August 1981.) The Deep Creek and Ocean View ridership fell well within the estimated range while ridership in Bower's Hill was above the estimated range in July and below in August but averaging very close to the middle value of the estimate.

In this situation the use of elasticities to estimate ridership changes due to fare increases created reasonably accurate estimates of ridership after the change. The direct estimation model also worked very well when applied in an area, such as Ocean View, whose characteristics fell within the range of the calibration data. The analogy approach, however, did not fare as well, even when an adjacent area of similar size and density was used. This illustrates the difficulty in assuming similarity between two areas. It is clear that some other factors, not considered when drawing the analogy, had significant effects on ridership in Deep Creek and Bower's Hill.

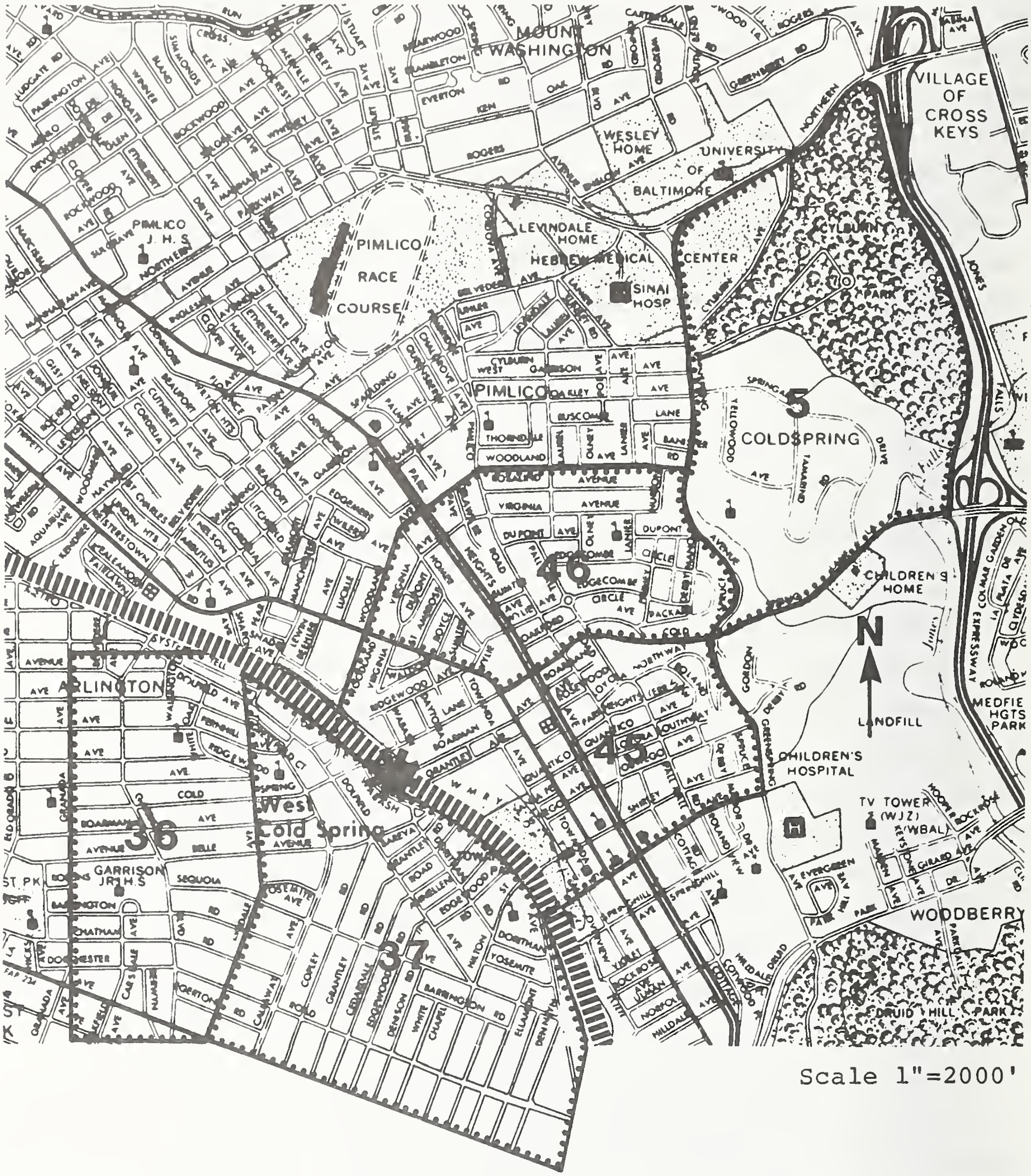
5.2 New Feeder Bus Service: Baltimore Metro

The planning of community feeder bus services can be illustrated using data from the feeder bus study done for the new Baltimore Metro rail rapid transit system (28, 29). Several new metro stations are located in the residential areas of northwest Baltimore. In 1977, the Maryland Mass Transit Administration (MMTA) began a study of feeder bus alternatives for four of these stations. This case study will focus on the West Cold Spring Lane Station which is located about 4 miles from downtown Baltimore. The area is residential and contains many narrow streets not suitable for full-size transit vehicles. Prior to the opening of the Metro station the area was served by several fixed route buses operating only on major streets.

A recent regional transportation study included an estimation of transit trips and their assignment to the rail line and bus routes. The assignment produced estimates of boardings at each rail station. The study assumed that five regional transportation zones (see Figure 5-1) would form the drawing area of the West Cold Spring Lane Station. Table 5-4 shows the 3-hour AM peak

Figure 5-1

WEST COLD SPRING LANE STATION AND SURROUNDING AREAS



Zone Boundaries

36 Zone Numbers

Baltimore Metro

West Cold Spring Lane Station

Table 5-4:

TRIP ORIGINS FOR WEST COLD SPRING LANE STATION (AM PEAK)

Zone	Rail Trips	% Using WCSL Station	Trips Using WCSL Station	Average Distance to WCSL Station (in feet)
5	220	45	99	8200
36	236	50	118	3400
37	673	80	538	3200
45	720	100	720	2600
46	480	100	480	4200

Source (22)

Table 5-5:

PARAMETERS FOR ESTIMATION OF FEEDER MODE SHARE

Average walking speed	3 mph
Average auto speed	20 mph
Average bus speed	11 mph
Auto operating costs	5¢/mile
Parking Cost	50¢
Parking Terminal Time	2 minutes
Bus Fare for Feeder Trips	5¢

Source (22)

period rail trips from each zone, the percent of those trips using West Cold Spring Lane Station, and the average walking (or driving) distance from each zone to the station. Given this information, the MMTA needed to estimate ridership on several alternative feeder services. A mode choice model developed in Cleveland was specifically modified for this purpose (see Section 4.2). The services actually examined in the study were all fixed route services. However, community opposition eventually prevented fixed-route transit on residential streets. The techniques for planning demand-responsive community transit services that are presented here might have been used had this been known earlier in Baltimore's planning process.

Initial Feasibility

To test the initial feasibility of community feeder services, the modified Cleveland mode choice model (equations 4-5 and Table 4-4) can be applied using rough estimates for the various parameters. The resulting approximate modal shares and usage can be combined with estimates of costs and compared to whatever feasibility criteria has been established, whether it is deficit per feeder bus passenger, parking lot capacity, or any other criteria.

In this case, let us assume that there is land available on-site for 600 long-term parking spaces. Any further increase in parking capacity will require construction of a garage. Rough cost estimates have determined that a community transit system in the five zones feeding the station would be preferable to construction of a garage if the system could be operated with no more than 8 vehicles. Also, possible community objections to the garage structure and the additional traffic on adjacent streets may make construction of a garage infeasible. Therefore, the planners must determine whether long-term parking demand can be kept under 600 spaces through implementation of the community feeder bus service.

The modified Cleveland model was used to make an initial assessment of the feasibility of community feeder bus service under the following assumptions:

- Doorstep demand-responsive feeder service implies a walk distance to the bus of zero

- For each zone, an average bus travel distance to the station of 50% greater than the driving distance due to the more roundabout routing of a demand-responsive system.

- An average bus speed of 11 mph.

- an average wait time of 10 minutes for the feeder service.

The rail ridership and walk/drive distances for each zone from Table 5-4 were used along with other parameters from the actual feeder bus study shown in Table 5-5. Because income in the zones was high, the planners assumed that all riders would have access to autos. (Given the purpose of the analysis this assumption would also produce a conservative estimate of ridership.) The resulting mode shares are shown in Table 5-6.

Screening of Options

These results show that a typical demand-responsive feeder service is capable of keeping parking demand down to the required level. The analysis, however, is only an initial feasibility study with some broad assumptions about bus system configuration, travel time, and wait times. A more detailed analysis of specific options is necessary for selection and implementation of an option. For each proposed option, planners may need to explore feasible service configurations (e.g., routing and stop checkpoint locations) and determine their effects on walk access time, headways (and/or wait time), and average bus travel distances. This refined information can be entered into the model so that more precise mode shares are estimated for each option. The decision on the final service configuration can then be made, taking into account both projected ridership and costs.

The service area was divided into four sectors for purposes of designing alternative service configurations for the analysis. The four sectors are as follows:

A - Zones 5 and 46

B - Zone 45

C - Approximately 3/4 of Zone 37

D - Zone 36 and the remainder of Zone 37

The division between sectors C and D was created to allow a more even distribution of trips between sectors.

Three distinct options have been generated for this situation. They represent three different service configurations. The three options are as follows:

Table 5-6:

INITIAL MODE SPLITS FOR GENERAL DEMAND-RESPONSIVE FEEDER SERVICE

	5	36	37	45	46	Total
Percent Splits						
	Zone					
Walk	1.8	29.2	32.0	40.8	19.8	30.6
Bus	39.5	30.0	28.9	25.2	33.8	29.3
Park-and Ride	43.8	25.6	24.4	20.6	30.1	25.5
Kiss-and-Ride	14.9	15.2	14.8	13.4	16.3	14.7
Trips						
Walk	2	35	172	294	95	597
Bus	39	35	155	181	162	573
Park-and-Ride	43	30	131	148	145	498
Kiss-and-Ride	15	18	80	97	78	287
All Trips	99	118	538	720	480	1955

1. A fixed route community transit service with one fairly circuitous route operating to each sector with the following characteristics for each route:

   A - length 1.4 miles; 11 stops
   B - length .7 miles; 7 stops
   C - length .7 miles; 8 stops
   D - length 1.0 miles; 10 stops

   Each route would require one community transit vehicle operating on a twenty minute headway.

2. A demand-responsive checkpoint service with a grid of checkpoints in each sector as follows:

   A - A 4 by 2 grid in zone 46 and 4 points in Zone 5.
   B - A 4 by 2 grid.
   C - A 5 by 2 grid.
   D - A 3 by 3 grid.

   Each sector would require two vehicles in order to maintain twenty minute headways.

3. A fully demand-responsive service providing doorstep service to all users. Two vehicles would be required in each sector to provide twenty minute headways.

Average walk distance to bus stops (or checkpoints) for all users and bus in-vehicle times were calculated for each option using the techniques described in Appendix B. They are shown in Table 5-7. Average wait times are estimated at half the assumed headway.

The same mode choice model as was used for the initial feasibility estimate can be applied to each option using the distances and time values from Table 5-7. Application of the model to various options and scenarios can be accomplished easily through the use of a simple spreadsheet program on a microcomputer. This approach was used in the development of this case study; the results are shown in Table 5-8. The doorstep option attracted the highest bus ridership and thus the lowest parking demand. Despite the lowest ride times, the fixed-route option attracted the fewest riders due to the high bus access distances. All three options achieved the necessary limitation on parking and thus can be retained for final evaluation. The final decision on service configuration typically will depend not only on estimated ridership but also on costs, community acceptance and other factors.

In late 1983 the new rail rapid transit line to downtown Baltimore was opened. A fixed-route feeder system was implemented in June, 1984 with buses

Table 5-7:

AVERAGE WALK AND RIDE TIMES FOR FEEDER SERVICE OPTIONS

	Zone				
	5	36	37	45	46
Fixed Route					
Avg. Walking Distance (ft.)	800	800	800	1000	1000
Avg. Ride Time (min.)	8.3	3.8	3.5	3.7	3.8
Avg. Wait Time (min.)	10	10	10	10	10
Checkpoint					
Avg. Walking Distance	800	650	650	600	600
Avg. Ride Time	11.0	5.4	5.7	5.1	5.2
Avg. Wait Time	10	10	10	10	10
Doorstep					
Avg. Walking Distance	0	0	0	0	0
Avg. Ride Time	19.7	7.0	8.0	9.2	8.9
Avg. Wait Time	10	10	10	10	10

Table 5-8:

ESTIMATED MODE SHARES FOR FEEDER SERVICE OPTIONS

	Zone						
	5	36	37	45	46	Total	% of Total Riders
Fixed Route Option							
Walk	2	39	194	338	111	683	35.0
Bus	33	25	107	100	110	375	19.2
Park-and-Ride	47	34	148	171	168	569	29.1
Kiss-and-Ride	16	20	90	111	91	328	16.8
All Trips	99	118	538	720	480	1955	100.0
Checkpoint Option							
Walk	2	39	196	328	106	671	34.3
Bus	29	24	102	118	127	400	20.5
Park-and-Ride	51	34	149	166	160	561	28.7
Kiss-and-Ride	17	20	91	108	87	323	16.5
All Trips	99	118	538	720	480	1955	100.0
Doorstep Option							
Walk	2	36	183	321	101	644	32.9
Bus	27	32	130	131	142	462	23.7
Park-and-Ride	52	31	140	162	154	539	27.6
Kiss-and-Ride	18	19	85	106	83	310	15.9
All Trips	99	118	538	720	480	1955	100.0

operating only on non-residential streets. Initial reports have indicated that the model performed very well in predicting ridership on these services.

