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August 1983

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16. Abstract

Timed transfer is a transit operating strategy in which vehicles from different routes are routed and scheduled to meet simultaneously at common stops to facilitate no-wait or minimum-wait passenger transfers. Timed transfers are being used primarily in medium-density areas, where transit demand may be too low to support high-frequency transit service on a system of intersecting routes. This report examines timed transfer systems to gain a better understanding of their applications and services.

The report describes various U.S. and Canadian timed transfer services, alternative transit options and the areas best suited to timed transfer. The effects of timed transfer on transit providers, transit users and the community and an evaluation of timed transfer services, ridership and costs, are included. The more complex multiple focal point timed transfer bus services are emphasized and are examined in the three case studies of Ann Arbor, Michigan, Boulder, Colorado, and Portland, Oregon. Where possible, implications and conclusions are drawn from these experiences for the benefit of others interested in implementing similar services.

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Timed Transfer, Focal Points, Transfer, Suburban Transit, Medium-Density Transit, Case Studies, Routes and Schedules, Coordinated Transit, Transit Centers

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PREFACE

This report is part of the UMTA Service and Management Demonstration Program, TSC Project Evaluation Series for the U.S. Department of Transportation. Mr. Robert Waksman of the Transportation Systems Center (TSC) served as technical monitor. Mr. Joseph Goodman of the Urban Mass Transportation Administration (UMTA) was helpful in reviewing plans and materials and in offering valuable suggestions.

The analysis was performed by SYSTAN, Inc. under the management of Dr. Roy E. Lave. Ms. Debra A. Newman served as project leader. Other SYSTAN staff members who participated in the work include Ms. Marlies Bebendorf, Dr. Paul S. Jones, Mrs. Juliet McNally, and Dr. John W. Billheimer.

Many individuals at each of the timed transfer sites provided valuable support for data collection and useful opinions and perceptions. These include:

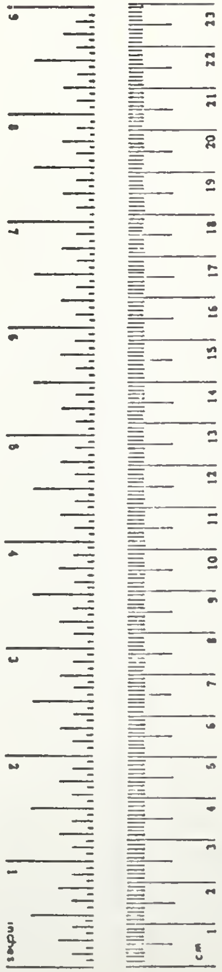
- <u>Ann Arbor</u>: Steven Fern, Thomas Hackley, Perry Schechtman, and Chris White;
- <u>Boulder</u>: Jerry Eddy, Jim Finch, Martha Hecox, William Hoople, David Leahy, Cis Leroy, Ron Mathis, Jim Oliver, Virgil Salazar, Joe Smith, Wayne Stiska, and Chris Veasey;
- <u>Edmonton</u>: John Bakker, Robert Rynerson, Dave Sinclair and Brian Sullivan;
- <u>Nassau County</u>: Larry Molson and Norman Silverman;
- <u>Norristown</u>: Charles Berriage, Ed Lynch and Charles Webb;
- <u>Portland</u>: Paul Bay, Bob Douglas, Clyde Earl, Rick Gleason, Jim Howell, Michael Kyte, Robert Prowda, Stephen Smith and Ken Stanley;
- <u>Sacramento</u>: Robert Blymyer and Mark Lonergan;
- <u>Tacoma</u>: King Cushman, Jim Denno, Robin Moore, Mary Jo Porter, and Dan Riley;
- <u>Vancouver</u>: John Day, Victor Sharmon, and Brian Sullivan; and
- <u>Victoria</u>: Dennis Grimmer, Dale Lapointe, and Glen Leicester.

The American Public Transit Association and its Suburban Issues Subcommittee were most helpful in distributing and collecting the timed transfer survey questionnaires. This survey, which provided valuable insights, could not have been completed without their assistance.

METRIC CONVERSION FACTORS

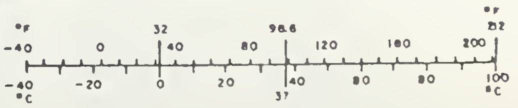
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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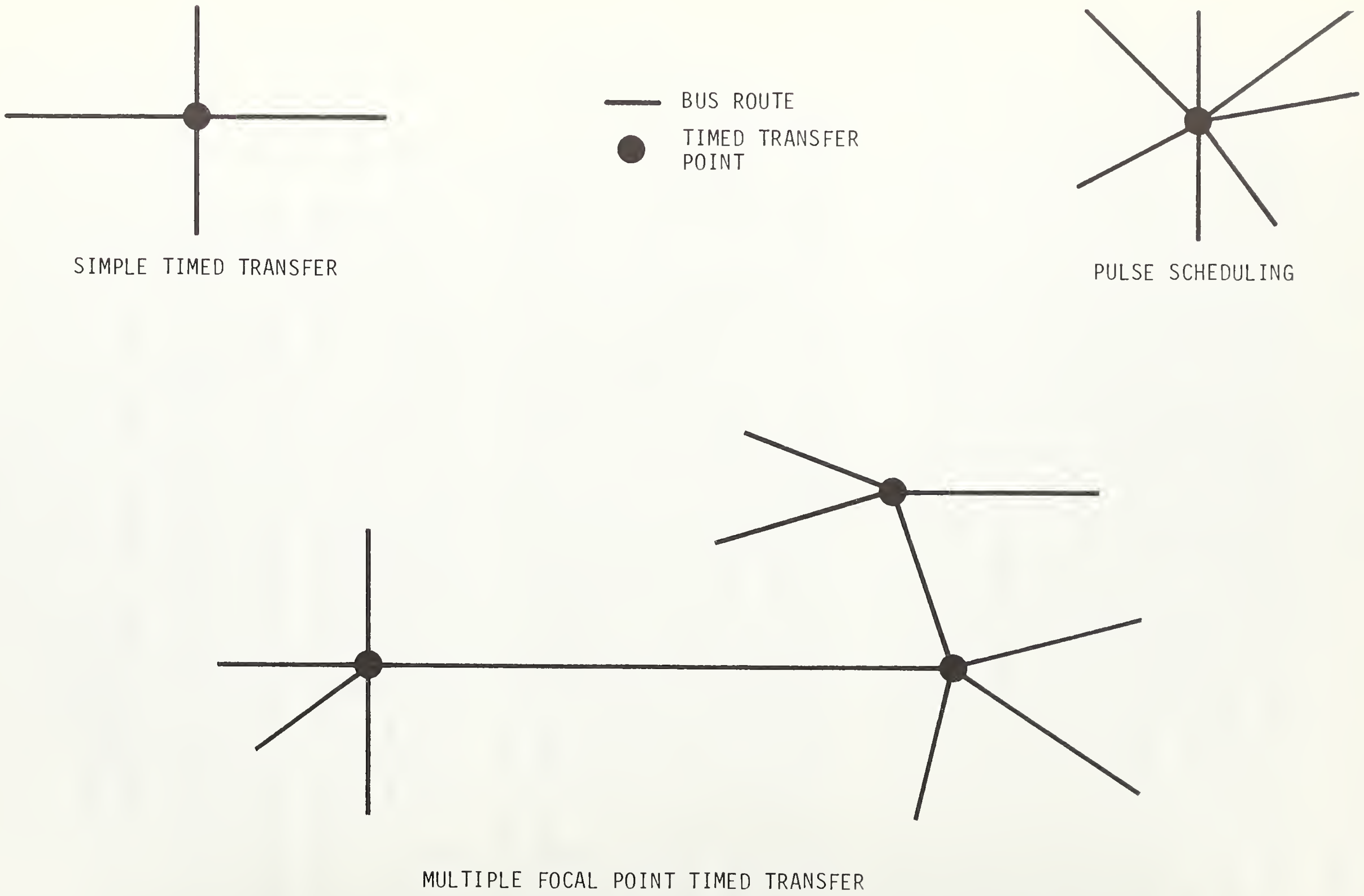
EXECUTIVE SUMMARY

Introduction

Timed transfer is a transit operating strategy designed to minimize the waiting time of passengers who transfer between routes and to facilitate passenger use of the bus system. Timed transfers are implemented in transit systems serving suburban areas of larger cities and suburb-to-CBD trips in lower density medium-size communities. In these settings, a large percentage of trips will, if taken by transit, require transfers due to the highly dispersed origins and destinations of these trips. Because low ridership on many suburban routes dictates headways of up to 60 minutes, transfer wait times with conventional transit service can be extremely long. The conventional transit alternative of reducing headways to lessen these transfer times can be very costly.

Timed transfer systems maintain the long headway routes, but establish particular transfer points at which vehicles from different routes are scheduled to meet together at regular intervals for a short time period to exchange transferring passengers. By minimizing passenger transfer times, timed transfer systems seek to improve transit accessibility and travel times between the highly dispersed origins and destinations requiring transfers and to encourage increased transit usage for such trips. These potential benefits must be weighed against the added costs involved in synchronizing the meeting of buses from different routes to produce the short transfer times.

The simplest timed transfers involve two intersecting routes which are scheduled and operated so that some or all buses on the routes meet at the transfer point at the same times (see Exhibit 1). "Pulse scheduling" involves buses from several routes. Here, buses on all (or most) routes that meet at the major transfer point are scheduled to arrive nearly simultaneously, hold until all buses have come in, and then leave together. Finally, there are multiple focal point timed transfers, where timed transfers are operational at more than one transfer point. At each point, several trunk, feeder, and circulator routes meet in timed transfers, with some of the routes serving more than one transfer point.



SIMPLE TIMED TRANSFER

PULSE SCHEDULING

MULTIPLE FOCAL POINT TIMED TRANSFER

EXHIBIT 1. TYPES OF TIMED TRANSFERS

Study Objectives

Multiple focal point timed transfers are relatively new to North American bus operations. While the first multiple-focal point operation was begun in Edmonton, Alberta in 1964, other multiple-focal point systems were not implemented until the mid-1970's in Canada and the late-70's in the United States. Single focal point timed transfer systems, which had been used extensively in the United States from the 1930's to the 1950's, started becoming popular again in the mid to late 1970's. With a growing number of U.S. properties adopting a variety of timed transfer services, UMTA's Office of Service and Management Demonstrations (SMD) in 1979 sponsored this case study evaluation of timed transfer systems. This was to be a generalized study to identify the state-of-the-art in timed transfer systems and to provide guidance to transit properties considering timed transfer implementation. The study was to examine the operational feasibility of timed transfers and the impacts of timed transfers on service design and provision, operating costs, user level of service, and ridership.

Study Scope and Methodology

The study uses an examination of several existing timed transfer systems in the United States and Canada to analyze and evaluate the timed transfer concept in general. Three U.S. multiple focal point bus systems -- in Ann Arbor, Michigan; Boulder, Colorado; and Portland, Oregon -- were selected for in-depth examination. In Boulder, an earlier system was designed around multiple focal point timed transfers; in the more recent system, transfers were facilitated by a combination of coordinated schedules and timed transfers. A few Canadian sites, in Edmonton, Alberta, and Vancouver, British Columbia, were examined because the North American multiple focal point timed transfer bus concept originated in Canada. In addition, a wide range of other types of U.S. timed transfer systems were reviewed including Eugene, Oregon; Nassau County, New York; Norristown, Pennsylvania; Sacramento, California; and Tacoma/Pierce County, Washington.