5.3 New Community Circulator Service: Merrill, Wisconsin Merrill-Go-Round

The city of Merrill, Wisconsin (population 9600; area 5.5 sq. mi.) has had a long history of public transportation. One of the earliest electric street railways in the country was converted to a fixed-route bus system in the 1920's. After years of losses the system was taken over by the city in 1955. Ridership declined rapidly from over 70,000 riders annually in the 1950's to only 29,000 in 1970 at which time high deficits forced discontinuation of the service (30). In 1971 the city authorized a private taxi company to provide subsidized shared-ride taxi and school bus service. Ridership on the taxi service was initially about 22,000 annually. Despite the subsidy, operating losses forced a fare increase. A state subsidized free "dial-a-bus" service for the elderly and handicapped was operated in 1973 and 1974 but was stopped when funding was discontinued. Meanwhile, the taxi company continued to operate the taxi service at a loss and agreed to continue only until the city could replace the service. In 1973 the city applied for state transit operating assistance but was told that only the school bus portion of the transit system was eligible. However, the city would be eligible for demonstration funding if the school bus, taxi, and elderly "dial-a-bus" service were integrated into a single system. The service would serve as a demonstration project whose results could be applied throughout the state.

The city was faced with the problem of designing a community transit service that would integrate the existing school, taxi, and elderly transportation services. The service needed to provide reasonable service levels to all residents and be accessible to the elderly population of the city. It was decided that the service should operate twelve hours per day, six days per week.

To obtain an initial rough estimate of potential ridership on the system two techniques from Chapter 3 (the direct estimation model for small city services on page 42 or analogies from the tables in Appendix A) potentially could be used. Because Merrill's population of 9600 is slightly below the lower limit for the systems on which the direct estimation model was calibrated, it would be preferable to use analogies if a good analogy can be found.

Table A-1 in Appendix A lists small city community transit systems. From this list it can be seen that the city of Cadillac, Michigan bears a close resemblance to Merrill in both population and density. Other systems with similar densities and also with relatively low populations include Delano and Turlock, California, and Grand Haven, Michigan. Data for these cities and their community transit systems are repeated in Table 5-9 along with socio-economic data for Merrill. (Socio-economic data are all from the 1980 census to insure comparability.)

The system in Turlock has more limited service hours than the other three services and than the twelve hours per day, six days per week service planned for Merrill. This probably accounts, at least partially, for the much lower trip rate in Turlock. The systems in the other three cities are more closely analogous to the system envisioned for Merrill. If the trip rates for these three cities are applied to Merrill's population of 9600, a range of estimated ridership of 190-260 per weekday results. Of the three cities and their systems, Cadillac bears the closest resemblance to Merrill in population, density, percent elderly, and hours of service as well as being from the same part of the country. Cadillac's trip rate was also the highest of the three indicating that the ridership on the Merrill system may be toward the higher end of the range, but the entire range should be retained to remain conservative.

Another factor which must be considered in Merrill is that it is known that the system will be providing school service for approximately 80 trips per day, a significant number compared to a total estimated daily ridership of 190-260. Since it is not known what percent of trips in Cadillac, Grand Haven, or Delano are school trips it is not possible to modify the estimates to account for a known number of school trips. However, it can be assumed that the significant number of school trips will again push ridership toward the upper end of the range.

In 1975, after several months of study, a doorstep deviation service was implemented providing service at 30 minute headways at nine checkpoints as well as door-to-door service when requested. A premium fare was charged for

Table 5-9:

RIDERSHIP AND SOCIO-ECONOMIC DATA FOR SELECTED SYSTEMS

	Delano, CA	Turlock, CA	Cadillac, MI	Grand Haven, MI	Merrill[1]
Hours of service	11 M-F 9 Sat	10 M-F --	12 M-F 10 Sat	12 M-F 7 Sat	-- --
Annual Ridership	96,500	64,500	83,200	114,000	--
Avg. Weekday Ridership	310 (est)	250	290	420	--
Weekday Ridership per thousand population	20 (est)	13.8	27.6	23.2	--
Population	15,300	18,000	10,490	18,000	9,600
Density	1,960	1,800	1,720	1,840	1,740
% Elderly	10.9	12.7	15.5	14.9	18.9
% without autos	9.9	9.3	14.8	8.5	13.0
Median Income (1979)	$13,400	$14,700	$12,600	$16,100	13,300

1 Source 1980 Census of Population and Housing

doorstep service. In 1976, the first full year of service, annual ridership was 79,537 (1526 per week), or approximately 265 per weekday, slightly higher than estimates. The trip rate of 27.9 weekday rides per thousand population was extremely close to that of Cadillac, Michigan, the city in Appendix A which most closely resembled Merrill.

This example shows that a comparison to a city and a system which very closely resemble the city being studied and its proposed system can yield a very good estimate of ridership. Even estimates based on ridership in other similar cities can yield reasonable estimates. These estimates may be more accurate than those of other simple modeling procedures particularly when the city being studied is somewhat atypical of the cities on which the model was calibrated. Thus, a close analogy may be better than a model used near or beyond the limits of its applicability.

APPENDIX A: DATA ON COMMUNITY TRANSIT OPERATIONS

In developing this Handbook, data on about 100 community transit services have been compiled from published sources and telephone conversations with operators and with state and regional agencies. These data are tabulated below. Table A-1 contains socio-economic data for communities where services are (or have been) operated, while ridership and operational data presented in Table A-2. Table A-3 lists the principal sources used in compiling the ridership and operational data.

Tables A-1 and A-2 are divided into three sections based on the following settings for community transit:

- free-standing small cities
- circulator services in suburbs or neighborhoods of larger cities
- feeder services in larger urban areas

To use this appendix, locate cities of similar size and/or density to the community being studied, selecting the portion of the table that best matches the community (e.g., suburb). The table also can be used to identify communities with similar age, vehicle availability and income characteristics. After similar systems have been located, use Table A-2 to locate ridership and operational data for these systems.

<u>Table A-1: Socio-economic Data</u>

Systems in this table are listed in order from highest to lowest population within each category (suburban circulator, suburban feeder, small city).

Population and Service Area data were collected from the sources identified in Table A-2 (and listed in Table A-3). This information is for the Data Year, which is listed in both tables. The service areas are in square miles. The population and area figures quoted here are in most cases from the listed sources and are not guaranteed to reflect actual operating conditions in all locations. Comparisons with 1980 Census figures indicated that population and service area data often included outlying areas which, while technically lying within the service area, received little or no service. In cases where the discrepancy appeared large, individual operators were contacted to revise the figures to match the actual situation as closely as possible. It should be noted, however, that the selection of service area boundaries for reporting purposes can have significant effects on population density which is used in the direct estimation procedures presented in Section 3.2 (and on the ridership density values listed in Table A-2).

Other Transit indicates the presence or absence of complementary or competing transit service in the community. "LHO" indicates the presence of line-haul transit to other parts of the region that provides little or no service within the community.

Age, Vehicle Availability, and Income data were obtained from the 1980 Census of Population and Housing for those systems where the service area closely matched city or town boundaries.

Table A-2: Ridership and Operational Data

Systems in this figure are listed alphabetically by state and city within each of the three categories.

Source lists the reference number of the source from which the data were obtained. These sources are listed in Table A-3 and are numbered separately from the overall list of references for this manual. In some cases, additional or modified data were obtained directly from the operator. Some additional data for California systems were obtained from source 9.

Data Year is the year for which ridership, operational and total population data were collected. (All socio-economic data are for 1980)

Weekday Riders figures are the average weekday ridership as reported in the source. These figures, however, often appear to be rough estimates rather than calculated values.

Annual Riders and Weekday Riders as supplied may include fixed-route or subscription services operated in conjunction with many-to-many dial-a-ride or shared-ride taxi operations, while in a few cases this ridership has been excluded. Such mixed services are not common among those listed in this appendix and larger "integrated" systems were excluded entirely.

Weekday Riders/1000 is the average weekday ridership per 1000 population.

Weekday Trip Density is the average weekday ridership per square mile.

TABLE A-1

SOCIO-ECONOMIC DATA

SMALL CITY CIRCULATOR SYSTEMS

CITY	ST	DATA YEAR	POPULATION	AREA	DENSITY	OTHER* TRANSIT	% UNDER 18 YEARS	% OVER 65 YEARS	%0 VEH AVAIL.	%0 OR 1 VEH AVAIL.	% INCOME <$10,000	% INCOME <$25,000	MEDIAN INCOME
MADISON	WI	75	200000	48.5	4124	YES	20.5	8.7	17.3	62.3	29.3	71.3	$16,510
DAVENPORT	IA	73	98500	19.7	5000	YES	29.1	10.5	10.5	48.3	25.1	67.6	$18,834
DERBY	CT	81	78000	56.0	1393	NO	.	.	.	.	.	.	.
BENTON HARBOR	MI	83	56828	51.6	1101	NO	32.6	10.8	13.9	53.5	33.5	74.2	$15,236
NILES	MI	83	43712	5.5	7948	NO	27.6	14.9	15.8	58.7	37.3	79.3	$14,059
MONROE	MI	81	42600	50.5	844	NO	29.3	13.3	12.3	52.0	25.7	67.9	$19,160
FAIRFIELD	CA	76	40000	7.8	5128	NO	31.9	4.4	5.8	40.9	24.0	68.1	$17,975
FORT L. WOOD	MO	.	40000	12.0	3333	NO	26.5	0.2	2.2	56.2	32.7	92.2	$12,305
MIDLAND	MI	83	37000	31.0	1194	NO	29.5	8.0	5.2	40.0	19.3	53.5	$23,542
KINGSTON	ON	74	36100	12.0	3008	LHO	.	.	.	.	.	.	.
VISALIA	CA	81	35400	16.9	2095	NO	29.9	10.3	7.5	43.3	28.4	71.0	$16,724
TRAVERSE CITY	MI	83	31203	11.2	2786	NO	23.7	14.5	13.3	52.8	33.0	75.1	$15,321
LOMPOC	CA	77	31155	9.9	3147	NO	28.5	7.6	7.6	46.3	32.4	74.1	$16,345
MERCED	CA	75	30000	10.0	3000	NO	30.7	9.3	14.3	51.6	35.2	77.1	$14,137
XENIA	OH	77	28000	9.0	3111	NO	31.2	9.1	9.4	45.0	29.4	77.6	$15,920
WINONA	MN	81	27642	15.1	1831	NO	20.6	16.3	16.6	59.2	.	.	.
OTTUMWA	IA	81	27381	18.0	1521	NO	24.7	19.2	13.7	51.6	34.8	77.8	$14,462
HOLLAND	MI	83	27137	14.2	1911	NO	26.2	13.4	9.5	50.6	26.3	72.5	$17,176
STRATFORD	ON	.	24000	5.7	4211	NO	.	.	.	.	.	.	.
MADERA	CA	81	22000	6.7	3284	NO	32.8	11.4	13.3	49.7	38.1	80.4	$13,518
MT PLEASANT	MI	75	20500	5.1	4020	NO	13.2	6.2	9.0	52.3	37.2	78.0	$13,576
ADRIAN	MI	83	20382	6.4	3185	NO	27.6	13.3	11.0	56.2	29.4	75.9	$15,929
ROSEVILLE	CA	81	20300	27.9	728	NO	27.4	12.2	7.8	42.1	28.7	69.3	$17,661
ISHPEMING	MI	83	20277	.	.	NO	26.0	16.5	16.4	55.1	35.0	75.4	$16,217
ALPENA	MI	83	19805	15.0	1320	NO	27.4	15.2	14.0	56.7	38.3	79.5	$14,439
TULARE	CA	81	18700	8.9	2101	NO	33.1	11.6	11.4	48.0	36.6	80.2	$13,547
BARSTOW	CA	77	18600	21.9	849	NO	32.6	7.6	10.9	46.3	25.8	72.1	$17,932
MARSHFIELD	WI	81	18221	20.0	911	NO	27.7	14.2	12.9	54.0	30.4	75.5	$15,850
TURLOCK	CA	77	18000	10.0	1800	NO	27.7	12.7	9.3	48.7	34.7	75.9	$14,710
GRAND HAVEN	MI	83	18000	9.8	1837	NO	26.3	14.9	8.5	54.1	30.0	74.1	$16,117
WISCNSN RAPIDS	WI	81	17995	.	.	NO	26.4	15.2	10.3	54.3	31.2	74.3	$16,150
LUDINGTON	MI	83	17696	5.0	3539	NO	25.2	19.5	16.0	62.0	37.5	82.4	$13,415
BATAVIA	NY	77	17000	5.5	3091	NO	26.0	16.9	14.8	62.6	32.7	75.8	$15,442
HEMET	CA	76	16700	5.9	2831	NO	12.3	48.3	11.4	71.8	45.5	90.9	$10,896
TRACY	CA	77	16500	5.0	3300	NO	31.4	10.1	9.4	45.6	28.8	74.0	$16,630
ATASCADERO	CA	81	16000	14.5	1103	NO	28.6	11.8	3.3	30.8	24.5	69.6	$18,528
RIDGECREST	CA	81	16000	20.0	800	NO	31.4	5.9	3.3	31.2	17.1	55.6	$22,991
DELANO	CA	81	15300	7.8	1962	NO	34.5	10.9	9.9	45.8	37.2	81.6	$13,442
SAULT ST. MARIE	MI	83	15136	15.7	964	NO	25.3	13.9	16.4	63.4	42.7	83.5	$12,176
VICTORVILLE	CA	76	12650	15.1	838	NO	27.9	11.8	8.2	47.1	33.0	75.5	$15,175
BIG RAPIDS	MI	83	11995	5.1	2352	NO	12.4	6.4	12.6	56.8	43.2	81.2	$11,811
CADILLAC	MI	77	10490	6.1	1720	NO	29.2	15.5	14.8	61.1	40.9	83.9	$12,648

* No = No Other Transit
LHO = Line-haul only
YES = Competing Local Transit

TABLE A-1 (cont.)

SOCIO-ECONOMIC DATA

NEIGHBORHOOD/SUBURBAN CIRCULATOR SYSTEMS

CITY	ST	DATA YEAR	POPULATION	AREA	DENSITY	OTHER* TRANSIT	% UNDER 18 YEARS	% OVER 65 YEARS	%0 VEH AVAIL.	%0 OR 1 VEH AVAIL.	% INCOME <$10,000	% INCOME <$25,000	MEDIAN INCOME
HOLLYWOOD	CA	76	243535	13.0	18733	YES	.	.	.	.	.	.	.
ELACIA	CA	76	143562	18.6	7718	YES	.	.	.	.	.	.	.
WATTS	CA	76	122445	9.6	12755	YES	.	.	.	.	.	.	.
ONTARIO-UPLAND	CA	77	102800	32.0	3213	LHO	31.2	7.7	6.0	37.7	22.2	64.3	$20,025
DETROIT	MI	.	102711	9.5	10812	YES	.	.	.	.	.	.	.
FULLERTON	CA	78	94000	22.0	4273	LHO	24.2	8.0	5.2	37.6	19.0	57.8	$21,656
ORANGE	CA	78	92500	19.6	4719	LHO	28.1	7.8	5.2	35.7	18.1	56.8	$22,100
SAN BERNARDINO	CA	77	85000	16.0	5313	YES	28.1	11.9	13.0	53.0	36.3	78.3	$14,095
BEVERLY/FAIRFAX	CA	76	83567	6.2	13479	YES	.	.	.	.	.	.	.
EL MONTE	CA	81	68000	9.1	7473	YES	35.2	8.0	12.1	54.1	35.6	80.9	$13,823
REDFORD TP	MI	77	66600	11.2	5946	LHO	24.4	11.1	5.0	34.7	13.4	50.7	$24,746
PACOIMA(LA)	CA	76	65650	11.4	5759	YES	.	.	.	.	.	.	.
LA HABRA	CA	78	65128	15.8	4122	LHO	26.3	8.5	5.7	39.4	18.7	60.5	$21,070
WATERFORD TP	MI	81	65000	29.7	2189	NO	29.5	7.0	2.8	33.7	14.5	53.1	$23,848
EL CAJON	CA	76	60500	12.0	5042	NO	26.2	10.8	9.6	47.4	31.7	75.4	$15,237
MONTEBELLO	CA	81	53000	8.5	6235	YES	27.5	10.8	11.3	48.7	25.9	69.1	$17,731
BELLFLOWER	CA	75	51700	6.1	8475	YES	24.0	10.9	7.6	48.9	28.2	73.7	$16,748
HICKSVILLE (LI)	NY	75	48100	6.8	7074	YES	24.3	8.8	4.9	36.6	12.0	47.9	$25,683
ARCADIA	CA	76	46400	11.3	4106	YES	23.3	14.8	4.2	31.7	17.7	50.2	$24,892
LA MESA	CA	76	45000	7.0	6429	NO	18.8	14.7	6.9	45.3	27.9	72.0	$16,802
LA MIRADA	CA	76	39696	7.0	5671	LHO	28.5	5.5	1.9	21.6	10.8	46.8	$26,066
BIRMINGHAM	MI	77	34000	6.0	5667	YES	23.5	13.0	5.3	43.6	12.2	43.1	$28,661
CORONA	CA	81	33100	24.0	1379	LHO	34.6	7.0	6.4	35.2	21.3	64.1	$20,693
HUNTINGTON PARK	CA	74	33000	3.0	11000	YES	34.0	8.8	25.7	69.0	43.3	86.9	$11,345
FERNDALE	MI	77	32130	4.8	6694	YES	26.5	13.0	10.1	52.3	25.1	70.2	$17,592
NATICK	MA	77	31053	16.0	1942	LHO	26.1	10.7	7.0	44.8	16.4	55.5	$22,898
MONROVIA	CA	76	29000	13.7	2117	LHO	26.4	12.5	9.7	48.9	30.2	73.8	$16,061
BETTENDORF	IA	81	27900	23.8	1172	LHO	32.6	5.9	2.7	32.4	17.1	40.3	$15,249
TOLEDO	OH	.	26700	3.5	7629	YES	.	.	.	.	.	.	.
CLAREMONT	CA	76	24950	18.0	1386	YES	24.7	9.9	5.7	35.4	15.4	46.1	$26,867
TRENTON	MI	77	24400	7.4	3297	YES	27.8	8.3	4.9	35.8	14.8	43.1	$27,622
FAIRFAX	VA	75	23000	6.0	3833	LHO	25.6	5.6	2.8	35.8	11.5	48.1	$25,810
MT CLEMENS	MI	77	20300	4.0	5075	YES	26.9	11.8	13.1	55.4	30.0	70.6	$17,109
LEMON GROVE	CA	81	20000	3.7	5405	YES	26.4	13.2	7.0	34.3	23.1	72.1	$17,941
HARPER WOODS	MI	77	18600	2.6	7099	YES	18.5	20.8	9.2	54.1	21.0	59.0	$21,436
COLTON	CA	76	18270	4.0	4568	YES	31.8	9.6	11.6	48.5	33.0	80.0	$14,294
CORONADO	CA	81	18000	4.9	3673	YES	17.9	13.9	13.0	55.8	24.1	62.4	$19,850
RUBIDOUX	CA	76	17493	8.5	2058	LHO	31.6	8.7	10.7	44.5	32.3	74.9	$16,569
EL SEGUNDO	CA	76	15750	5.5	2864	YES	21.4	8.1	5.4	47.6	15.0	36.4	$23,067
BENSENVILLE	IL	77	13900	7.0	1986	YES	25.6	8.9	5.3	43.4	13.1	55.3	$23,102
BEDFORD	MA	77	12500	14.0	893	LHO	27.5	8.2	3.9	32.0	12.4	42.0	$28,554

* NO = No Other Transit
LHO = Line-haul Only
YES = Competing Local Transit

TABLE A-1 (cont.)

SOCIO-ECONOMIC DATA

NEIGHBORHOOD/SUBURBAN FEEDER SYSTEMS

CITY	ST	DATA YEAR	POPULATION	AREA	DENSITY	OTHER* TRANSIT	% UNDER 18 YEARS	% OVER 65 YEARS	%0 VEH AVAIL.	%0 OR 1 VEH AVAIL.	% INCOME <$10,000	% INCOME <$25,000	MEDIAN INCOME
REGINA	SA	75	63000	9.0	7000	LHO	.	.	.	.	.	.	.
OTTAWA-CARLTON	ON	74	43500	6.1	7131	LHO	.	.	.	.	.	.	.
HADDONFIELD	NJ	74	40100	10.9	3679	LHO	.	.	.	.	.	.	.
COLUMBUS	OH	72	37045	2.5	14818	LHO	.	.	.	.	.	.	.
BRAMALEA	ON	74	32000	6.5	4923	LHO	.	.	.	.	.	.	.
DALLAS	TX	75	32000	13.0	2462	LHO	.	.	.	.	.	.	.
ANACOSTIA	DC	75	30000	1.5	20000	LHO	.	.	.	.	.	.	.
NEEDHAM	MA	77	29746	12.8	2333	LHO	26.5	12.9	4.8	38.2	13.0	39.9	$29,062
GAITHERSBURG	MD	77	27000	6.5	4154	LHO	28.1	4.1	4.2	47.3	13.7	60.9	$21,118
CAMBRIDGE	ON	75	24346	8.0	3043	LHO	.	.	.	.	.	.	.
BAY RIDGES	ON	77	23650	12.0	1971	LHO	.	.	.	.	.	.	.
YORK MILLS(TOR)	ON	75	20800	3.4	6064	LHO	.	.	.	.	.	.	.
CALGARY	AB	76	15000	3.0	5000	LHO	.	.	.	.	.	.	.
KITCHENER	ON	77	11000	4.2	2619	LHO	.	.	.	.	.	.	.
BURLINGTON	ON	75	10890	6.0	1815	LHO	.	.	.	.	.	.	.