The basic study design strategy was to examine the structure, operation, and impacts of timed transfers at the three primary sites and to compare timed transfers at those sites with other transit alternatives, particularly emphasizing the systems that preceded or followed timed transfer at each site. Available data were obtained from the three sites on the configuration of the timed transfer system routes, the manner in which schedules were constructed, the timed transfer mechanism, level of service, coverage, ridership, and costs. These data were supplemented by information from the other timed transfer sites in the U.S. and Canada drawn from discussions with transit operators, operating records, and direct site observations. In addition, data on bus passenger activity and bus performance were collected at the timed transfer points in Ann Arbor, Boulder, and Portland, on two to three weekdays during 1980 and 1981 for the purpose of identifying individual and overall bus route performance and determining the operational feasibility of timed transfer. Data collectors recorded bus arrival and departure times, the number of passengers boarding and disembarking, and the incidence of passengers missing their timed transfers.

Description of the Systems Examined

Among the three primary multiple focal point timed transfer systems examined, the Ann Arbor system replaced the very costly but comprehensive Teltran combined fixed route/dial-a-ride system. The present system, implemented in 1979, contains seven timed transfer focal points. Twelve Ann Arbor routes are timed to arrive at the downtown transfer point at 15 and 45 minutes after the hour. Between two and five of these routes make timed transfers at the other six focal points. At each timed transfer point in the system, buses from many of the converging routes are scheduled for simultaneous arrival, but will wait up to two minutes for a late arrival. Two-way radio contact is maintained between the bus drivers and a central dispatcher. At the dispatcher's discretion, buses will wait up to five minutes instead of the predetermined two minutes. On the last run of the day, buses will wait until late buses arrive.

The Boulder system has evolved from a small three-point timed transfer system initiated in 1973 to a larger four-point timed transfer system (1978) transfer system and then to a coordinated transfer system (1979), where transfers are favored in one direction only. When the four-point timed transfer system was in place in 1978, nine local routes served Boulder. Six met at the downtown timed transfer point, and three met at each of the other three timed transfer points. Schedules were arranged for timed transfers during the morning and evening peaks, but not always during the off-peak periods. Although drivers on these routes were not required to wait until transfers were accomplished, they were made aware of their scheduled "meet" buses at each transfer point. Since that time, however, Boulder's scheduling objectives have changed. A major goal now is to deliver the maximum number of bus trips with given resources, an objective not totally in accord with a timed transfer system. Thus, some timed transfers have been changed to coordinated transfers, and indications are that some routes no longer have any transfers coordinated with other routes.

The Westside area of Portland is served by a timed transfer system which includes: (1) synchronized scheduling of all bus routes operating through two transfer centers; (2) trunk routes connecting the transit centers with downtown Portland; (3) local and crosstown routes radiating from the transit centers into surrounding communities; and (4) special peak-hour-only routes. Service at the two transit centers -- Beaverton and Cedar Hills -- is scheduled for every 20 minutes during peak hours (7-9 a.m. and 4-6 p.m.) and every 30 minutes during the midday. Eight routes serve the Beaverton center, four routes serve Cedar Hills, and three of these routes serve both centers. Six routes operate to the downtown Portland transit mall. Transfer layover times of from two to seven minutes are scheduled for buses making timed transfer connections. All buses are scheduled to leave at the same time. A dispatcher stationed at Beaverton can, at his discretion, dynamically hold buses to await the arrival of a late bus.

Among the timed transfer sites examined in less detail in the study, the Canadian sites, in Edmonton and Vancouver, and the U.S. sites in Nassau County and Tacoma, are all multi-focal point systems, while the Eugene, Sacramento, and Norristown sites are single point pulse systems.

The Setting for Timed Transfers

All of the timed transfer systems examined in the study operate in either medium density cities or in medium density suburbs of major cities. Population densities at nine of the ten timed transfer sites examined range from 2,250 to 6,000 persons per square mile. In these medium density areas, less costly conventional transit, with necessarily long headways on many routes, cannot adequately serve the large percentage of trips with dispersed origins and destinations because of the long wait times of the transfers involved. It can be hypothesized that timed transfer systems have not been implemented in lower density settings because overall demand levels are simply too low to justify the systems' added costs and complexities. Their absence in higher density settings likely reflects the ability of conventional radial and/or grid services to provide adequate service levels for trips with dispersed origins and destinations.

Design Considerations and Operational Effectiveness

Timed transfer systems are designed to improve transit accessibility and travel times between the highly dispersed origins and destinations requiring transfers. At the heart of the timed transfer system is the route network configuration in which all or most routes meet together at one or more timed transfer nodes. Routes are structured to serve most or all of the more frequently traveled origin-destination pairs directly, and to provide service requiring a transfer for many trips with dispersed origins and destinations. In such a network, some routes will be designed to provide service between passenger origin points and timed transfer nodes, while other routes will be structured to link the same timed transfer nodes with passenger destination points.

The key to the operational success of a timed transfer system is the ability to minimize the wait time and physical discomfort of the transfer. Physical discomfort is minimized by designing transfer facilities which minimize walking distance between buses, avoid conflicts between transferring passengers and vehicles, and provide waiting passengers some protection from the weather. Wait times are minimized through the design of coordinated meetings of buses at timed transfer points. To accomplish this, headways on the different routes are designed to be the same, or some to be integer multiples of others. In this way, all buses on routes with long headways and a large percentage of buses on short headway routes can be scheduled to arrive at the timed transfer points at the same time. In order to insure a high probability of successful transfers between all the routes scheduled to arrive at the timed transfer points at the same time, transfer windows, which provide scheduled overlapping layover at the timed transfer points, are built into the schedule of each of these routes.

At the multiple focal point timed transfer sites in Ann Arbor and Portland, routes which terminate at the timed transfer points tend to have scheduled windows of between five and ten minutes, depending on the routes' individual routing and scheduling circumstances. For routes whose transfer nodes are mid-route, the windows range from two to six minutes, with the windows for the trunk routes on the low end and those for the local routes on the high end. This design serves to minimize waiting times for through passengers, particularly those on the more heavily used trunk routes.

The Boulder system has been designed more toward schedule coordination than toward timed transfers. While most of the routes have scheduled windows of four to six minutes at the transfer points, not all of the windows are scheduled to coincide. Rather, some of the windows end just as others begin, making short wait transfers possible between some route pairs but not between others. Such a policy makes sense only where transfers between lines are strongly directional.

The configurations of the transfer points, the routes, and the schedules within individual settings can dictate or severely constrain the design of the timed transfer system. As explored in theoretical and case study examples, routes and schedules for pulse and two-point systems impose few constraints. However, as the number of timed transfer points increases and the number of routes meeting at multiple points increases, the constraints on the routes and schedules become increasingly complex. It was the consensus of transit providers who were familiar with timed transfer operations that before designing these systems, it is necessary to look at all routes and schedules as an interrelated network system. Phased or incremental implementation was identified as a means of reducing the complexity of such systems.

Bus arrival and departure time data taken at the Ann Arbor and Portland timed transfer points indicate that the operational effectiveness of the timed transfer mechanism is fairly good. During the period in which this data was collected, 95 percent of the passengers at the seven Ann Arbor transfer points successfully made their transfers, while at the two Portland timed transfer points, 98 and 99 percent of the passengers successfully transferred. At the two sites, reliability, measured as the mean and variability of arrival time about the schedule at the timed transfer points, varied significantly between local and trunk routes. Local routes tended to be most reliable, presumably because they traveled through less congested areas than the trunk routes. They reached the timed transfer points ahead of the through trunk lines and followed them out, minimizing delays for through trunk lines. Trunk lines that terminated at transfer points were less reliable than local routes. Trunk routes that had mid-route transfer stops had the least reliable arrivals at the transfer points. In most cases, trunk route buses with mid-route transfers stopped at the transfer points only for the amount of time required for passenger transferring.

It is clear that accurate schedules and fairly reliable service are needed to insure the operational success of timed transfers. The design and maintenance of accurate schedules requires periodic monitoring of route running times and timely schedule adjustments as needed. From a general examination of timed transfer operations and from observations at the study sites, it can be postulated that the effects of unreliable service can be counteracted to some extent by closer supervision of buses, improved driver operation at the timed transfer points, and possibly increased window size at the timed transfer points. Through closer supervision of buses, dispatchers can take corrective action to ensure that early or late buses arrive at the timed transfer point at the proper time, and they can hold on-time buses late at the transfer point to wait for late arriving buses. Regular en route reporting by drivers, as is done in Ann Arbor, can facilitate this supervision and provide an information base for emergency situations. Drivers can be instructed, as in Portland, to wait for any late arriving buses that they see coming as they are ready to pull out.

While increasing window size is a means of improving the chances of successful meets, there are clear disadvantages to increasing it too much. Past a certain point, larger windows increase waiting time and travel time for a far larger number of transit system users than are helped through facilitation of successful transfers. Also, the added window time that must be incorporated into the schedules might significantly increase operating costs. The operational data taken at the Ann Arbor and Portland sites indicate that a high proportion of successful transfers can be completed with windows of five to ten minutes at the transfer points for all but the trunk routes not terminating at the transfer points, and with windows of only two to three minutes for these trunk routes. It cannot be concluded that these are the minimum values that should be used for timed transfer windows elsewhere since the operational effectiveness of a timed transfer system with smaller windows is unknown.

User Level of Service Impacts

A major purpose of timed transfer systems is to reduce transfer wait time significantly for passengers making many kinds of crosstown and suburban trips. An examination of the structure of and service supplied by timed transfer systems indicates that, in many cases, average transfer wait times ranging from 10 to 15 minutes on conventional service can be reduced to 5 minutes or less on timed transfer systems. Timed transfer systems may also reduce wait times for passengers using only trunk service, since timed transfer systems often consolidate trunk service, making trunk route service frequencies higher than on more conventional service. On the other hand, timed transfer systems will increase travel time for some passengers because routes are diverted to transfer points and passengers may have to wait onboard buses while the timed transfers are completed. Furthermore, some passengers who in a more conventional system would have direct service may be forced to transfer with the timed transfer system.

To facilitate the adjustments passengers will have to make and to try to overcome their long-term resistance to transferring, most timed transfer operators have necessarily initiated marketing campaigns, set up community meetings, distributed new maps and schedules, and provided on-site staff assistance.

This study was, for the most part, unable to examine the extent and composition of transferring at the three primary timed transfer sites before and after timed transfer implementation. An onboard survey conducted by Ann Arbor in April 1981 indicated that about 21 percent of the passengers using the timed transfer system required one transfer, and less than one percent required two transfers. By comparison, on the previous combination fixed route/dial-a-ride system, 29 percent of the passengers made one transfer and three percent made two. This earlier system, however, required transfers between dial-a-ride zones.

This study did conduct an analysis of door-to-door travel times at the Ann Arbor, Boulder and Portland timed transfer sites before and after timed transfer implementation using a set of 11 to 20 origin-destination pairs at each site considered representative of travel there. In Ann Arbor, timed transfer fixed-route trips were found to be slightly faster than the same 1979 fixed route/dial-a-ride system trips. In Portland, the sample trip analysis suggested that the timed transfer service was also slightly better than the conventional low-level services it replaced. However, in Boulder, the transit services oriented more toward coordinated transfers were slightly faster than the earlier timed transfer services.

Ridership Impacts

In a timed transfer system, it is expected that a larger percentage of passengers will transfer than in a more conventional system. Much of this increased transferring is hypothesized to be the result of the greater attractiveness of transit trips with dispersed origins and destinations, which will encourage new passengers to take trips requiring transfers. In addition, the very structure of the system may force others to transfer who could have made the same trip without transferring in a more conventional system. Some of these riders forced to transfer may curtail or eliminate their transit trip making.

Given this expected high rate of transferring, it was not surprising to find that the number of unlinked trips increased substantially at the three primary sites following the implementation of timed transfer systems. One transferring passenger makes two or more unlinked trips. Only the number of unlinked passenger trips could be measured directly. Thus, it is unclear to what extent the total number of passengers increased, or whether any increase in the number of unlinked trips was due simply to a given number of passengers making more transfers. Furthermore, even if the number of passengers did increase following timed transfer implementation, it would be impossible to tell how much, if any, of that increase could be attributed to the timed transfer mechanism itself and not to service expansions which were generally implemented simultaneously.

Cost-Effectiveness

A timed transfer system, when compared with a more conventional fixed route system with similar service frequencies and route destinations, provides improved level of service for many trips with dispersed origins and destinations requiring transfers. It may provide better or worse level of service for other trips, depending upon passengers' origin-destination pairs and the timed transfer system's structure. The greatest benefits of a timed transfer system will accrue to new transit users who are attracted to it because of the improved level of service provided for the dispersed origin-destination trips.

It can be concluded that a timed transfer system should be given consideration only if there are some indications that: (1) a market exists specifically for this service (i.e., the service can attract new ridership from among those trips with dispersed origins and destinations requiring transfers), and (2) any improvements in service for new passengers are not unduly at the expense of passengers who could be served directly with more conventional service, particularly those now forced to transfer.

While timed transfer systems likely provide superior level of service than more conventional fixed route systems providing comparable service frequencies and route destinations, they are clearly more costly to operate. There are start-up and capital costs associated with the introduction of timed transfer systems, and incremental operating costs involved in providing the synchronized arrival and departure of buses from different routes at transfer points necessary to make timed transfers work. Start-up and capital costs depend on the kinds of systems they replace, the capital investments at the transfer points, the initial planning, marketing, scheduling, training and supervisory efforts, and any changes in vehicle or equipment expenses. Incremental operating costs result from the need to: (1) set headways on intersecting timed transfer routes to multiples of each other even if demand patterns indicate that somewhat longer headways are adequate, and (2) provide sufficient extra layover time at the transfer points and at route ends to insure synchronized arrivals and departures.

In Ann Arbor, most of the capital and start-up costs for timed transfer services resulted from the replacement of most of the dial-a-ride vans used in the previous Teltran dial-a-ride service with conventional buses. As the new buses were financed entirely through Federal and state subsidies, the local transit agency did not incur any new costs. Existing dial-a-ride transfer points were used by the timed transfer system as were the existing radios in the dial-a-ride vans. Annual system costs declined about 13 percent in the year following timed transfer system implementation, but this was primarily attributable to the switch from the more costly dial-a-ride service.

Data from Boulder indicates that conventional bus purchases for fleet expansion prior to timed transfer implementation were directly related to a simultaneously occurring increase in service. A planned transit center for downtown Boulder (a 5000 square foot building) was estimated to cost about $1.7 million in 1979, of which about half was for land acquisition. Operating cost data indicated a steady increase in operating costs from before timed transfers in 1977 to during timed transfers in 1978 to after timed transfers in 1980 that could, in large part, be explained by a combination of service expansions and overall rises in unit operating costs due to escalating wage rates and fuel costs.

In Portland, the following capital and start-up costs were incurred with the introduction of timed transfer services in 1979:

Shelters	$10,000
Curb modifications, signs	90,000
Marketing	50,000
Driver training	160,000
Extra supervision	110,000
Total	$420,000

Bus lease costs were incurred in expanding the size of the fleet, but much of these costs can be directly associated with the provision of expanded service. Operating costs increased by 46 percent following timed transfer implementation, but again, much of this increase can be attributable to service expansion.

At all three sites, bus purchase and leasing costs and operating cost increases attributable to timed transfer implementation could not be determined because of simultaneously occurring sizeable changes in the quantity and type of service provided. Nevertheless, these costs must be taken into account when considering the cost effectiveness of converting from a conventional bus system to a timed transfer system with comparable frequencies and route destinations. The available data do indicate that timed transfer systems offer a less costly alternative to providing improved level of service for trips with dispersed origins and destinations than does increasing service frequencies on conventional fixed route service. And, as shown in Ann Arbor, timed transfer services appear to offer a viable, less costly, alternative to a comprehensive integrated dial-a-ride/fixed route system.

Unresolved Issues and Future Course of Study

This study was mainly a generalized state-of-the-art and case study review which provided detailed descriptions of a number of timed transfer sites, presented operators' perceptions, and examined design considerations and the workability of timed transfers. As such, the study should provide guidance to transit operators considering the implementation of timed transfers at their sites.

However, this study was not an SMD evaluation where SMD funds are allocated to collect detailed data before and after project implementation, and the data forms the basis for in-depth, rigorous evaluation. Instead, the study had to rely on available data furnished by the study sites. As a result, the study, was somewhat limited in the conclusions it could draw. It was unable to resolve satisfactorily the important issue of whether the added costs of converting from a conventional bus system to a timed transfer system with comparable service frequencies and route destinations are worth an uncertain set of added benefits. Less costly conventional transit in these medium density areas, with necessarily long headways on many routes, cannot adequately serve the large percentage of trips with dispersed origins and destinations because of the long wait times of the transfers involved. The study was unable to adequately quantify the added costs of timed transfers, nor could it measure the ridership impacts, specifically whether the timed transfer systems were able to tap a new market and attract new riders without negatively impacting riders who would be well served with more conventional transit. This was because: (1) the implementation of substantial service changes, usually expansions, simultaneously with timed transfer implementation made it difficult to separate out the effects of one from the other; (2) there was no opportunity to conduct onboard surveys before and during timed transfer implementation which would have yielded information on changes in passenger trip making, transfer incidence, and perceptions; and (3) there was an absence of time series ridership and cost data which might have made it possible to isolate some of the timed transfer impacts.

1. INTRODUCTION

1.1 BACKGROUND

1.1.1 What is Timed Transfer?

Timed transfer is a transit operating strategy in which vehicles are routed and scheduled to meet simultaneously at common stops to facilitate passenger transfers. In timed transfer systems, common stops are located at activity centers or focal points[1] that are origins or destinations for many trips. Route connections are scheduled so that no-wait or minimum-wait transfers are possible.

1.1.2 Where are Timed Transfers Being Used?

Timed transfers are being implemented primarily in suburban areas and medium-size communities, where transit demand is too low to support high levels of conventional transit service. Timed transfer systems have also been used to attract new transit riders and have been especially popular as a means of introducing or extending transit into new low density service areas. In the United States, timed transfer bus systems with multiple focal points are operating or have operated in Ann Arbor, Michigan; Boulder, Colorado; suburban areas of Portland, Oregon; and Pierce County (Tacoma), Washington. A multiple focal point bus and rail timed transfer system also operates in Nassau County, New York. In Canada, multiple focal point timed transfer systems operate in Edmonton, Alberta and Vancouver and Victoria, British Columbia.

Single focal point timed transfer bus operations, or "pulse" systems, have a long history of successful operation in the U.S., particularly from the 1930s to the 1950s. Pulse systems are relatively easy to implement in small communities where downtown "meets" provide transfers among radial routes. Pulse systems are also common in larger communities for late night "owl" services. Some single-point locations include: Bellingham, Washington; Brockton, Massachusetts; Eugene, Oregon; Longmont, Colorado; Norristown, Pennsylvania; Rochester, New York; Sacramento, California; and Superior, Wisconsin. Although the use of single-point timed transfers among buses and single and multiple

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[1] Timed transfer systems are often referred to as "focal point" systems.

point timed transfers among other modes of transport will be discussed, this report will concentrate on the use of multiple point timed transfer bus systems.

1.1.3 History of Timed Transfer Systems

Although the use of timed transfers with multiple focal points is relatively new to North American bus operations, the timed transfer concept is not new. One western European railroad has operated a timed transfer system for over thirty years. Many airlines have built their services around focal point airports and use timed transfer operating strategies. Furthermore, many U.S transit operators have operated single focal point timed transfers for years.

During World War II, the Dutch Railways developed an intercity railroad network with scheduled 30-minute "meets" at major terminals. This system provided convenient access among all parts of the country. Schedule maintenance and on-time reliability were stressed to insure that transfer wait times and total travel times were minimized. Today, this timed transfer rail system still operates in the Netherlands and local feeder bus services are scheduled to connect with the railways.

The West German railroads and the Swiss Federal Railways (SBB) also use timed transfer focal point systems of operation. In June, 1980 SBB rerouted practically all of Zurich's main line long-haul passenger trains through their new airport terminal. Every hour, air travelers are offered the certainty of at least one intercity train and every half hour at least one train to Zurich's main station. In 1981, SBB plans to expand this service nationwide with an express intercity train, a semi-fast train and an all-stations regional train -- at fixed hourly intervals, at every major terminal. Extra peak service and international peak express service will be superimposed on the domestic structure.[2]

The timed transfer concept has also been used extensively in the U.S. airline industry to bring dispersed groups of passengers to focal terminals for coordinated transfers to connecting routes. Most seasoned American air travelers have experienced timed transfers in the Atlanta, Chicago or Denver "focal point" airports. Incoming flights are scheduled to arrive at approximately the same time. Layover schedules are coordinated to allow concurrently arriving passengers to disembark, walk to their connecting gate and board their outbound flight. Departing flight schedules are then coordinated to take-off at approximately the same times.

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[2] Allen G. Freeman, "Window on Europe: Switzerland's New Air-intercity Rail Line," Passenger Train Journal, October/November, 1980.

In recent years, many of the airlines have posted personnel and television-type screens next to popular incoming flight gates to indicate connecting flight information. Heavily travelled connecting flights may also be assigned to proximate gates, to minimize passenger walk and transfer time. And, if bad weather or congested air traffic causes a small delay on a major inbound flight, the ground supervisory staff may elect to hold outbound connecting flights, rather than facing stranded airline customers. All of these strategies are now being tried in timed transfer bus operations.

1.1.4 Timed Transfer Objectives

American public transit systems have had similar objectives for developing timed transfer services. Exhibit 1.1 lists the major objectives for six of the transit systems included in this evaluation. Each of these systems generally addressed one or more of the following objectives:

- Improve accessibility to more areas and activities;
- Minimize travel times, especially to downtown;
- Simplify route structure and/or schedule;
- Increase transit ridership; and
- Improve operating efficiency.