* NO = No Other Transit
LHO = Line-haul Only
YES = Competing Local Transit

TABLE A-2

RIDERSHIP AND OPERATING DATA

SMALL CITY CIRCULATOR SYSTEMS

CITY	ST	SOURCE	DATA YEAR	ANNUAL RIDERS	AVERAGE WEEKDAY RIDERS	WEEKDAY RIDERS /1000	WEEKDAY TRIP DENSITY	ANNUAL VEH. HOURS	ANNUAL VEH. MILES	SERVICE HOURS WEEKDAY	SERVICE HOURS SATURDAY	SERVICE HOURS SUNDAY	FLEET SIZE	PEAK VEH. USAGE	BASE FARE	FARE IN 1984 DOLLARS
ATASCADERO	CA	2	81	67840	187	11.7	12.90	7700	128000	8.50	0.00	0.00	3	3	.	.
BARSTOW	CA	1	77	45290	136	7.3	6.21	6174	91165	11.00	8.00	5.00	4	4	$0.75	$1.27
DELANO	CA	2	81	96543	.	.	.	12314	193086	11.00	9.00	6.00	9	6	$0.60	$0.68
FAIRFIELD	CA	1	76	93773	350	8.8	44.87	11938	179825	12.00	8.00	0.00	5	5	$0.50	$0.90
HEMET	CA	1	76	24000	100	6.0	16.95	5760	70125	8.00	0.00	0.00	3	3	$0.50	$0.90
LOMPOC	CA	1	77	43670	178	5.7	17.98	4524	66039	10.00	7.00	0.00	2	2	$0.25	$0.42
MADERA	CA	2	81	60940	.	.	.	6682	99902	11.00	5.00	5.00	5	5	$0.50	$0.56
MERCED	CA	1	75	85800	330	11.0	33.00	.	.	10.00	0.00	0.00	4	4	$0.25	$0.48
RIDGECREST	CA	2	81	36160	.	.	.	8928	144640	12.00	12.00	0.00	3	2	$0.75	$0.85
ROSEVILLE	CA	2	81	68614	269	13.3	9.64	11551	152476	12.00	0.00	0.00	6	5	$0.50	$0.56
TRACY	CA	1	77	36117	151	9.2	30.20	4408	61581	12.00	0.00	0.00	4	3	$0.50	$0.85
TULARE	CA	2	81	42823	.	.	.	3563	118953	.	.	.	4	.	.	.
TURLOCK	CA	1	77	64480	248	13.8	24.80	.	.	10.00	0.00	0.00	4	4	$0.50	$0.85
VICTORVILLE	CA	1	76	7908	31	2.5	2.05	2772	35396	11.00	0.00	0.00	1	1	$0.50	$0.90
VISALIA	CA	2	81	23718	.	.	.	4096	57849	.	.	.	7	.	.	.
DERBY	CT	2	81	248040	.	.	.	30102	326368	.	.	.	14	.	$1.00	$1.13
DAVENPORT	IA	5	73	.	1032	10.5	52.39	.	.	24.00	24.00	24.00	23	.	$0.75	.
OTTUMWA	IA	8	81	154528	618	22.6	34.33	.	.	12.00	0.00	0.00	.	4	$0.50	$0.56
ADRIAN	MI	3	83	96720	378	18.5	59.06	13330	169545	12.00	0.00	0.00	6	5	$0.75	$0.77
ALPENA	MI	3	83	82676	283	14.3	18.87	12355	158465	12.00	10.00	4.00	6	5	$0.80	$0.82
BENTON HARBOR	MI	3	83	118465	468	8.2	9.07	20727	257968	11.00	0.00	0.00	12	11	$0.90	$0.93
BIG RAPIDS	MI	3	83	96902	333	27.8	65.29	15441	145833	12.00	9.50	0.00	8	6	$1.00	$1.03
CADILLAC	MI	1	77	83157	289	27.6	47.38	11071	135570	12.00	10.00	0.00	4	4	$0.50	$0.85
GRAND HAVEN	MI	3	83	114048	418	23.2	42.65	16047	258768	12.00	7.00	0.00	12	7	$0.75	$0.77
HOLLAND	MI	3	83	109037	377	13.9	26.55	18026	245869	13.20	8.00	0.00	10	7	$0.75	$0.77
ISHPEMING	MI	3	83	28340	94	4.6	.	6713	87061	14.00	6.00	10.00	3	2	$2.50	$2.57
LUDINGTON	MI	3	83	85812	300	17.0	60.00	11766	129664	12.00	8.00	0.00	9	7	$1.50	$1.54
MIDLAND	MI	3	83	133717	490	13.2	15.81	24091	354786	16.50	10.50	0.00	15	12	$1.00	$1.03
MONROE	MI	2	81	189570	.	.	.	26851	421267	.	.	.	15	.	.	.
MT PLEASANT	MI	5	75	.	227	11.1	44.51	.	.	12.00	11.00	4.00	5	.	$0.50	$0.95
NILES	MI	3	83	121951	417	9.5	75.82	25368	306124	17.00	15.00	7.00	12	7	$0.50	$0.51
SAULT ST. MARIE	MI	3	83	83688	313	20.7	19.94	11704	147243	8.00	0.00	0.00	5	4	$1.00	$1.03
TRAVERSE CITY	MI	3	83	80685	297	9.5	26.52	17238	225223	12.00	12.00	0.00	10	8	$1.00	$1.03
WINONA	MN	8	81	227500	875	31.7	57.95	.	.	12.00	0.00	0.00	.	4	$0.40	$0.45
FORT L. WOOD	MO	5	.	.	1000	25.0	83.33	.	.	.	.	.	80	.	$0.40	.
BATAVIA	NY	1	77	86400	400	23.5	72.73	7800	104000	12.00	0.00	0.00	7	4	$0.70	$1.19
XENIA	OH	1	77	80000	259	9.3	28.78	.	.	12.00	12.00	12.00	12	12	$0.50	$0.85
KINGSTON	ON	5	74	.	375	10.4	31.25	.	.	17.00	17.00	0.00	6	.	$0.35	$0.73
STRATFORD	ON	5	.	.	219	9.1	38.42	.	.	6.00	6.00	0.00	5	.	$0.35	.
MADISON	WI	1	75	641000	2466	12.3	50.85	.	.	24.00	24.00	24.00	30	30	$0.65	$1.24
MARSHFIELD	WI	10	81	30747	99	5.4	4.95	8760	78929	18.00	18.00	18.00	3	3	$1.00	$1.13
WISCNSN RAPIDS	WI	10	81	30323	.	.	.	9675	106460	17.50	17.50	18.00	4	.	$2.00	$2.26

TABLE A-2 (cont.)

RIDERSHIP AND OPERATING DATA

NEIGHBORHOOD/SUBURBAN CIRCULATOR SYSTEMS

CITY	ST	SOURCE	DATA YEAR	ANNUAL RIDERS	AVERAGE WEEKDAY RIDERS	WEEKDAY RIDERS /1000	WEEKDAY TRIP DENSITY	ANNUAL VEH. HOURS	ANNUAL VEH. MILES	SERVICE HOURS WEEKDAY	SERVICE HOURS SATURDAY	SERVICE HOURS SUNDAY	FLEET SIZE	PEAK VEH. USAGE	BASE FARE	FARE IN 1984 DOLLARS
ARCADIA	CA	1	76	53025	145	3.1	12.83	9370	163991	12.00	12.00	12.00	3	3	$0.75	$1.35
BELLFLOWER	CA	1	75	16172	63	1.2	10.33	2064	.	8.00	5.00	0.00	1	1	$0.25	$0.48
BEVERLY/FAIRFAX	CA	1	76	81300	266	3.2	42.90	14628	167928	12.00	8.00	0.00	6	6	$0.15	$0.27
CLAREMONT	CA	1	76	19404	76	3.0	4.22	2534	26100	9.50	0.00	0.00	2	2	$0.50	$0.90
COLTON	CA	1	76	10800	42	2.3	10.50	3770	.	11.00	0.00	0.00	3	3	$0.50	$0.90
CORONA	CA	2	81	84074	400	12.1	16.67	14933	215574	13.00	9.00	0.00	7	5	$1.00	$1.13
CORONADO	CA	2	81	12600	.	.	.	1249	16154	9.00	9.00	0.00	1	1	$0.50	$0.56
EL CAJON	CA	1	76	176818	550	9.1	45.83	44400	792000	24.00	24.00	24.00	18	14	$0.50	$0.90
EL MONTE	CA	2	81	61200	.	.	.	12119	226667	.	.	.	6	.	.	.
EL SEGUNDO	CA	1	76	11558	50	3.2	9.09	1560	18000	6.00	0.00	0.00	1	1	$0.00	$0.00
ELACIA	CA	1	76	123768	491	3.4	26.40	21504	312132	11.00	0.00	0.00	10	8	$0.15	$0.27
FULLERTON	CA	1	78	138000	400	4.3	18.18	28000	460000	13.00	13.00	0.00	12	11	$0.50	$0.79
HOLLYWOOD	CA	1	76	73044	239	1.0	18.38	21240	301728	12.00	8.00	0.00	9	9	$0.15	$0.27
HUNTINGTON PARK	CA	5	74	.	100	3.0	33.33	.	.	9.00	9.00	0.00	3	.	$0.50	$1.04
LA HABRA	CA	1	78	144000	470	7.2	29.75	21700	295000	13.00	13.00	0.00	11	10	$0.50	$0.79
LA MESA	CA	1	76	110000	375	8.3	53.57	16500	270000	14.00	10.00	5.50	6	6	$0.50	$0.90
LA MIRADA	CA	1	76	119399	389	9.8	55.57	15710	208197	12.00	8.00	0.00	7	7	$0.25	$0.45
LEMON GROVE	CA	2	81	31400	.	.	.	3134	47576	24.00	24.00	24.00	3	3	$0.50	$0.56
MONROVIA	CA	1	76	10432	41	1.4	2.99	2240	.	7.00	0.00	0.00	1	1	$0.75	$1.35
MONTEBELLO	CA	2	81	27030	.	.	.	4083	38070	.	.	.	4	.	$1.00	$1.13
ONTARIO-UPLAND	CA	1	77	78142	263	2.6	8.22	14832	171060	7.50	0.00	0.00	7	7	$0.50	$0.85
ORANGE	CA	1	78	157000	500	5.4	25.51	26600	403700	13.00	13.00	0.00	12	11	$0.50	$0.79
PACOIMA(LA)	CA	1	76	37224	121	1.8	10.61	9574	134840	12.00	8.00	0.00	4	4	$0.15	$0.27
RUBIDOUX	CA	1	76	23849	79	4.5	9.29	3931	60480	13.00	12.00	0.00	1	1	$0.25	$0.45
SAN BERNARDINO	CA	1	77	100992	329	3.9	20.56	20238	.	12.00	7.00	0.00	10	10	$0.50	$0.85
WATTS	CA	1	76	86436	343	2.8	35.73	13188	175212	11.00	0.00	0.00	9	9	$0.15	$0.27
BETTENDORF	IA	2	81	29574	.	.	.	5188	84497	.	.	.	2	.	$1.00	$1.13
BENSENVILLE	IL	1	77	22000	85	6.1	12.14	.	30000	6.00	0.00	0.00	4	3	$0.50	$0.85
BEDFORD	MA	1	77	28000	65	5.2	4.64	.	.	9.25	0.00	0.00	6	3	$0.50	$0.85
NATICK	MA	6	77	60000	190	6.1	11.88	8571	.	9.50	8.00	0.00	.	3	.	.
BIRMINGHAM	MI	1	77	38400	123	3.6	20.50	8436	.	12.00	8.00	4.00	4	4	$0.50	$0.85
DETROIT	MI	5	.	.	400	3.9	42.11	.	.	16.00	16.00	0.00	11	.	$0.00	.
FERNDALE	MI	1	77	52800	220	6.8	45.83	.	.	12.00	6.00	0.00	4	4	$0.50	$0.85
HARPER WOODS	MI	1	77	36000	150	8.1	57.25	.	.	8.00	0.00	0.00	2	2	$0.50	$0.85
MT CLEMENS	MI	1	77	75600	307	15.1	76.75	.	.	11.00	0.00	0.00	6	6	$0.50	$0.85
REDFORD TP	MI	1	77	50400	208	3.1	18.57	.	.	12.00	0.00	0.00	6	6	$0.60	$1.02
TRENTON	MI	1	77	.	230	9.4	31.08	.	.	.	.	.	.	5	$0.60	$1.02
WATERFORD TP	MI	2	81	60450	.	.	.	15304	262826	.	.	.	6	.	.	.
HICKSVILLE (LI)	NY	1	75	296300	814	16.9	119.71	.	.	24.00	24.00	24.00	40	40	.	.
TOLEDO	OH	5	.	.	275	10.3	78.57	.	.	15.00	0.00	0.00	7	.	$0.00	.
FAIRFAX	VA	4	75	.	260	11.3	43.33	.	.	13.00	5.00	0.00	4	3	$0.25	$0.48

TABLE A-2 (cont.)

RIDERSHIP AND OPERATING DATA

NEIGHBORHOOD/SUBURBAN FEEDER SYSTEMS

CITY	ST	SOURCE	DATA YEAR	ANNUAL RIDERS	AVERAGE WEEKDAY RIDERS	WEEKDAY RIDERS /1000	WEEKDAY TRIP DENSITY	ANNUAL VEH. HOURS	ANNUAL VEH. MILES	SERVICE HOURS WEEKDAY	SERVICE HOURS SATURDAY	SERVICE HOURS SUNDAY	FLEET SIZE	PEAK VEH. USAGE	BASE FARE	FARE IN 1984 DOLLARS
CALGARY	AB	1	76	343161	1100	73.3	366.67	.	.	.	.	.	15	6	$0.45	$0.81
ANACOSTIA	DC	4	75	26920	.	.	.	.	.	5.50	0.00	0.00	6	6	$0.25	$0.48
NEEDHAM	MA	6	77	136836	438	14.7	34.35	11899	.	11.00	12.00	0.00	.	4	.	.
GAITHERSBURG	MD	1	77	187000	600	22.2	92.31	.	.	13.00	8.00	0.00	.	8	$0.25	$0.42
HADDONFIELD	NJ	1	74	365000	1000	24.9	91.74	63306	840755	24.00	24.00	24.00	18	14	$0.30	$0.62
COLUMBUS	OH	1	72	160000	500	13.5	200.00	15000	.	12.00	9.00	0.00	4	4	$0.25	.
BAY RIDGES	ON	1	77	389660	1500	63.4	125.00	.	.	.	.	.	14	9	$0.50	$0.85
BRAMALEA	ON	5	74	.	1570	49.1	241.54	.	.	16.00	10.00	0.00	14	.	$0.35	$0.73
BURLINGTON	ON	1	75	130000	457	42.0	76.17	15900	93600	17.00	17.00	0.00	6	3	$0.40	$0.76
CAMBRIDGE	ON	1	75	156000	548	22.5	68.50	17160	171600	11.00	11.00	0.00	6	5	$0.40	$0.76
KITCHENER	ON	1	77	138000	700	63.6	166.67	14352	178610	18.00	18.00	0.00	3	3	$0.45	$0.76
OTTAWA-CARLTON	ON	5	74	.	2400	55.2	393.44	.	.	17.25	17.25	0.00	27	.	$0.55	$1.14
YORK MILLS(TOR)	ON	1	75	351000	1350	64.9	393.59	31980	325000	14.00	0.00	0.00	8	8	$0.50	$0.95
REGINA	SA	1	75	812000	2800	44.4	311.11	67210	672100	18.00	18.00	7.50	26	14	$0.45	$0.86
DALLAS	TX	1	75	.	26	0.8	2.00	.	.	14.00	0.00	0.00	5	4	$0.50	$0.95

Table A-3:

SOURCES FOR APPENDIX A

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1. Billheimer, J.W., et al., Paratransit Handbook, a Guide to Paratransit Implementation. Volume 2, Preapred by Systan, Inc. for USDOT/UMTA, Report No. UMTA-MA-06-054-7A-3, Los Altos, CA (January 1979).