1.2 OVERVIEW OF THE STUDY

1.2.1 Purpose

In 1979, the Transportation Systems Center (TSC) in its role as evaluator of SMD projects, asked SYSTAN, Inc. to conduct a special evaluation study of timed transfer systems. The objectives of the study were to identify the state-of-the-art in timed transfer systems; to examine selected timed transfer systems operating in the United States and Canada; to collect descriptive data and operating statistics; to evaluate the effectiveness, the efficiency and the impacts of these systems; and to learn more about the potential future applications for timed transfer. This information is summarized in this report.

Exhibit 1.1

SYSTEM OBJECTIVES

SYSTEM	OBJECTIVES
Ann Arbor[1]	• Provide access to employment with sufficient peak-hour capacity. • Provide direct and convenient service. • Minimize trip time between major activities. • Provide equitable service to all groups and improve service quality for individual riders. • Provide home-based local services. • Provide cost-efficient services. • Provide a high level of service to downtown. • Provide service for midday (non-work) trips.
Boulder[2]	• Improve bus routing to increase level of service and to simplify the route structure. • Improve interline coordination and minimize transfer delay. • Distribute service more equitably over entire service area. • Improve transit travel times. • Increase operating efficiency of vehicles and drivers. • Increase transit ridership.
Portland[3]	• Improve local service in suburban neighborhoods and to major activity centers to more effectively serve county travel patterns. • Provide high quality peak-hour service to downtown. • Increase bus ridership in new service area. • Improve cost efficiency in new service area.
Tacoma[4]	• Increase accessibility to more activity centers. • Provide more frequent local service. • Expand service outside Tacoma to add mobility for area residents. • Provide special commuter services. • Provide special elderly and handicapped services. • Provide services between local towns and cities to military bases and connections to adjacent Metro (Seattle) services. • Meet mobility needs cost-effectively.
Norristown[5]	• Provide better area coverage. • Design an easier to understand route and fare structure. • Improve schedule coordination with other SEPTA routes. • Make transferring easier. • Increase passenger accessibility to entire system.
Sacramento[6]	• Reduce travel time between downtown and suburban neighborhoods, especially during the midday. • Simplify the route structure. • Simplify the schedule by using clocked headways at timed transfer terminals. • Increase the number of passenger-per-vehicle service hours.

[1] Ann Arbor Transit Authority — Table 1 — "Ranked Objectives," Revised November, 1978.

[2] Donnelly, Robert and Paul Ong, *Evaluation of the Denver RTD Route Restructuring Project*, DeLeuw Cather and Company, San Francisco, CA, September, 1980, p. 1.

[3] Gleason, Rick, "Westside Service Evaluation," Tri-Met Planning Department, Portland, Oregon, October, 1980, p. I-3.

[4] Cushman, King, *Comprehensive Transit Plan: Final Report*, Parsons Brinkerhoff, Seattle, Washington, December, 1979, p. iii.

[5] Webb, Charles L., *The Frontier Division: A SEPTA Success Story,* SEPTA Planning Department, Philadelphia, May, 1979, pgs. 14-18.

[6] Thompson, Paul D., "The Transit Center Concept as Applied in Sacramento, California" Case Study No. 5 (UMTA-WA-11-0007-5), September, 1980, p. 1.

1.2.2 Scope

SYSTAN identified over 60 transit systems in the United States, Canada and other foreign countries where some form of timed transfer service exists or is being planned. These sites were identified from the recent case study literature[3] and through discussions with U.S. and Canadian transit researchers and operators. Exhibit 1.2 lists these sites.

Most of the U.S. systems are single focal point bus operations, which have existed for many years. The more innovative multiple focal point bus systems have developed in the United States only recently. Several of these followed the example of earlier Canadian systems. Of the U.S. systems listed in Exhibit 1.2, several are operating between many focal points, some include multiple modes of transportation and others are only in the planning stages. Exhibit 1.3 classifies the U.S. sites according to the following categories:

- Multiple Focal Point Systems
  - Fixed-Route Bus Only
  - Multi-Mode

- Single Focal Point Systems
  - Fixed-Route Bus Only
  - Multi-Mode

Three U.S. multiple focal point bus systems were selected for in-depth evaluation. The three sites are: Ann Arbor, Michigan; Boulder, Colorado; and Portland, Oregon. A few Canadian sites are discussed because the North American multiple focal point timed transfer bus concept originated in Canada. In addition, descriptive examples are presented for a wide range of other types of U.S. timed transfer systems, including: Eugene, Oregon; Nassau County, New York; Norristown, Pennsylvania; Sacramento, California; and Tacoma/Pierce County, Washington.

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[3] Two primary sources included: Charles River Associates, Inc. State of the Art of Current Practices for Transit Transfers, Cambridge, MA, July 1981 (Report No. UMTA-MA-06-0049-80-13); and

Schneider, Jerry et.al. Planning and Designing a Transit Center Based Transit System: Guidelines and Examples from Case Studies in Twenty-Two Cities, Seattle, WA, September 1980 (Report No. UMTA-WA-11-0007-RR80-2).

Other sources are included in the references.

Exhibit 1.2

TIMED TRANSFER SITES

U.S. Systems

- Albany, New York
- Ann Arbor, Michigan
- Bellingham, Washington
- Boulder, Colorado
- Brockton, Massachusetts
- Chigago, Illinois
- Cleveland, Ohio
- Columbus, Ohio
- Davenport, Iowa
- Denver, Colorado
- Des Moines, Iowa
- Eugene, Oregon
- Everett, Washington
- Fresno, California
- Haverhill/Lawrence, Massachusetts
- Indianapolis, Indiana
- Knoxville, Tennessee
- Lafayette, Indiana
- Lewistown, Maine
- Longmont, Colorado
- Los Angeles County, California
- Memphis, Tennessee
- Minneapolis, Minnesota
- Nassau County, New York
- New York City, New York
- Norristown, Pennsylvania
- Norwalk, Connecticut
- Orange County, California
- Portland, Oregon
- Radnor, Pennsylvania
- Rochester, New York
- Sacramento, California
- San Diego, California
- San Francisco, California
- San Jose, California
- Seattle, Washington
- Sioux City, Iowa
- Superior, Wisconsin
- Tacoma, Washington
- Toledo, Ohio
- Washington, D.C.
- Westport, Connecticut

Canadian Systems

- Edmonton, Alberta
- Kamloops, British Columbia
- Kelowna, British Columbia
- Kitimat, British Columbia
- London, Ontario
- Nanaimo, British Columbia
- Penticton, British Columbia
- Prince George, British Columbia
- Prince Rupert, British Columbia
- Saskatoon, Saskatchewan
- Vancouver, British Columbia
- Victoria, British Columbia

Other Foreign Systems

- Belinda, Kenya
- Canberra, Australia
- West Germany
- Jutland, Denmark
- New Delhi, India
- Osaka, Japan
- Switzerland

Exhibit 1.3

CLASSIFICATION OF U.S. TIMED TRANSFER SYSTEMS

Multiple Focal-Point Systems		Single Focal Point Systems	
Fixed-Route Buses	**Multi-Mode**	**Fixed-Route Buses**	**Multi-Mode**
Boulder, CO	Ann Arbor, MI	Albany, NY	Norristown, PA
Denver, CO*	Nassau County, NY	Bellingham, WA	Cleveland, OH
Everett, WA	Norwalk, CT	Brockton, MA	Indianapolis, IN*
Fresno, CA	San Diego, CA*	Columbus, OH	New York City, NY
Haverhill/Lawrence, MA	Seattle, WA*	Davenport, IA*	
Knoxville, TN	Westport, CT	Des Moines, IA*	
Lafayette, IN		Eugene, OR	
Lewistown, ME		Longmont, CO	
Los Angeles, County, CA*		Memphis, TN	
Minneapolis, MN*		Orange County, CA	
Portland, OR		Rochester, NY	
San Francisco, CA		Sacramento, CA	
San Jose, CA*		Sioux City, IA*	
Tacoma/Pierce County, WA		Superior, WI	
		Toledo, OH	
		Washington, DC	

*Planned system

1.2.3 Issues and Impacts

Major issues and impacts of timed transfer transit systems are examined from the standpoint of transit operators, policy makers, and planners. These include the:

- Setting and Structure: What geographic features, population densities, and transit demands lend themselves to timed transfer operations? What type of route structure and network is appropriate? And what service alternatives should be considered, where should transfer centers be located, and how should routes and schedules be coordinated?

- Implementation Implications: What are the implications for planning, designing, and implementing a timed transfer system? What institutional barriers may prevent operators from offering timed transfer systems, travelers from using them, and the community from accepting them? And what experiences are available to help guide others who may be interested in implementing timed transfer?

- Impacts: What are the impacts of operating a timed transfer system? What are the effects on the level and quality of service, the ridership, and the costs? And how do these impacts compare with other service alternatives?

- Case Studies: What specific site experiences are available on timed transfer? What type of systems preceeded timed transfer, what motivated the change in services and how were the routes and schedules designed? And what are some of the detailed operating experiences in these sites?

1.2.4 Evaluation Data and Analysis

An evaluation plan was designed during the early phases of this study. This plan identified the major timed transfer evaluation issues, and proposed analyses strategies and data collection requirements. The basic analyses strategy was to compare timed transfer with other transit alternatives, with particular emphasis on, the systems that preceeded or followed timed transfer in each site. Detailed data on the site, level of service, ridership and costs before and after timed transfer would thus yield the changes and impacts resulting from timed transfer.

Changes in Evaluation Strategy

The proposed evaluation strategy was constrained by several factors. There was no demonstration or prime site, that was implementing a timed transfer system that coincided with the evaluation's schedule. Secondly, many of the timed transfer sites that were identified, did not have operating records of their services prior to implementing timed transfer. Thus, no comparison would be possible. Of those sites that did have operating records, some of the before and after data were not comparable or sufficiently detailed and many of the operators did not have time or staff to collect, compile or explain the data. Finally, in practically all cases, the installation of timed transfer was accompanied by a significant expansion and change in services or fares. Thus, the evaluation was constrained by the timed transfer sites' schedules, available data, cooperation of individual transit operators and major changes in services.

Data Collection

Information was drawn from operating records at existing North American timed transfer sites, direct site observations and surveys. A questionnaire was sent to each timed transfer agency requesting data on the transit service area, on demographic and socio-economic characteristics, on routes, schedules, fares, operating characteristics, ridership, reliability, and from any user surveys. These data were supplemented by local transportation reports, census data, operator timetables, marketing information and conversations and interviews with numerous operators, planners, schedulers, drivers, street supervisors, community groups and users at the timed transfer sites.

Transit operators interested in suburban transit issues were asked to participate in the study by submitting their opinions on a timed transfer survey, distributed by the American Public Transit Association. The study team also interviewed several transportation researchers who have been interested in the timed transfer network concept, transit centers or related transfer issues. And an investigation was made into studies concerning medium-density transit, transfer issues, routing and scheduling, transit reliability and related topics. For those interested readers, a comprehensive listing of references follows the Appendix.

The timed transfer study team also collected more detailed data at three study sites -- Ann Arbor, Boulder and Portland. Using the forms contained in Exhibits I and II in Appendix A, data collectors recorded actual bus passenger activity and bus performance at the timed transfer points on two to three weekdays in Ann Arbor, Boulder and Portland during 1980 and 1981. Data collectors recorded the time at which each bus arrived, the number of passengers who disembarked, the number of passengers who boarded and the bus departure time. Where possible, transferring passengers were differentiated from originating passengers. When one or more disembarking passengers missed a transfer, this was also noted. Additional information (e.g. bus number) was collected for testing and verifying the data. In cooperation with this study, RTD in Boulder conducted on-board passenger surveys and transfer counts.