2. Systan Inc., Demand Responsive Paratransit Handbook, Volume 5, Preliminary Draft, Prepared for USDOT/UMTA, Los Altos, CA (August, 1983) 104 pp.

3. Michigan Department of Transportation, "Operational Data - Bus Transit Program" and "Bus Inventory", Prepared by the Bureau of Urban Public Transportation, Lansing, MI (1983).

4. Metropolitan Washington Council of Governments and National Capital Region Transportation Planning Board, "Paratransit Service in the Washington Metropolitan Area, Case Studies." (March, 1977) 27 pp.

5. Peat, Marwick, Mitchell and Co., "Analyzing Transit Options for Small Urban Communities." Volume 3, Summary of Management and Operations Experience. Report No. UMTA-IT-06-9020-78-3, Washington, D.C. (January 1978) 175 pp.

6. Massachusetts Bay Transportation Authority, Suburban Experiments, Prepared by the Department of Community Affairs and Marketing, Boston, MA (May 1978) 80 pp.

7. Teal, Roger, University of California

8. Institute for Urban Transportation, Indiana University, Transit Works: 10 Rural Case Studies. (June 1982) 100 pp.

9. State of California, Office of the State Controller, Annual Report 1981-1982, Financial Transactions Concerning Transit Operators and Non-Transit Claimants Under the Transportation Development Act. (1982) 349 pp.

10. Wisconsin Department of Transportation, Bureau of Transit, Wisconsin Urban Transit Annual Report. (1982)

APPENDIX B: PROCEDURES FOR ESTIMATING AVERAGE WALK, WAIT AND RIDE TIMES

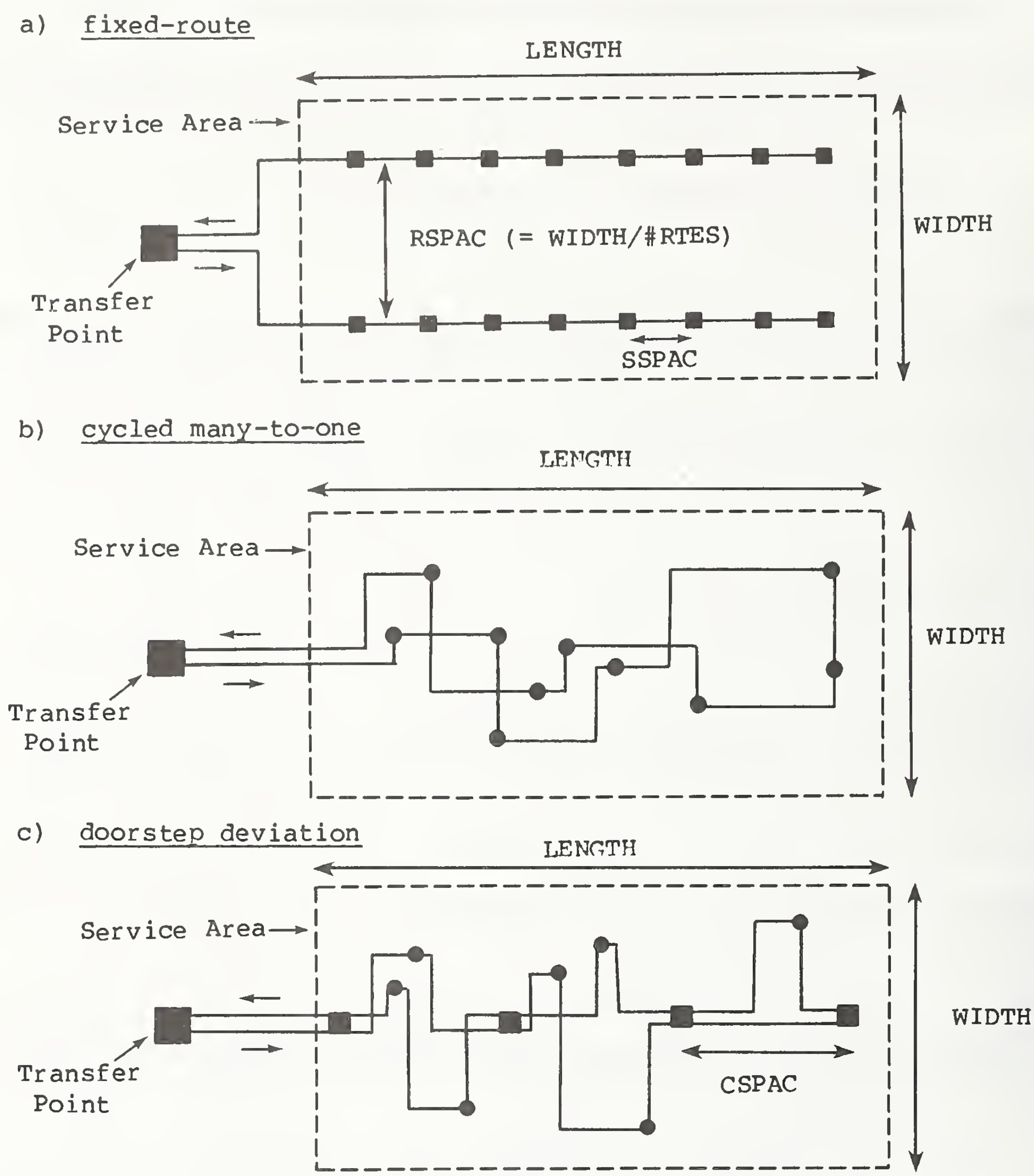
Procedures have been developed for estimating measures of the service quality provided by a variety of community transit services (1, 2). These are presented below in simplified forms that are appropriate for feasibility and screening studies. If more refined ridership estimates are required for detailed service planning, the procedures can be applied on a segmented basis to portions of a community to better capture variations in physical layout and population characteristics.

The procedures make certain simplifying assumptions about a service area which should be understood by a user so adjustments can be made, if necessary, to specific planning situations. Basically, the procedures assume a rectangular service area over which trips are evenly distributed. Routes, stops, and checkpoints also are evenly spaced. As an example, Figure B-1 shows typical configurations of different feeder modes in a community in terms of parameters used in the procedures.

Section B.1 covers the estimation of average walk time. Section B.2 presents procedures for estimating ride time on feeder/distribution and mixed service modes, and illustrates the results of a sample analysis with varying ridership. Section B.3 discusses wait time, response time and schedule delay on these modes. Section B.4 presents procedures for estimating service quality measures for dial-a-ride and shared-ride taxi operations, i.e., modes that primarily serve intra-community travel.

Figure B-1:

TYPICAL SERVICE AREA CONFIGURATIONS



Key:
- LENGTH = service area length (in miles)
- WIDTH = service area width (in miles)
- SSPAC = stop spacing (in miles)
- CSPAC = checkpoint spacing (in miles)
- RSPAC = route spacing (in miles)
- ■ = signed stop
- ● = doorstep stop

B.1 Walk Time

Average walk time is calculated using the following equation:

$$TWLK = \frac{60.0}{WKSPD} * DWLK * DIR \qquad (B-1)$$

where: TWLK = average walk time (in minutes)

DWLK = average walk distance (in miles)

WKSPD = average walking speed (in mph)

DIR = 1 (for feeder trips)

= 2 (for circulation trips)

Data compiled on walking speeds are displayed in Figure B-2, which shows speed distributions observed at two sites in New York City and the effect of crowding on different types of pedestrians.

The following equations, which are keyed to diagrams in Figure B-3, show how average walk distances can be determined for different modes operating in a community with a grid street pattern. Factors ranging to 1.5 can be used to adjust the average distances calculated using these equations to account for currilinear or disconnected street pattents.

For a fixed-route service, average walk distance can be calculated as follows:

$$DWLK = \frac{RSPAC + SSPAC}{4} \qquad (B-2a)$$

The same equation can be used for jitney service, with SSPAC = 0.

For a checkpoint service, average walk distance will depend on the configuration of the points, as follows:

orthogonal:

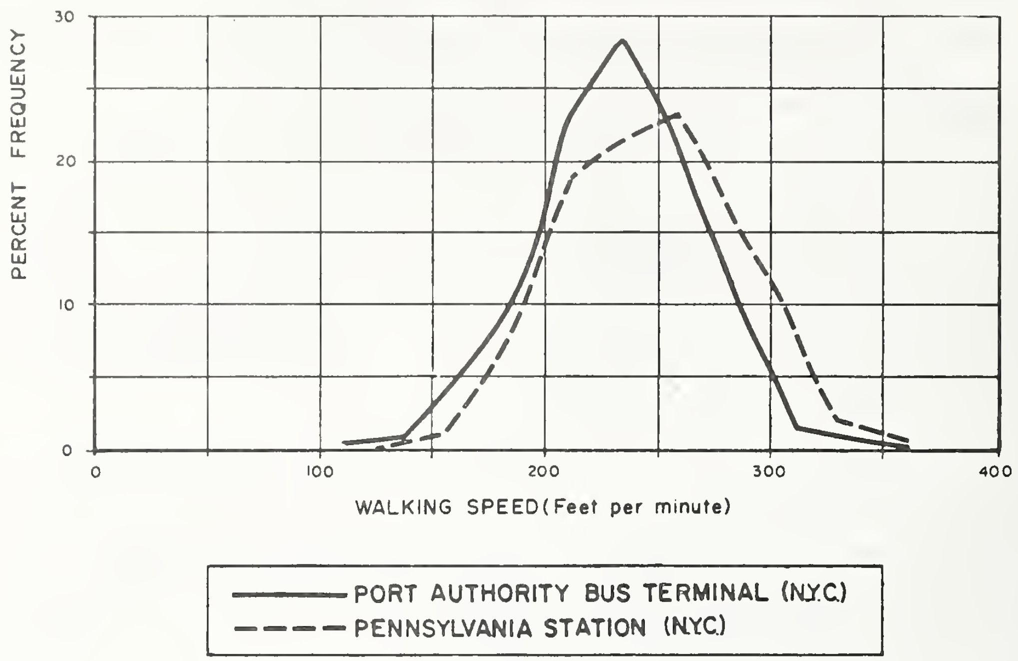
$$DWLK = 0.50 * CSPAC \qquad (B-2b)$$

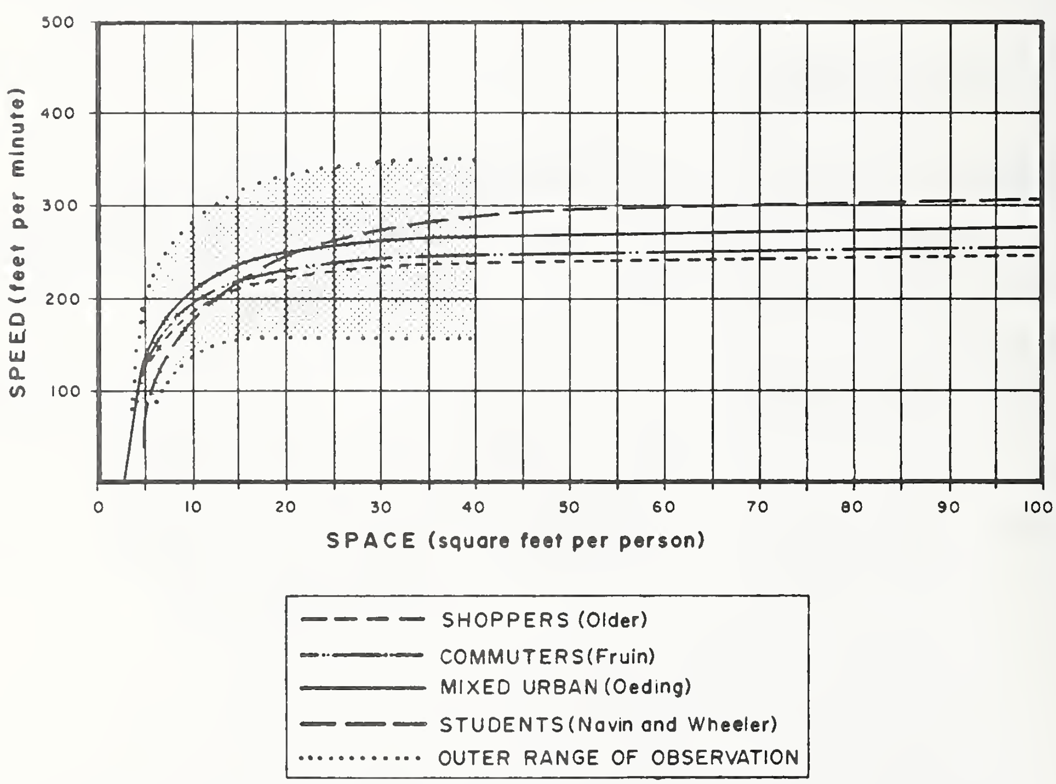
offset:

$$DWLK = 0.48 * CSPAC \qquad (B-2c)$$

Figure B-2:

TYPICAL WALKING SPEEDS



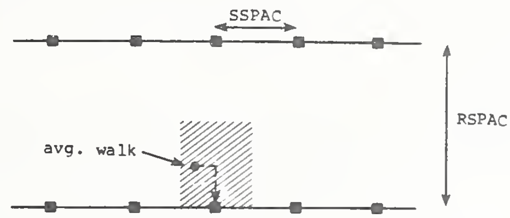


Source: Reference__

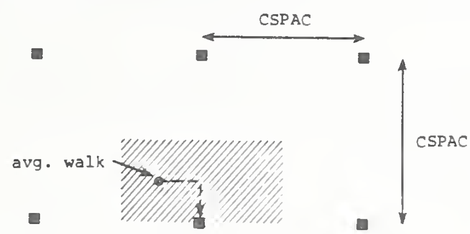
Figure B-3:

PROCEDURES FOR ESTIMATING WALK DISTANCE

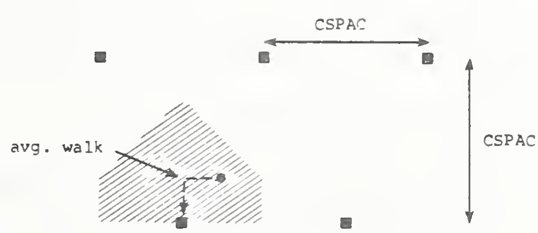
a) <u>fixed-route</u>



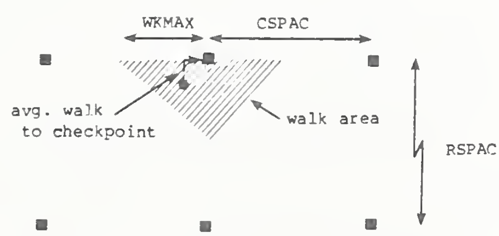
b) <u>checkpoint (orthogonal grid)</u>



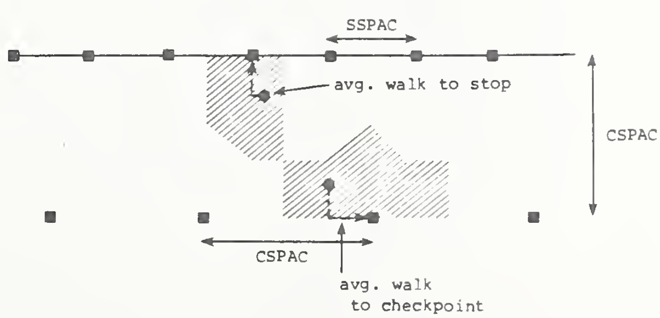
c) <u>checkpoint (offset grid)</u>



d) <u>doorstep deviation</u>



(e) <u>checkpoint deviation</u>



To calculate average walk distance for a deviation service, the service area has to be split into two portions as shown in Figure B-3. The fraction of passengers boarding or alighting at a checkpoint with doorstep deviation service can be calculated from the areas in the diagrams. If WKMAX is less than half of checkpoint and route spacing, the following equation can be used:

$$PCCD = \frac{2.0 * WKMAX^2}{CSPAC * RSPAC} \qquad (B\text{-}3a)$$

where: PCDD = fraction of passengers using checkpoints

WKMAX = maximum walking distance (in miles, typically ranging from 0.25 to 0.75)

Average walk time (for all riders) can then be calculated as follows:

$$DWLK = PCDD * DFAC * WKMAX \qquad (B\text{-}2d)$$

where: DFAC = .50

With a checkpoint deviation service, riders may walk to either a checkpoint or a stop along a route. If route spacing is twice checkpoint spacing, as shown in Figure B-3, the fraction walking to checkpoints (PCCD) can be calculated using the following equation:

$$PCCD = \frac{.5 * CSPAC^2 + .5 * SSPAC^2 - .25 * CSPAC * SSPAC}{CSPAC^2} \qquad (B\text{-}3b)$$

$$= .5 \text{ (if SSPAC = CSPAC)}$$

$$= .438 \text{ (if SSPAC = .5 * CSPAC)}$$

The average walk time is calculated as follows:

$$DWLK = DFAC * CSPAC \qquad (B\text{-}2e)$$

where: DFAC = .48 (if SSPAC = CSPAC)

= .45 (if SSPAC = .5 * CSPAC)

B.2 Ride Time for Feeder/Distribution Trips

The average ride time for a trip to or from a line-haul station or central transfer point can be calculated using the following basic equation:

$$TRID = 0.5 * (TSTP + TRUN) + TEXT \qquad (B\text{-}4a)$$

where: TRID = average ride time of a passenger (in minutes)

TSTP = total time due to stops made during an average collection or distribution tour (in minutes)

TRUN = running time of a bus on an average collection or distribution tour within the community (in minutes)

TEXT = any bus running time between the community boundary and line-haul station (in minutes)

0.5 = a factor indicating that travellers are evenly distributed across the community.

External running time (TEXT) is calculated using the following equation:

$$TEXT = \frac{60.0 * DEXT}{BSPD} \qquad (B\text{-}5)$$

where: DEXT = over-the-road distance from the point where a bus leaves the community to the station (in miles)

BSPD = average running speed of the bus (in mph)

The other two components of ride time are functions of ridership for many modes, so some iteration may be necessary between the procedures discussed below and the ridership estimation technique being applied. In many cases, the distribution and collection phases of a service, and their respective volumes, can be treated separately. One exception is a bus or jitney operating in a one-way loop, where collection and distribution occur along the entire journey of a bus. For feeder routes serving two or more stations, the distribution tour from one station will overlap with the collection tour for another station, so the analysis may be more complex.

Another complicating factor may be local riders. Those traveling between routes or sectors can be treated like feeder or distribution trips (and their ride time will be twice the value calculated using equation B-4a). Local trips made on a single route or sector may travel on only one portion of the tour, or may be carried over from the distribution to the collection phase (or vice versa) depending on operating policy. Appropriate adjustments to equation B-4 can be made to estimate the average ride time of local trips. For example, if local trips are carried within a sector (with half carried in each service direction), their average ride time would be calculated as follows:

$$TRID = 0.25 * (TSTP_{in} + TSTP_{out} + TRUN_{in} + TRUN_{out}) \qquad \text{(B-4b)}$$

A diagram, such as the one shown in Figure B-4, should be constructed before applying the procedures described below to clarify which tour phases and riders are included in an analysis. The procedures generally should be applied to the heavy travel direction (e.g., to the transfer station in the A.M.), or to both directions.

Time due to stops (TSTP) on a distribution or collection tour can be calculated using the following equation:

$$TSTP = \left[(NAS_s + 1) * \frac{TPS_s}{60}\right] + \left[NAS_d * \frac{TPS_d}{60}\right] + \left[\frac{PVOL}{BTRIP} * \frac{TBD + TAL}{60}\right] \qquad \text{(B-6)}$$

where: NAS_s = the number of on-route stops actually made in the community on an average collection or distribution tour

TPS_s = time spent decelerating, accelerating and opening and closing doors at an on-route stop (in seconds)

NAS_d = number of off-route stops (doorstep or checkpoint) made on an average collection or distribution tour

TPS_d = time spent decelerating, etc. at an off-route stop, including time spent finding address (in seconds)

PVOL = average number of passengers on the route or sector during the analysis period

BTRIP = number of bus trips planned or estimated for the route or sector during the analysis period

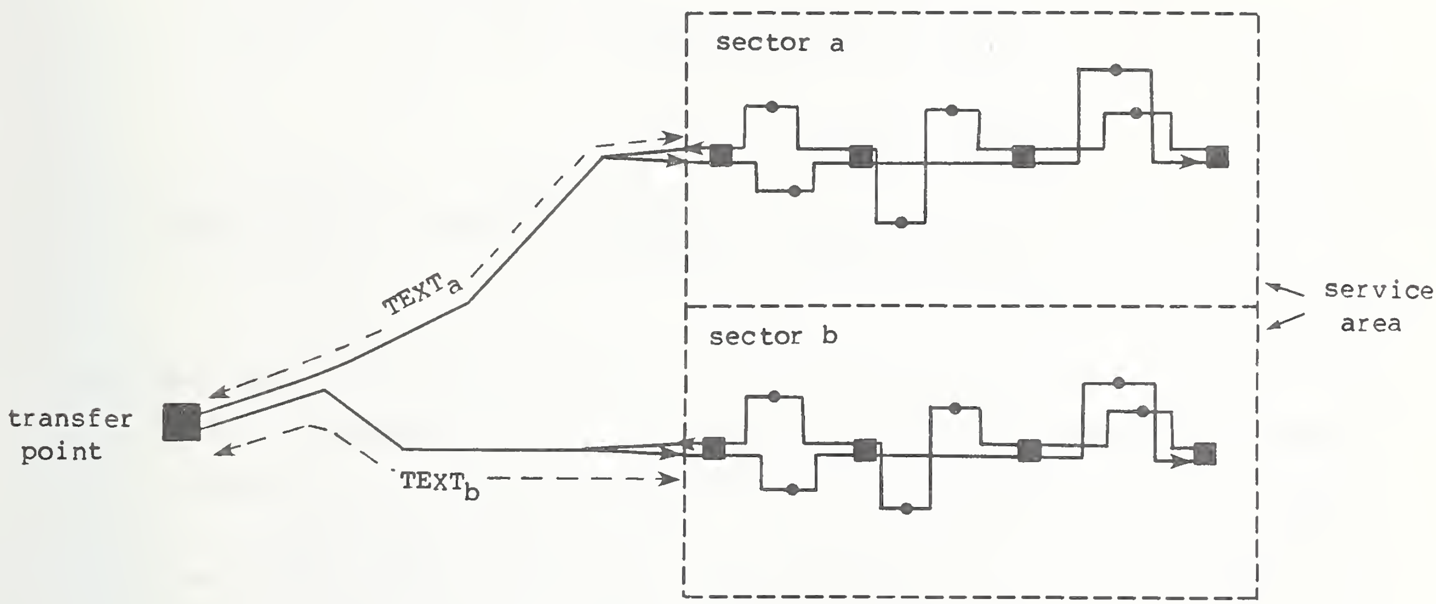
TBD = average boarding time of a passenger (in seconds)

TAL = average alighting time of a passenger (in seconds)

Typical values of TPS, TBD and TAL are shown in Table B-1. If necessary, a weighted average of appropriate values should be used in applying equation B-6.

Figure B-4:

SAMPLE ANALYSIS DIAGRAMS



Market segments for service with 2 sectors:

-outbound from sector a	TRID = 0.5 $*$ ($TSTP_{out}$ + $TRUN_{out}$) + $TEXT_a$
-outbound from sector b	TRID = 0.5 $*$ ($TSTP_{out}$ + $TRUN_{out}$) + $TEXT_b$
-inbound to sector a	TRID = 0.5 $*$ ($TSTP_{in}$ + $TRUN_{in}$) + $TEXT_a$
-inbound to sector b	TRID = 0.5 $*$ ($TSTP_{in}$ + $TRUN_{in}$) + $TEXT_b$
-local intra-sector	TRID = 0.25 $*$ ($TSTP_{in}$ + $TSTP_{out}$ + $TRUN_{in}$ + $TRUN_{out}$)
-local inter-sector	TRID = 0.5 $*$ ($TSTP_{in}$ + $TSTP_{out}$ + $TRUN_{in}$ + $TRUN_{out}$) + $TEXT_a$ + $TEXT_b$

The number of stops made on an average bus trip can be calculated using the following equation:

$$NAS_i = STOP_i * PROB_i \quad \text{(B-7)}$$

where: $STOP_i$ = number of potential stops of type i (e.g., on-route)

$PROB_i$ = probability of making a stop of type i

$= 1 - \exp(-APPS_i)$

$APPS_i$ = average number of passengers boarding or alighting a bus at a stop of type i

$$= \frac{PVOL}{BTRIP} * \frac{PCS_i}{STOP_i}$$

PCS_i = fraction of all loadings and alightings that take place at stops of type i.

The equation for $PROB_i$ is plotted in Figure B-5 for easy reference.

For doorstep feeder service, the value of NAS can be set to the average number of passengers per bus trip (e.g., PVOL/BTRIP) and equation B-7 is not needed. For fixed-route or checkpoint service, the equation is applied with APPS calculated by dividing the average number of passengers (per bus trip) by the number of stops or checkpoints. For deviation services, the passengers have to be divided between on-route and off-route stops, which can be done graphically as shown in Figure B-3 (see equations B-3a and 3b). The number of stops of each type is then determined using the appropriate method. In all cases, local trips boarding and alighting on the route or sector have to be counted twice.

Running time within a community (TRUN) depends on the mode of operation. Estimation procedures derived from equations in references 1 and 2 are presented below in equation and graphical form.