Analyses Techniques

The data were analyzed to identify and understand the impacts of timed transfer. Both qualitative and quantitative analyses were used. Analyses of the sites, the history of the systems and the timed transfer route structure, transfer points, schedules and system examples are primarily descriptive and were drawn from demographic and socio-economic data, background reports and route maps and schedules. Analyses of ridership and cost impacts were based on operating and financial reports collected from each site; comparisons among the sites both before and after timed transfer are included, whenever possible. In addition, three major evaluation analyses were conducted for each case study. These include:

1. Analyses to determine the relative speed and quality of timed transfer service;

2. Analyses to understand the location, level and direction of timed transfer passenger activity; and

3. Analyses to identify individual and overall bus route performance.

The relative speed and quality of timed transfer services are analyzed in terms of a small set of sample trips that represent travel in each of the case study sites. Great care was taken to see that the sample trips were characteristic of travel needs, but not related in any way to the available transit services. The approach followed was to select trip purposes, origins, destinations and times in a completely random fashion that conformed to general travel activity.

Trip characteristics were selected by first using the results of past transportation surveys and studies to identify trip ends (origins and destinations) and by then combining the trip ends to follow the major transportation patterns identified for each area. Origins were assigned to census tracts in accordance with population and then origin locations were selected randomly from each tract. Individual residential origins were picked to reflect population distributions. Employment, hospital or medical services and shopping destinations were picked to reflect the highest volumes of interzone trips, identified in Transit Development Programs or other travel studies. Each trip was assigned a purpose that was consistent with its destination. Times of day were selected in accordance with purpose. Work trips were timed to arrive at an arbitrarily selected morning hour. School trips were timed to meet class schedules. Medical trips were timed for mid or late morning appointments. Shopping trips were scheduled to begin at an arbitrarily selected mid-morning time. Eleven to twenty sample trips were selected in each of the three sites.

For each sample trip, the following three or four travel alternatives were examined: (1) automobile; (2) timed transfer bus services; (3) prior or subsequent bus services; and (4) walking for short trips. Automobile trips included time for short walks, warming up the automobile, and leaving a garage or parking space and automobile travel times were based on estimated travel speeds for different categories of streets at the time of day each sample trip was made. In general, uncongested freeway speeds were 55 miles per hour, uncongested arterial street speeds were 30 miles per hour and residential street speeds varied from 15 to 20 miles per hour. Freeway and arterial street speeds were reduced during peak periods and allowances were made for all right and left turns along automobiles routes. Bus transit times included time to walk to the boarding bus stop, waiting time for the bus, bus transit times, and walking time from the disembarking bus stop to the passenger's destination. Travelers were presumed to arrive at the bus stop two minutes prior to the bus's scheduled arrival, to walk at an average speed of 2 minutes per block, and to take 30 seconds to board and disembark from the bus. Bus travel times were based on the route's schedule.

To understand the location, level and direction of timed transfer passenger activity, passenger counts were taken at each timed transfer point. Passenger boardings, disembarkings and transferring and the number of riders on each departing bus were compiled. The analyses compared the data for each location, within each community. Individual routes and passenger loads were tracked during different times of the day.

To identify individual and overall bus route performance actual route performance is compared with scheduled route performance. Actual arrival and departure times were noted and the number of minutes that each bus was early or late was determined. Analysis reveals the mean time difference between the scheduled and actual time recorded and the variation of this difference, in terms of the range of minutes over which buses arrive and depart early or late. Individual routes and transfer points are analyzed further to identify specific problems.

1.3 READER'S GUIDE

This report is structured to help others interested in learning both general and specific information about different timed transfer systems. The Executive Summary presents a capsule picture of the entire report and highlights significant findings from the four major chapters. Chapter 1, the Introduction, gives the definition, location, history and objectives of timed transfer systems and gives an overview of the study. Chapter 2 discusses the major features of timed transfer systems, with separate sections on the characteristics of medium-density areas, timed transfer system structures, the alternative transit options and an overview of existing timed transfer systems. Chapter 3 examines some of the experiences with timed transfer systems from the perspective of the transit provider, the transit user and the community; and Chapter 4 examines the effects of timed transfer on transit service, patronage and costs. The final chapter, Chapter 5, contains detailed descriptive and analytical information on the three major case study sites -- Ann Arbor, Michigan; Boulder, Colorado; and Portland, Oregon. The bulk of the material contained in Chapters 2, 3 and 4 was drawn from these case study experiences. Following the text is an appendix which contains surveys, technical materials and supporting documentation for the report, followed by a list of general and site-specific references.

2. FEATURES OF TIMED TRANSFER SYSTEMS

The purpose of this chapter is to give the reader an appreciation for the variety of structures, modes and applications of timed transfer services that are possible and an understanding of the basic timed transfer niche. This chapter contains an overview of the structural features of timed transfer systems serving North American cities. The second section describes existing applications of timed transfer. The third section discusses two basic transit alternatives, conventional transit and paratransit, and the fourth section discusses the nature of the most likely timed transfer market.

2.1 STRUCTURE OF TIMED TRANSFER SYSTEMS

In its simplest form, a timed transfer occurs when two routes are scheduled so that some or all buses operating on both routes meet at a designated transfer point. The buses wait at this point until all transfers among them are complete. This simple concept, known as the "pulse" system, may be expanded with the introduction of additional bus routes at the transfer point and/or with the introduction of additional focal points. In its most complex form, an integrated timed transfer network can link different types of transportation services at a variety of transfer points, with each service adapted to meet the needs of its service area.

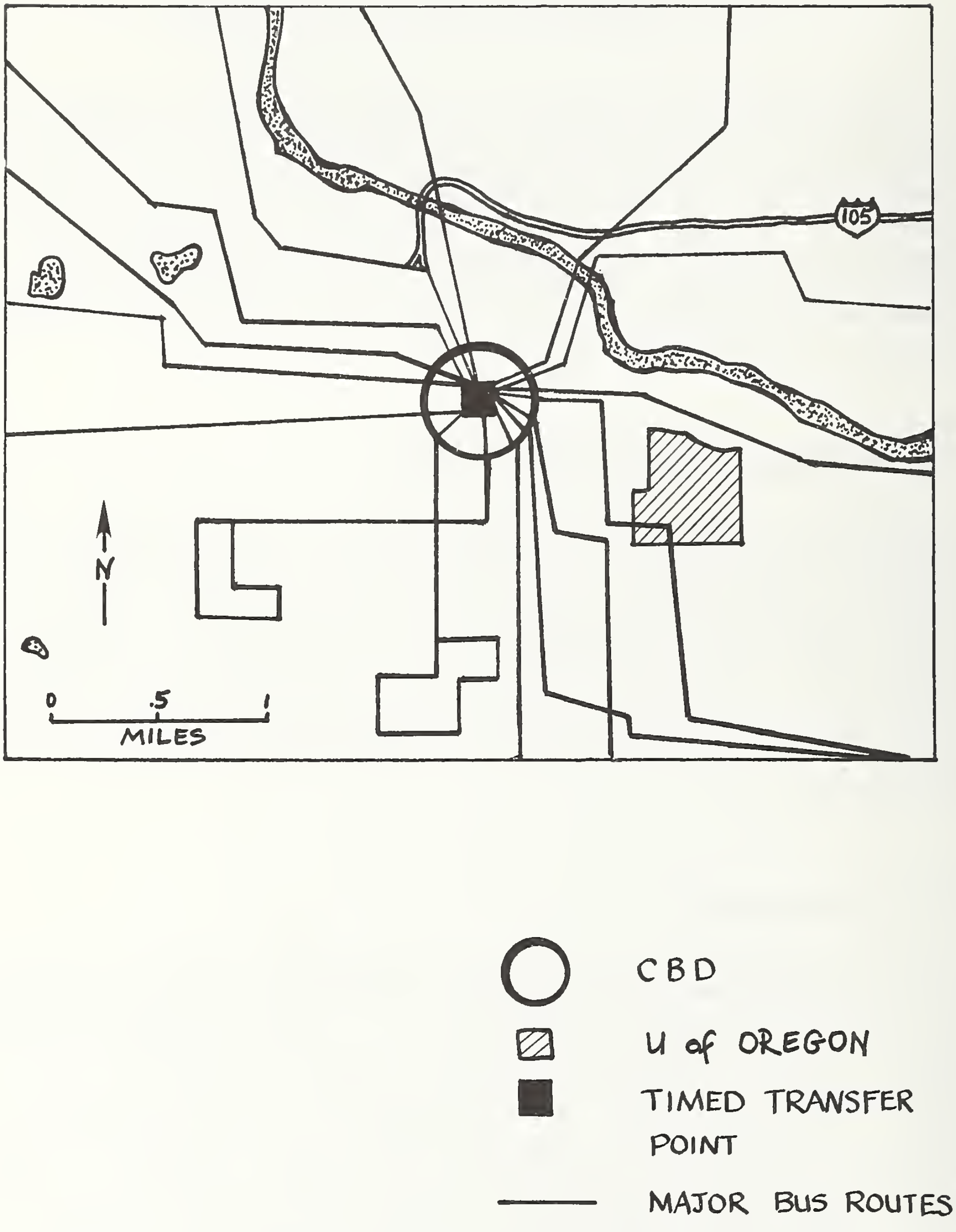
2.1.1 Pulse Systems

Pulse systems are timed transfer systems with only one transfer point. Pulse systems have their greatest potential for smaller systems, where services are usually infrequent (i.e., 30 or 60 minute headways), fewer vehicles are involved, all or most routes can be timed, and routes extend radially in several directions from the timed transfer point. Whereas radial systems may force all passengers to travel to a central point in order to transfer to another route, the timed pulse assures passengers of quick and easy connecting services. Exhibit 2.1 shows a schematic map of the initial Eugene, Oregon focal point radial pulse system. Some larger systems also use pulses at particular times of the day or to coordinate selected routes. For example, infrequent late night "owl" services pulse so riders do not have to wait for transfers in Rochester, New York.

Pulses can occur anywhere in the service area, but typically they occur at central, downtown locations and pulses can occur two, three or

Exhibit 2.1

THE EUGENE FOCAL POINT SYSTEM



four times an hour, but typically they occur at 30 minute intervals. Buses enter downtown from all directions, stop at the central transfer point and wait while passengers disembark, passengers transfer, and new passengers board; many riders may be destined for or coming from downtown locations. A few minutes later, the buses depart on their respective routes. Individual route lengths and travel times are carefully controlled to match the pulse cycle, to permit this schedule pattern to be repeated (eg. every half-hour throughout the day). The aerial photograph in Exhibit 2.2 shows fifteen buses "pulsing" at the downtown transfer center in Brockton, Massachusetts.

A few communities operate pulse demand-responsive paratransit systems. This is done by dividing the service area into zones and scheduling paratransit vehicle pick-ups and drop-offs into pulse interval tours. Ann Arbor, Michigan used to operate its entire dial-a-ride system on this zonal pulse concept and today operates its elderly and handicapped and late evening demand-responsive service on a 30-minute downtown pulse. Natick, Massachusetts has also adopted a zonal paratransit checkpoint system that "meets" downtown every half hour.

2.1.2 Simple Networks

The basic radial pulse concept can be expanded into a timed transfer network by establishing transfer points outside of the CBD and linking transfer points together with a series of overlapping radial pulse systems. This timed transfer network can then collect, transfer and distribute passengers to different transit routes in several locations. Such a network can eliminate unnecessary travel to downtown and provide convenient service for many local outlying trips. For example, Exhibit 2.3 shows a schematic map of the timed transfer "Direct Connection" service operating on the Westside of Portland, Oregon.

Timed transfer points are typically located near major activity centers, such as shopping malls, thus attracting additional local transit demand. Major trunk line routes provide direct service between downtown and these outlying transfer points. Local routes then radiate from each timed transfer point into lower-density residential areas to pick-up and drop-off local riders. Local routes serving each transfer point operate on the same headway schedule of 15, 30, 60 or even 120 minutes, depending on the demand. This timed transfer network provides local transit service to major activity centers, links different local routes together for access to other local destinations, and links local routes to major trunk routes for direct downtown service.

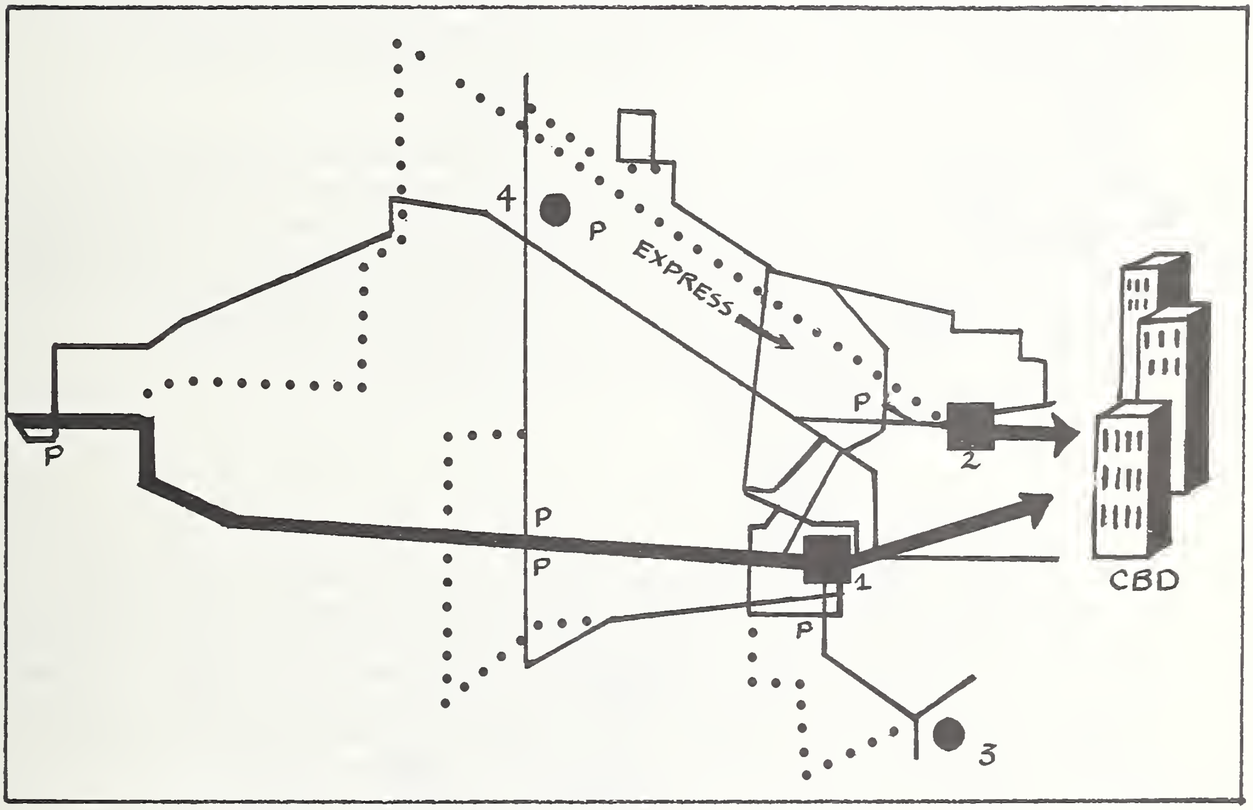
Exhibit 2.2

BROCKTON, MA DOWNTOWN PULSE

Photographed by: Stanley Bauman

Exhibit 2.3

THE PORTLAND (WESTSIDE) TIMED TRANSFER SYSTEM



Schematic Representation: Not Drawn to Scale

1	BEAVERTON
2	CEDAR HILLS
3	WASHINGTON SQUARE
4	TANASBOURNE MALL

■	TIMED TRANSFER POINTS
●	OTHER TRANSFER POINTS
P	PARK AND RIDE
▬	MAIN BUS ROUTES
—	OTHER BUS ROUTES
• • •	PEAK HOUR ONLY

2.1.3 Expanded Networks

Simple timed transfer networks can be expanded to include more timed transfer focal points and/or other modes of transit services. For example, local demand may be too low to justify conventional feeder routes or residential street patterns may be too circuitous or narrow to accommodate full-size transit vehicles. Some communities may select demand-responsive paratransit services to provide local feeder services to the transfer point. These smaller and more flexible vehicles would be scheduled to meet at the predetermined connecting transfer time. Other areas may have space available to provide park-and-ride lots or kiss-and-ride access at the transfer terminal.

To increase access and reduce travel time between communities, crosstown routes can also be added. These routes would link the major transfer focal points and crosstown schedules would be timed to meet the local feeders. By coordinating local, crosstown and major trunk routes through an expanded timed transfer network, transit systems can provide access throughout the service area. By matching route headways passengers can be assured of connecting transit services with virtually no waiting time at the connecting transfer points.

2.1.4 Integrated Systems

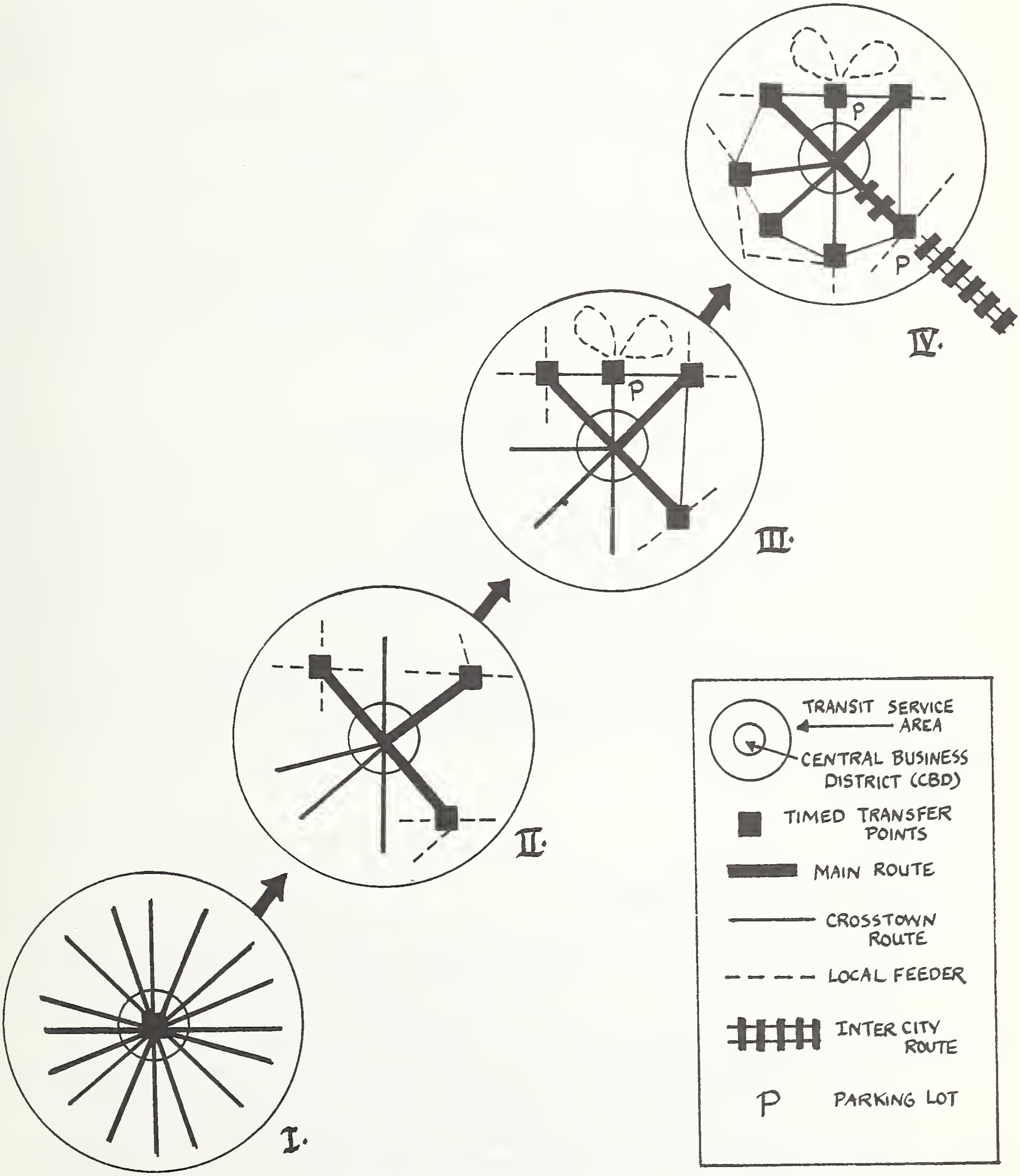
The number of timed transfer points and the number of services involved in each timed transfer system may vary widely. Some communities are physically larger than others and may develop transfer points in numerous outlying communities. Alternatively, timed transfer focal points may be developed in only one area or in selected communities. In any of these cases, an even larger family of transit services may be introduced into the timed transfer system.

If the demand for downtown service is sufficiently large, conventional bus services and vehicles may be replaced with higher capacity and faster services. These include: articulated buses; limited stop or express services; preferential traffic or highway treatments; and light rail services. Inter-city buses or inter-city rail services can be scheduled to coordinate with local transit services. Transportation to other cities or destinations, such as outlying airports, could also be coordinated. Intra-county bus services are timed transfer with inter-city rail services in Nassau County, New York.

Exhibit 2.4 illustrates the four types of timed transfer systems discussed in this section. The first illustration is a CBD-pulsed radial route configuration. In the second illustration, three timed transfer points are connected with high quality trunk line service. The network also provides local transit service around each timed transfer point and links local routes together for access to other local destinations. In the third illustration, a fourth timed transfer site is shown, with adjacent parking facilities and with local demand-responsive transit services. Crosstown services connect the

Exhibit 2.4

STRUCTURAL HIERARCHY OF TIMED TRANSFER SYSTEMS



major transfer points for longer trips. The fourth picture illustrates an integrated timed transfer system. All local routes feed major activity transfer centers and provide local services in outlying medium density areas. One community has local demand-responsive feeder services and two communities have parking facilities to connect with their timed transfer points. At each transfer point, passengers can transfer to a crosstown route or to a radial route destined for the CBD. Several services such as regular stop, limited stop, express, or light rail service may be offered along high-density corridors. Inter-city bus or rail services are also linked to this urban timed transfer network, for convenient transit connections to other cities.