For a fixed-route or jitney service, running time is calculated using the following equation:

$$TRUN = \frac{60.0 * DRUN}{BSPD} \quad \text{(B-8)}$$

Table B-1:

TYPICAL DWELL TIME VALUES

a) TPS (deceleration, etc.)

avg. running speed (mph)	TPS (sec.)*
10	6-8
15	7-9
20	9-11
30	12-14

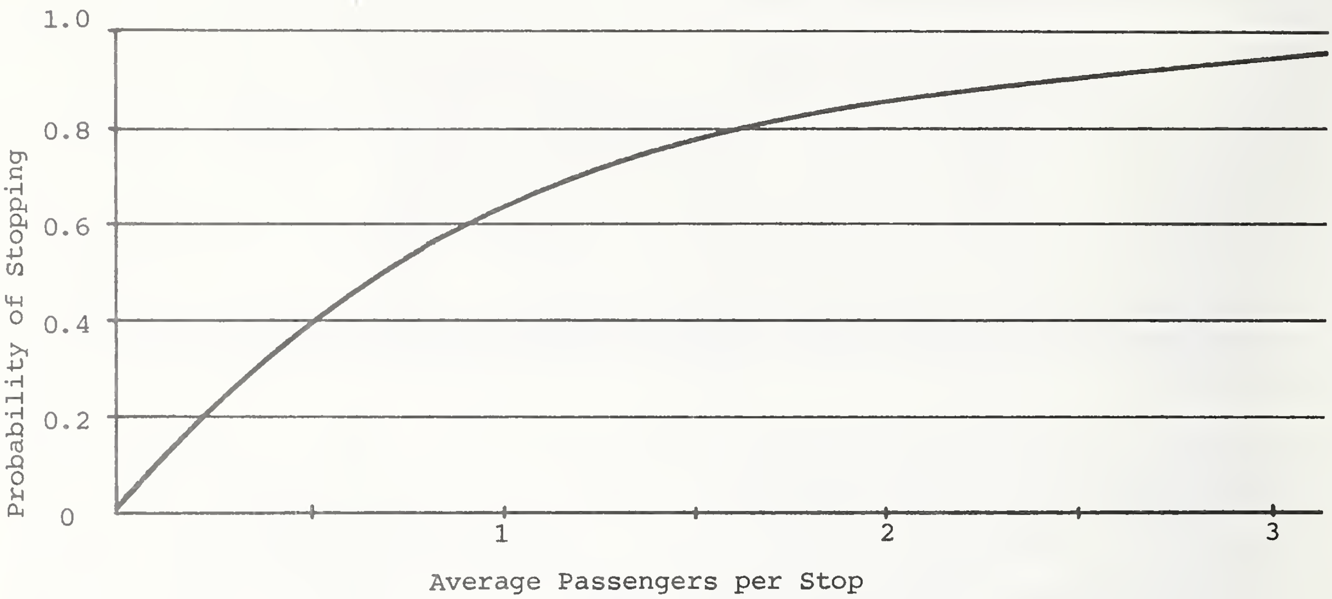
* Add 5-10 seconds if passengers cannot stand on a moving vehicle; add 30-40 seconds for a doorstep pick-up and 5-10 seconds for a doorstep drop-off.

b) TBD (boarding) or TAL (alighting)

movement	TBD or TAL (sec.)
boarding with simple fare or pass	2-3
boarding with zone fare	3-5
single door alighting	2
boarding or alighting with packages, strollers, canes, etc.	5-10
wheelchair boarding or alighting	60+

Figure B-5:

PROBABILITY OF MAKING A STOP



where: DRUN = average route distance (in miles)

= LNGTH * SCF (for essentially parallel routes)

SCF = street curvature factor

BSPD = average bus running speed (in mph)

For a <u>checkpoint service</u>, running time will depend on the number of checkpoints served and the amount of lateral travel. The following equation is used:

$$TRUN = \frac{60.0 * SCF}{BSPD} * \left[LNGTH + NROW * CSPAC * LFAC \right] \qquad (B-9)$$

where: NROW = number of rows of checkpoints with passengers to be served

$$= 1 - \exp(-APPS * NCPR) * \frac{STOP}{NCPR}$$

APPS = average number of boarding plus alighting passengers per checkpoint

NCPR = number of checkpoints per row

LFAC = 0 (if NCPR = 1, i.e., fixed-route)

= (0.25 * NCPR + 0.75 * ALFC) (if NCPR 1)

$$ALFC = 1 - 2 * \left(\frac{1}{2}\right)^b \qquad \text{(if NCPR = 2)}$$

$$= 2 - 2 * \left[\left(\frac{1}{3}\right)^b + \left(\frac{2}{3}\right)^b \right] \qquad \text{(if NCPR = 3)}$$

$$= 3 - 2 * \left[\left(\frac{1}{4}\right)^b + \left(\frac{2}{4}\right)^b + \left(\frac{3}{4}\right)^b \right] \qquad \text{(if NCPR = 4)}$$

b = NAS/NROW

NAS = average number of checkpoints where passengers board or alight (from equation B-7)

STOP = total number of checkpoints

A <u>doorstep subscription service's</u> running time can be estimated using the following equation:

$$TRUN = \frac{60.0 * SCF * (LNGTH + WIDTH)}{BSPD} * \left[a + b * (NAS + 1) - \frac{c}{(NAS + 1)} \right] \qquad (B-10)$$

where: NAS = actual number of stops (number of boarding plus alighting passengers for doorstep service)

$$a = 0.8 - \frac{0.18}{AR}$$

$$b = 0.01 + \frac{0.084}{\sqrt{AR}}$$

$$c = 0.31 - \frac{0.18}{AR} + \frac{0.084}{\sqrt{AR}}$$

AR = aspect ratio of the service area or sector

= LNGTH/WIDTH

For a <u>checkpoint subscription service</u>, equation B-10 is applied with one substitution; the expression (NAS + 1) is replaced with the value obtained by applying equation B-7 with $\left[\frac{PVOL}{BTRIP} + 1\right]$ instead of $\left[\frac{PVOL}{BTRIP}\right]$.

Running time for a <u>many-to-one service</u> can be estimated using the following equation:

$$TRUN = \frac{60.0 * 1.01 * SGF}{BSPD} * \sqrt{LNGTH * WIDTH} * \left[SFAC + a\right] \qquad \text{(B-11)}$$

where: a = 0.075 (for a central transfer point)

= 0.335 (for a transfer point at or beyond the community or sector boundary)

SGF = street geometry factor

= 1.27 (for a grid network)

$$SFAC = \left[1.0 - \frac{(VPRO - 1)}{8 * (VPRO - 0.5)^2}\right] * \sqrt{VPRO - 0.5}$$

$$VPRO = PVP \div \left[1 - \exp(-PVP)\right]$$

$$PVP = \frac{PVOL}{BTRIP} + 1$$

Running time for a deviation service depends on the number of deviations actually made. Running time for a <u>checkpoint deviation service</u> can be calculated using the following equation:

$$TRUN = \frac{60.0 * SCF}{BSPD} * (LNGTH + NACP * 2.0 * CSPAC) \qquad (B-12)$$

where: NACP = number of checkpoints actually served, calculated using equation B-7

For a doorstep deviation service, run time is calculated using the following equation:

$$TRUN = \frac{60.0 * SCF}{BSPD} \sqrt{RSPAC * CSPAC} * NCPT * (IFAC - 0.075) \qquad (B-13)$$

where: $IFAC = \left[1.0 - \frac{(VICP-1)}{8 * (VICP - 0.5)^2}\right] * \sqrt{VICP - 0.5}$

$VICP = PICP \div \left[1 - \exp(-PICP)\right]$

$PICP = \left[\frac{PVOL}{BTRIP} + 1\right] * \frac{(1-PCDD) * CSPAC}{LNGTH}$

PCDD = fraction of passengers using checkpoints, calculated using equation B-3a

NCPT = number of checkpoints per route

$= \frac{LNGTH}{CSPAC}$

The procedures presented above were applied to examine the various modes in a service area of 4 square miles. The following parameters were used:

BUSSPD	=	10 mph.
SGF	=	1.27
SCF	=	1.0
TPS	=	15 sec. (at signed stops)
	=	30 sec. (at doorstep stops)
TBD	=	3 sec.
TAL	=	2 sec.
WKMAX	=	0.375 miles
SSPAC	=	0.25 miles
CSPAC	=	0.50 miles (for checkpoint services)
	=	1.00 miles (for doorstep deviation)
RSPAC	=	0.50 miles (for fixed-route)
	=	1.0 or 2.0 miles (for deviation services)

The transfer point was 0.25 miles outside the service center, yielding values of DEXT that varied between 0.25 and 0.75 miles (to account for lateral travel) depending on the number of routes and sectors in the service area, and its shape.

Ride times estimated for various fixed-route and demand-responsive service options are plotted in Figure B-6. These curves assume a square service area 2 miles on a side. The volume axis represents the number of passengers leaving the entire service area in an operating cycle; this number should be divided by the number of routes or sectors to obtain the number of passengers per vehicle trip.

The figure clearly shows the sensitivity of ride time on demand-responsive services to volume. The differences between the ride time curves for many-to-one and doorstep subscription probably reflect the routing efficiencies that are easier to obtain with advanced or standing service requests, and the band between these curves should be treated as range over which ride times might vary depending on routing efficiency. The same is true of the narrower band between checkpoint only and checkpoint subscription. The difference in ride times between 1- and 2-sector operation on these modes reflects varying degrees of lateral movement that is necessary in travelling through the service area. Note that with 4 sectors, the checkpoints for a subscription or checkpoint-only service fall into a straight line, so the ride time should be about the same as the fixed-route service with 4 routes.

Figure B-7 contains similar plots for deviation services, with the fixed-route curves supplied for comparison. Figure B-8 contains plots for various modes in a service area with a 4:1 aspect ratio. In the latter figure, all modes are operated with only 1 route or sector.

Note that walk and wait time, which will vary by mode, are not included in these figures.

Figure B-6:

ESTIMATED RIDE TIMES ON FEEDER MODES (GRAPH 1)

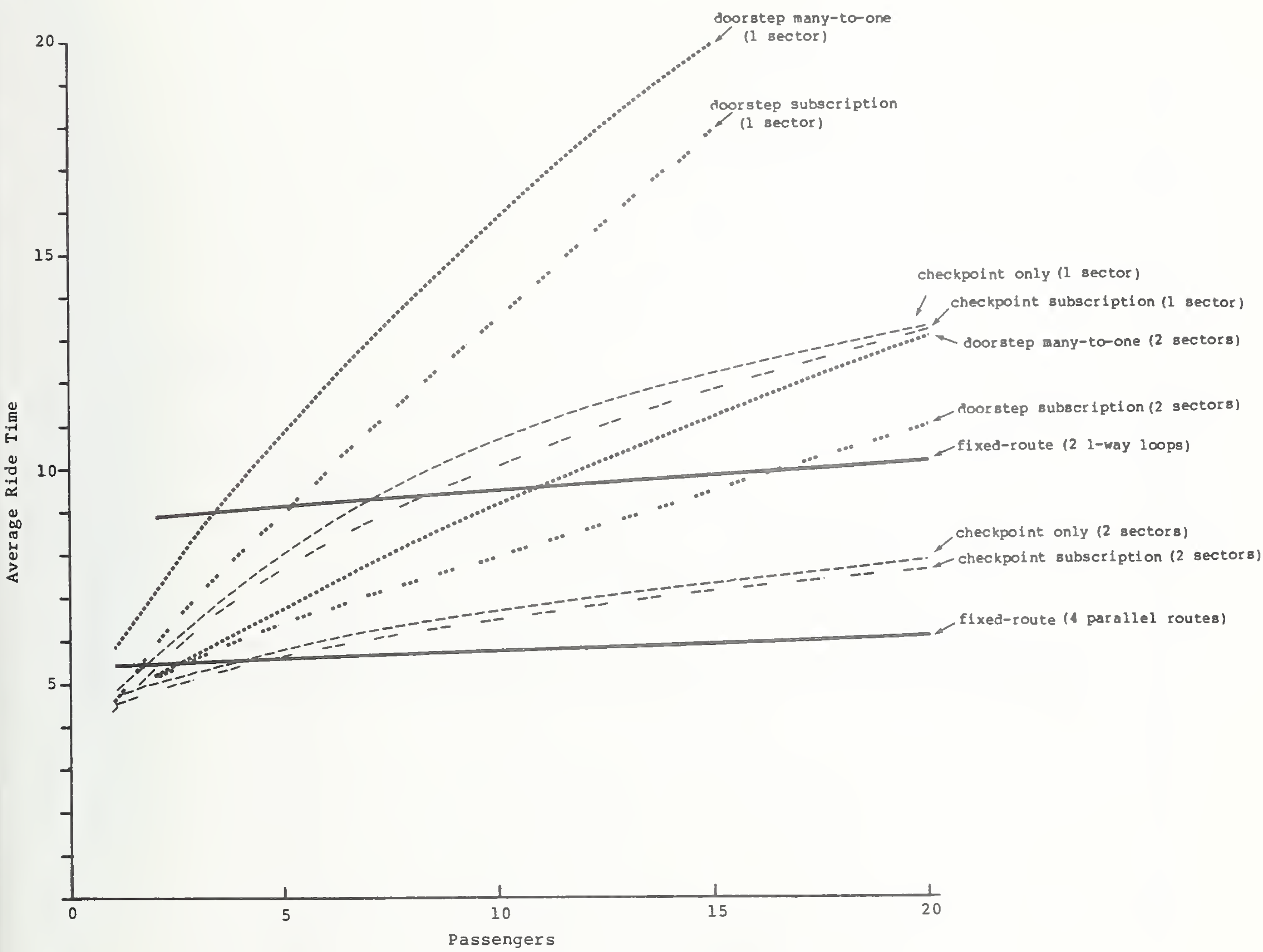


Figure B-7:

ESTIMATED RIDE TIMES ON FEEDER MODES (GRAPH 2)

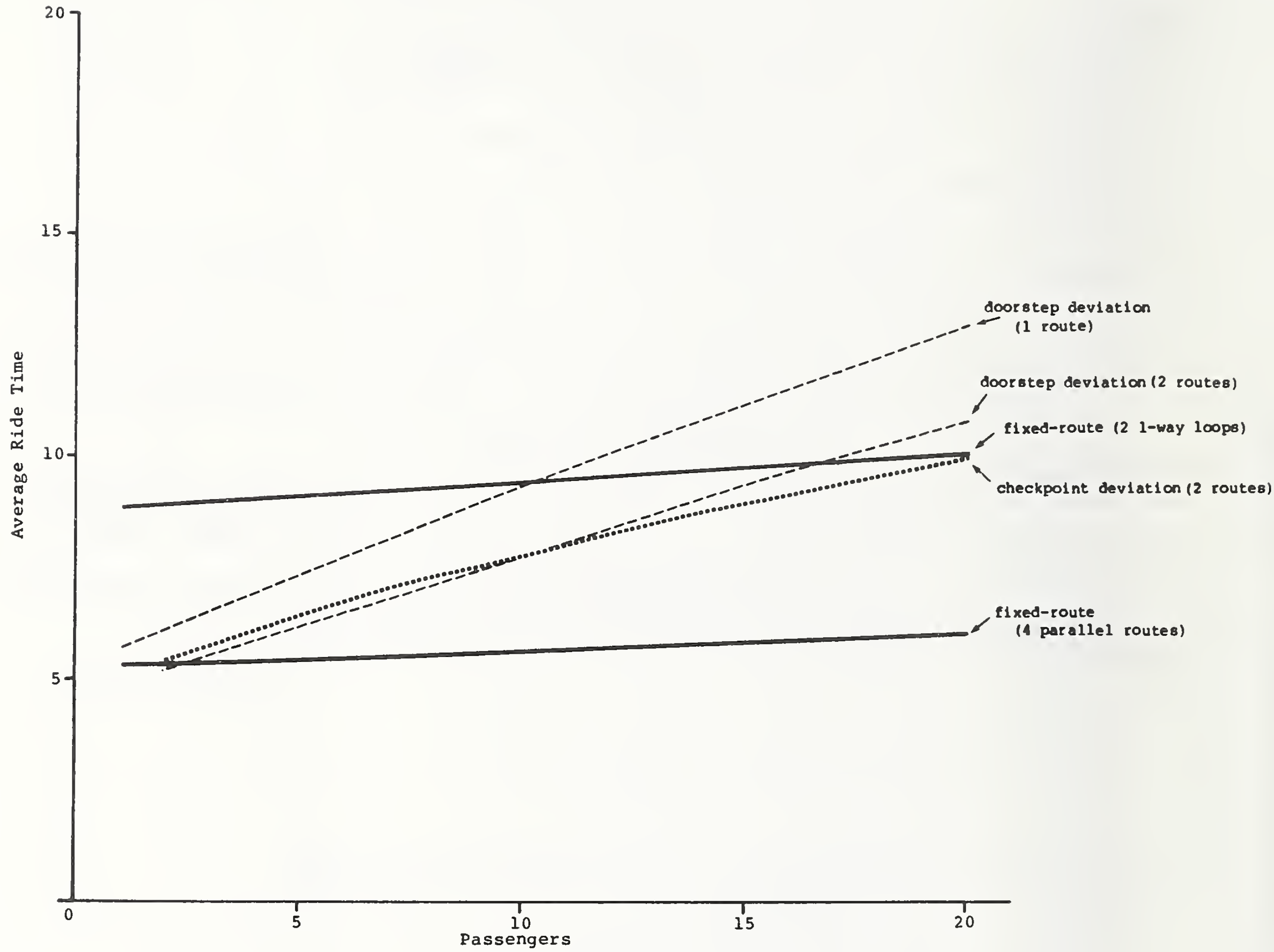
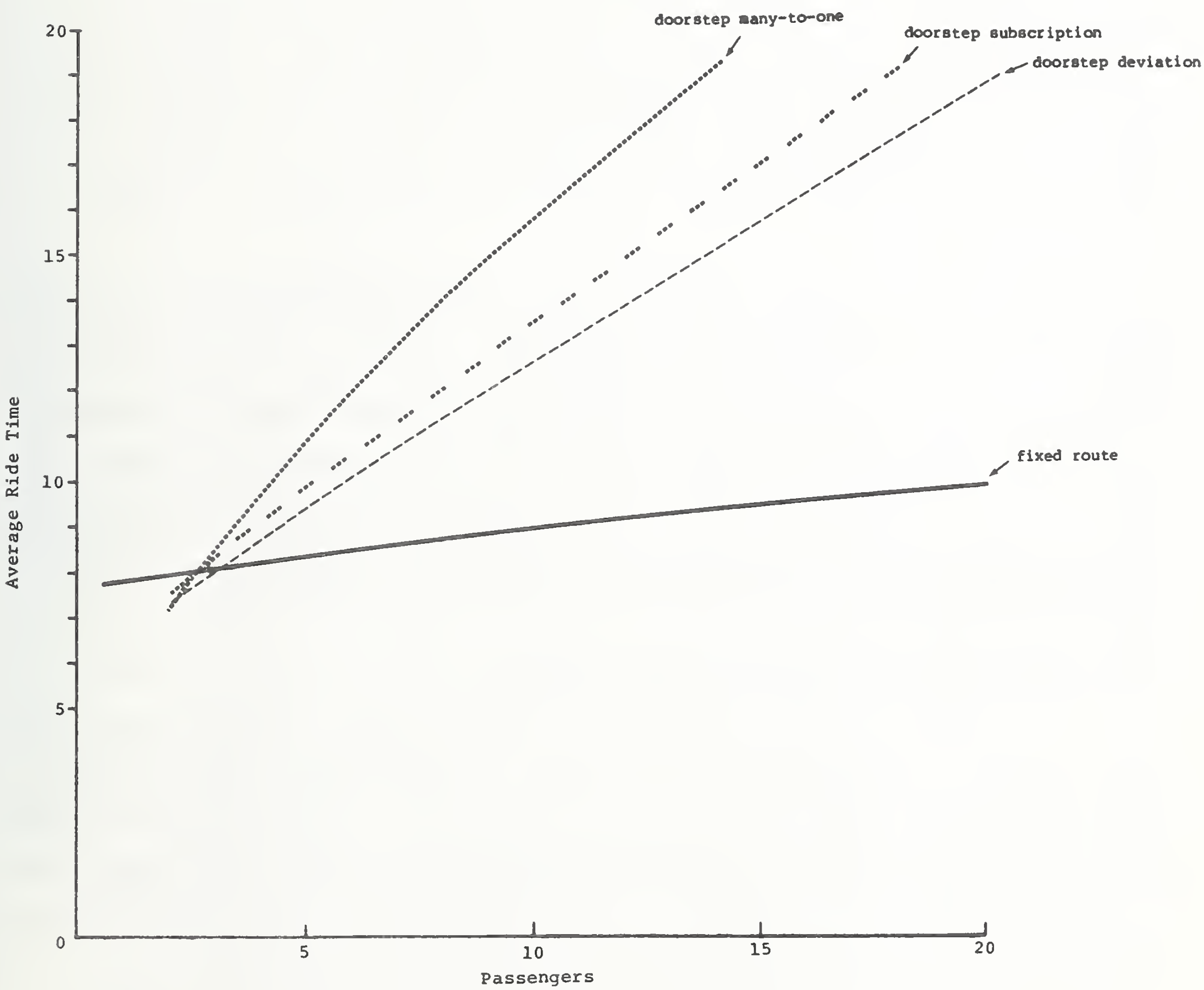


Figure B-8:

ESTIMATED RIDE TIMES ON FEEDER MODES (GRAPH 3)



B.3 Wait Time and Related Measures

Wait time elasticities and model coefficients capture two aspects of service quality that are difficult to separate:

- o the actual time spent waiting for a bus
- o the extent to which trips have to be advanced or delayed to coincide with transit schedules.

For regular route service, both aspects are related to the headway between successive vehicles, and one half the headway often is used as a combined measure of wait time and schedule delay. In assessing a feeder service, however, its frequency has to be considered in relation to the line-haul route being fed. For example, a coordinated feeder/distribution that meets all line-haul vehicles adds no schedule delay, and the additional wait time is only the one or two minutes of early arrival (or late departure) at the station needed to reliably coordinate the service.

Doorstep and deviation options also affect these measures and their significance, and least on outbound trips. Except with a subscription service, a traveller boarding at an off-route location cannot simply arrive at a stop. A service request must be made, and the minimum response time may add to wait time and schedule delay. For a checkpoint service, however, this added time may coincide with the walk to the checkpoint and not be fully noticed. For a doorstep service, all wait time is spent at home on the outbound trip, and may be less onerous than waiting at a bus stop.

B.4 Quality Measures for Many-to-Many Service

The principal quality measures for a many-to-many service are average ride time and average response time (i.e., the time that elapses between a request for service and the arrival of a vehicle). The procedure presented below to estimate these measures uses average productivity (i.e., passengers per vehicle-hour) as a parameter, so the procedure may have to be applied iteratively with the procedure selected for ridership estimation.

The equation used for estimating average ride and response time both use operating speed as a parameter. This value can be estimated as follows:

$$OSPD = BSPD * \left[1.0 - NAS * \frac{TPS}{60} - PROD * \frac{TBD + TAL}{60}\right] \qquad (B-21)$$

where:

OSPD = average operating speed (in mph)

BSPD = average running speed (in mph)

NAS = number of stops

= 2 * PROD (for doorstep service)

$= NCPT \left\{1 - \exp\left[-\frac{2 * PROD}{NCPT}\right]\right\}$ (for checkpoint service)

PROD = average vehicle productivity

$= \frac{PVOL}{.85 * FLEET * HOURS}$

PVOL = average number of passengers carried during the analysis period

HOURS= duration of the analysis period (in hours)

FLEET= fleet size

NCPT = number of checkpoints

TPS = time spent decelerating, accelerating and opening and closing doors at a stop, including time spent finding address (in seconds)

TDB = average boarding time of a passenger (in seconds)

TAL = average alighting time of a passenger (in seconds)

Typical values of TPS, TDP and TAL are shown in Table B-1.

Response time can be calculated using the following equation:

$$TRES = (1 + ALF + BET) * \left[\frac{60 * SGF}{2 * OSPD}\right] * \sqrt{\frac{AREA}{0.85 * FLEET}} * \exp(Y1) \qquad (B-22)$$

where: TRES = average response time (in minutes)

ALF = 0.5 (for manual dispatch)
= 0.0 (for computer dispatch)

BET = min (0.5, 0.05 * AREA) (for manual dispatch)
= 0.0 (for computer dispatch)

SGF = street geometry factor
= 1.27 (for a grid network)

AREA = service area (in square miles)

$$Y1 = K1 * (PROD)^{K2} * \sqrt{\frac{AREA + 4.0}{0.85 * FLEET + 12.0}}$$ (for doorstep service)

$$= K3 * (PROD)^{K4} * (AREA)^{K5}$$ (for checkpoint service)

K1 = 0.22 (for dial-a-ride)
= 0.20 (for shared-ride taxi)

K2 = 0.9 (for dial-a-ride)
= 1.0 (for shared-ride taxi)

K3 = 0.39

K4 = 0.34

K5 = 0.20

Average ride time on a many-to-many service can be calculated using the following equation:

$$TRID = \frac{60.0 * SGF * DIST}{OSPD} * \exp(Y2) - WADJ \qquad \text{(B-23)}$$

where:

TRID = average ride time (in minutes)

DIST = average trip distance (airline, in miles)

$$Y2 = K6 * \left[\frac{PROD * AREA}{FLEET}\right]^{K7}$$ (for doorstep service)

$$Y2 = K8 * (AREA)^{K9} * (FLEET)^{K10} * (PROD)^{K11}$$ (for checkpoint service)

K6 = 0.084

K7 = 0.7

K8 = 0.14

K9 = 0.46

K10 = 0.69

K11 = 0.71

WADJ = adjustment (for manually dispatched doorstep service only)

$$= \left[\frac{BET}{1 + ALF + BET} \right] * TRES$$

Finally, walk time for checkpoint many-to-many service can be estimated using the procedure presented in Section B.1.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1985—461-816/20056

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