2.2 OVERVIEW OF EXISTING APPLICATIONS

This section contains site and system descriptions of eight timed transfer systems serving North American cities, three in Canada and five in the United States. The systems are located in:

CANADA
- Edmonton, Alberta
- Vancouver, British Columbia
- Victoria, British Columbia

UNITED STATES
- Eugene, Oregon
- Nassau County, New York
- Norristown, Pennsylvania
- Sacramento, California
- Tacoma, Washington

Chapter 5 contains more detailed site and system descriptions and discusses the major impacts of timed transfer in the three case study sites of Ann Arbor, Michigan, Boulder, Colorado and Portland, Oregon.

CANADIAN SYSTEMS

2.2.1 Edmonton, Alberta

The first North American multiple focal point timed transfer bus system was implemented in Edmonton, Alberta. In 1964, Edmonton had a population of 343,000 spread in low to medium-density development. The Edmonton Transit System consisted primarily of radial routes emanating from the CBD. As the city grew, routes were extended into outlying growth areas. Indirect transit routing coupled with poor and infrequent transfer connections did not meet the needs of the growing suburban areas and contributed to Edmonton's low transit patronage. An opportunity for change was presented when, as part of the annexation agreement with adjoining Jasper Place, Edmonton was required to provide a high level of transit services to this relatively low-density area.

Dr. J.J. Bakker, a consultant to Edmonton Transit, was retained to explore means to provide good transit service to Jasper Place. He felt that the Dutch Railway timed transfer concept could be used to extend high quality bus services to outlying communities and to increase ridership. To facilitate transit connections, a transfer center was established in the Jasper Place Town Hall parking lot. Local feeder routes circulated within the Town, stopping at the transfer point every 30 minutes. A downtown bus route met local routes at the transit center at the same time.

During the peak hours, some feeder routes became express downtown routes so that some local riders did not have to physically transfer. Later, a trolley route was added to increase downtown service to a 10-minute frequency. Thirty-minute local services continued and a 30-minute crosstown route was added. Although this meant local and crosstown arriving passengers (every 30 minutes) would only make timed transfers with every third downtown trolley, passengers originating at the Jasper Place Town Hall and passengers arriving on late buses would not have to wait more than 10 minutes for the next trolley. Passengers travelling in the reverse direction knew which downtown buses would meet the less frequent local services.

The success of the timed transfer service and a growth in population to 435,000 and population density to 4,000 persons per square mile, encouraged Edmonton Transit to develop timed transfer operations at other strategic locations around the City. Selected locations include major shopping centers, such as Westmount, Northgate and Southgate, the University of Alberta and several light rail transit stations. In 1975, 67 peak period and 48 off peak period routes participated in this system with an average of 6 buses meeting at each point. Today, the entire Edmonton Transit System operates on the timed transfer concept. Thirteen major transfer points operate throughout Edmonton with all bus schedules coordinated to encourage timed transfers. Exhibit 2.5 identifies the major transit centers, the light rail line, the main bus routes, the crosstown routes and the local feeder services that comprise this timed transfer network in Edmonton.

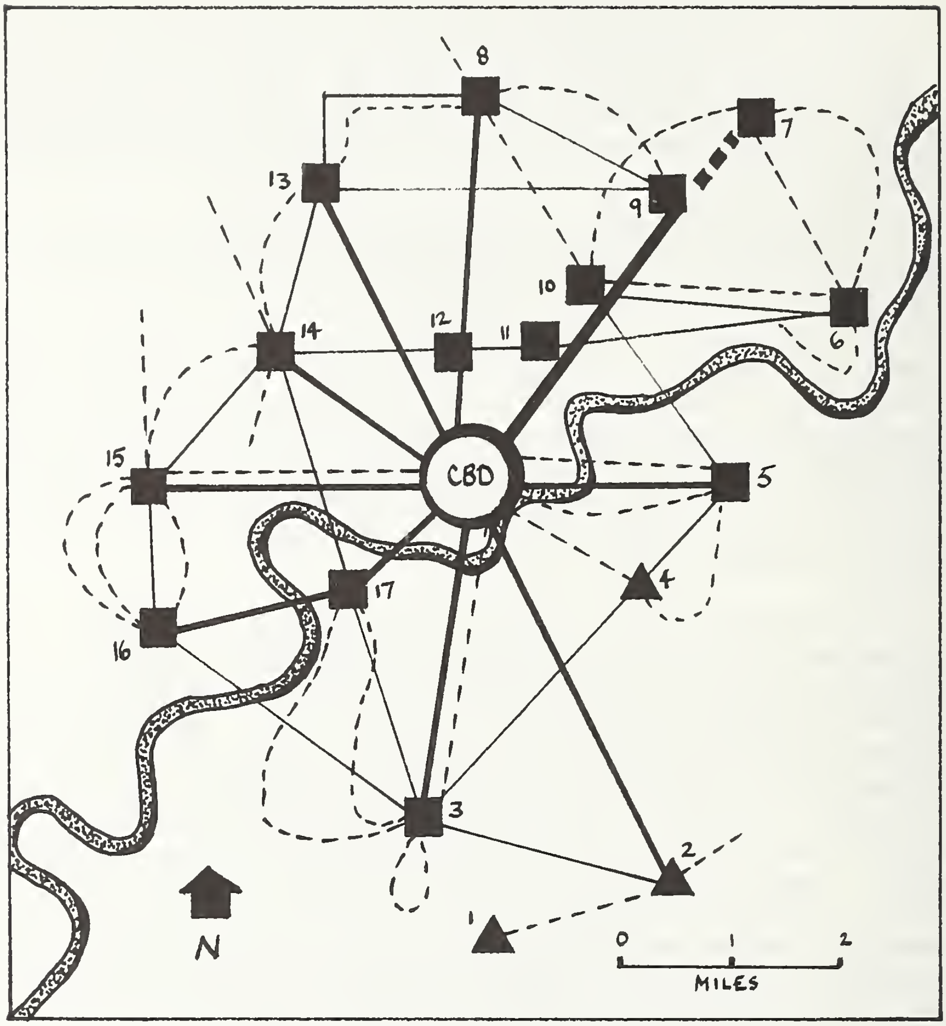
2.2.2 Vancouver, British Columbia

Vancouver, British Columbia, is the third largest metropolitan area in Canada. In 1973, the population of the Greater Vancouver Region was about 950,000 people; today it is over 1.5 million people. Practically all of this growth occurred in the suburbs, and today, the suburbs contain most of Vancouver's population.

In 1973, the Provincial Department of Municipal Affairs established the Bureau of Transit Services, to develop transit services throughout British Columbia. During the 1960's, mass transit had been largely neglected and most of Vancouver's suburban areas had little or no transit services. Following Edmonton's rationale and approach, the Greater Vancouver Transit System extended service and introduced timed

Exhibit 2.5

THE EDMONTON TIMED TRANSFER NETWORK



1	KASKITAYO
2	MILLWOODS
3	SOUTHGATE
4	BONNIE DOON
5	CAPILANO
6	ABBOTTSFIELD
7	CLAREVIEW
8	NORTHGATE
9	BELVEDERE
10	COLISEUM
11	STADIUM
12	KINGSWAY
13	118 AVENUE
14	WESTMOUNT
15	JASPER PLACE
16	MEADOWLARK
17	UNIVERSITY

■	TIMED TRANSFER POINTS
▲	PROPOSED TRANSFER POINTS
▬	LIGHT RAIL (■■■ INCOMPLETE)
━	MAIN BUS ROUTE
—	CROSSTOWN BUS ROUTES
----	LOCAL BUS FEEDERS

Adapted from Edmonton Transit, Edmonton, Alberta, 1980.

transfers in two suburban communities, Coquitlam and North Vancouver. Coquitlam had an average population density of 2,250 persons per square mile and North Vancouver averaged 7,656 persons per square mile.

Focal point transit centers were established at a regional shopping center (Lougheed Mall), a suburban central business district (Port Coquitlam) and a highway interchange on the northern bridge approach to Vancouver (Phibbs Exchange). Local route schedules were coordinated with express "Fast Bus" routes at these centers for quick and convenient passenger transfers. About one of every four local routes serving each center was through-routed to downtown Vancouver as a "Fast Bus" express route, similar to the strategy used in Edmonton. This strategy was found to reduce passenger travel time and to minimize the physical inconvenience of transferring for some passengers.

Since 1973, the Vancouver area has continued to grow especially in the lower density suburban areas, and the timed transfer network has been expanded throughout the region. Exhibit 2.6 shows Vancouver's timed transfer points and identifies the main bus lines and local feeder routes that are coordinated at each exchange. In general, off-peak services operate on 30-minute "clocked headways" and during peak periods services increase to every 15 minutes. A five-minute layover or dwell period is scheduled at each timed transfer center to permit passenger "exchanges."[1] As with most transit systems, the majority of tripmaking and transferring occurs during the peak periods. However, the number of off-peak trips has increased significantly, improving the peak to off-peak trip ratio. This is not surprising, because the major activity center focal points (e.g., shopping malls) serve as both destination points and transfer points throughout the day.

2.2.3 Victoria, British Columbia

The Capital Regional District serves the Greater Victoria metropolitan region, with a population of approximately 167,000. In 1974, one year after Vancouver initiated its timed transfer services, the District introduced the timed transfer concept into its regional system to extend transit services to the northeastern community of Gorden Head. A limited-stop "Fast Bus" trunk route linked downtown with timed local and cross-radial connections at the Gordon Head shopping center. This was the first Canadian application of timed transfer to such a small area. Peak and off-peak ridership increased significantly and by 1980, the Regional District had developed two more timed transfer centers. In January, 1981, the Capital Regional District extended transit services to three more timed transfer sites (Saanichton, Sidney Bus Deport and Western Exchange).

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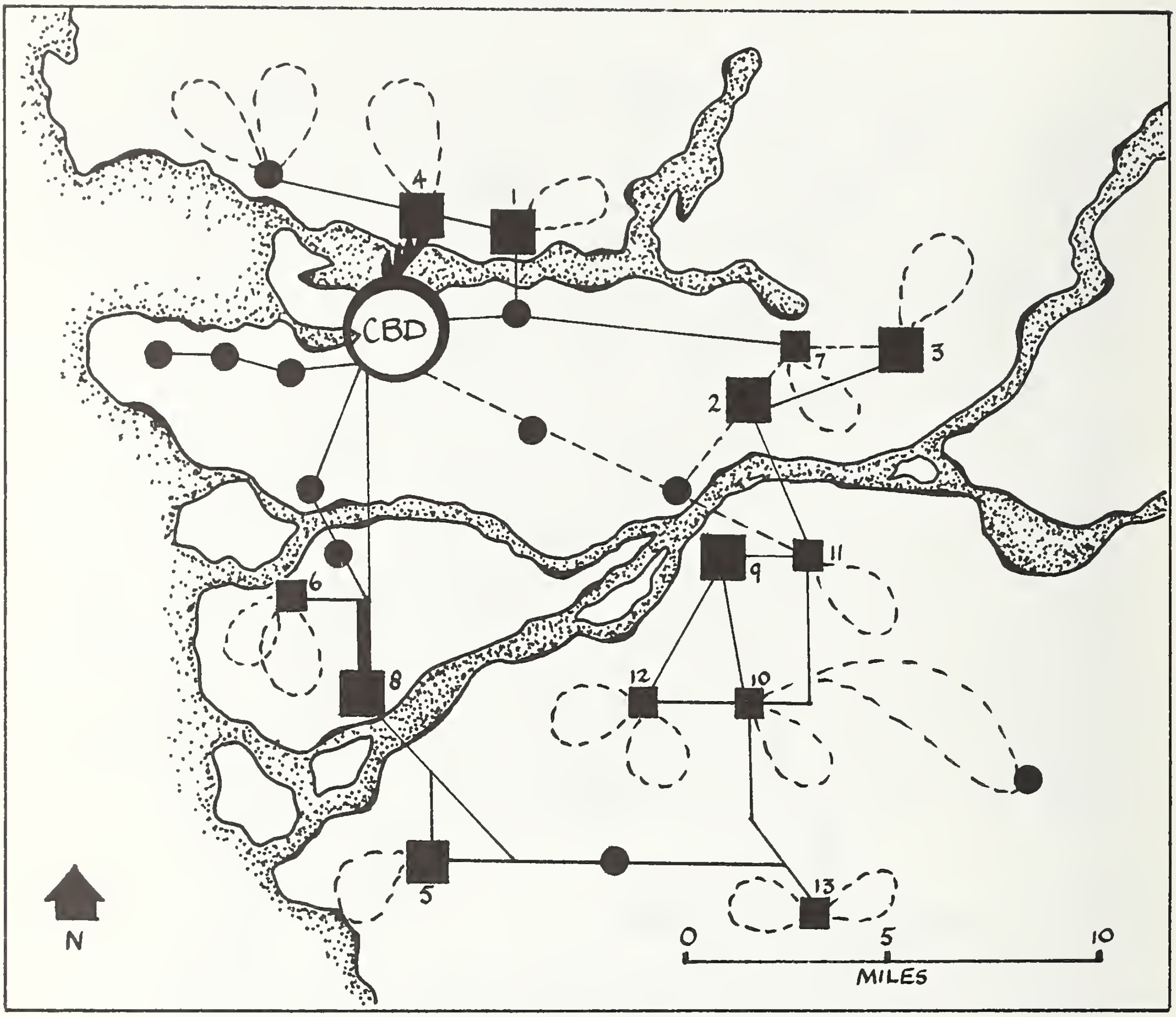
[1] To avoid the negative connotation often associated with passenger transferring Vancouver refers to their timed transfer centers as passenger "exchanges" (e.g., Phibbs Exchange, Ladner Exchange, Whalley Exchange, etc.).

Exhibit 2.6

THE VANCOUVER TIMED TRANSFER SYSTEM



1	PHIBBS EXCHANGE
2	LOUGHEED MALL
3	PORT COQUITLAM
4	LONSDALE QUAY
5	LADNER EXCHANGE
6	RICHMOND CENTER
7	WINSLOW LOOP
8	MASSEY EXCHANGE
9	WHALLEY EXCHANGE
10	NEWTON EXCHANGE
11	GUILDFORD
12	SCOTTSDALE MALL
13	WHITE ROCK

■	TIMED TRANSFER POINTS
●	OTHER TRANSFER POINTS
▬ ▬ ▬	PROPOSED LIGHT RAIL
▰	SEABUS
——	MAIN BUS LINES
- - - -	LOCAL FEEDERS
▬	PREFERENTIAL LANE

2.2.4 Other Canadian Systems

During the late seventies, the "timed transfer focal point" concept was also used by the Urban Transit Authority (UTA) to plan small community[2] transit systems throughout British Columbia. Some of these small B.C. community systems include: Prince George; Kamloops; Kelowna; Kitimat; Prince Rupert; Nanaimo; and Penticton.

In most of these smaller communities travel focuses on the downtown with perhaps one or two other major activity centers. It is relatively easy to identify focal points and to adapt timed transfer bus services to these areas. The UTA has found that timed transfer fixed-route services attract greater patronage and are less costly than the more personalized dial-a-ride services.[3]

When facing increasing population growth in suburban areas from 125,000 in 1974 to 150,000 in 1980, the Saskatoon Transit System in Saskatoon, Saskatchewan, expanded their conventional radial bus system into a three point timed transfer network. The entire rural Saskatchewan Province is also blanketed with an intercity timed transfer bus network provided by the Saskatchewan Transportation Company. London, Ontario, a medium-size city of about 257,000 population (3,780 persons per square mile), is also planning a timed "transfer terminal" system.[4]

Seventeen years ago timed transfer bus services were introduced in Edmonton. Today, over 20 Canadian transit systems employ the timed transfer concept. In most of these cases, timed transfer has been used to extend transit services into previously unserved low-density communities, to provide easier and faster connecting services between major activity centers, and to attract new riders to transit. And in most of these cases, these objectives have been achieved, although some higher costs have also resulted.

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[2] Independent urban areas with a population of under 100,000.

[3] Urban Transit Authority of British Columbia, Guidelines for Public Transit in Small Communities, Small Communities Branch, Victoria, B.C., Canada, September, 1980.

[4] The London Transit Commission, Transfer Terminal System: Concept Study, LTC: London, Ontario, Canada, June, 1980.

2.2.5 Eugene, Oregon

Site Description. Eugene, Oregon, is one of the two major cities in Lane County, midway between Portland and the California border. Eugene is a college-oriented town (University of Oregon), with a small, rapidly developing downtown area surrounding the Eugene Mall. The Mall, reserved for pedestrians, houses many retail and service industry firms as well as government offices. Employment in the downtown comprises 12,900 persons or 15 percent of Eugene's labor force of 84,000. The transit district, which includes surrounding communities, serves a total population of 225,000 (1978).

System Description. Public transit is provided by Lane Transit District (LTD). LTD operates 26 radial bus routes with the Eugene Mall being the focal pulse point of the system. Twenty routes operate on 30-minute headways all day. The Eugene Mall has a two-and-a-half-block long curbside bus stop adjacent to a wide sidewalk. Retail establishments line both sides of the street. The pulse system has been successful and Eugene is planning to extend it to a multiple focal point timed transfer system.

2.2.6 Nassau County, New York

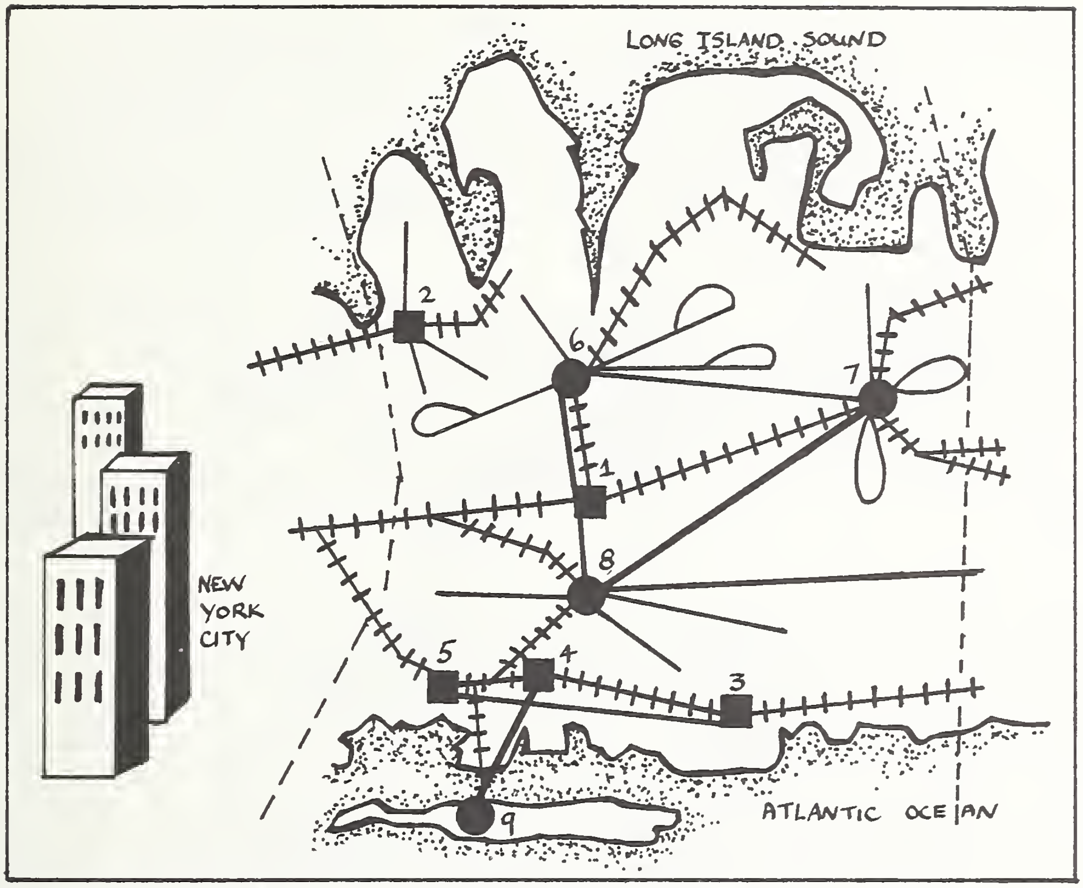
Site Description. Nassau County, New York, is located on Long Island approximately 20 miles east of New York City. This suburban area of 298 square miles has a population of 1.43 million (1975), living in an average density of 5,034 inhabitants per square mile. The county has been described as a suburban metropolis. The median income was $14,625 in 1970 and 49 percent of all households owned two or more automobiles.

The region has a skilled resident labor force of 650,400 persons (1976), and an employment base of 601,800 jobs. Most of the jobs are in government agencies, service industries and retail establishments. Of all county employees, about 71 percent commute to their place of work by car or carpool, and 20 percent use various kinds of public transportation. Many Nassau County residents work in New York City and depend on public transportation.

System Description. The Long Island Railroad (LIRR) operates commuter rail services throughout Nassau County. In 1973, Nassau County purchased ten privately owned bus companies and turned them over to the Metropolitan Suburban Bus Authority (MSBA) to operate. Between 1973 and 1976, the MSBA consolidated management, coordinated operations, and expanded services. In 1976, the MSBA began designing its bus schedules to coordinate with the arrival of LIRR trains, establishing timed transfer points at rail stations. Most rail stations are located in town centers within walking distance of many central suburban business activities. Timed transfer bus services are scheduled at five locations: Great Neck, Freeport, Rockville Center, Lynbrook, and Mineola. Three more sites are planned (see Exhibit 2.7). Bus routes with headways of 7-1/2, 15, 30 or 60 minutes, radiate from these stations to serve residential neighborhoods and businesses.

Exhibit 2.7

THE NASSAU COUNTY TIMED TRANSFER SYSTEM



Schematic Representation: Not drawn to scale

1	MINEOLA
2	GREAT NECK
3	FREEPORT
4	ROCKVILLE CENTRE
5	LYNBROOK
6	ROSLYN
7	HICKSVILLE
8	HEMPSTEAD
9	LONG BEACH

■	TIMED TRANSFER POINTS
●	OTHER BUS/RAIL TRANSFER POINTS
----	NASSAU COUNTY SERVICE AREA BOUNDARIES
┼┼┼┼┼	LONG ISLAND RAILROAD
——	MAIN BUS ROUTES

2.2.7 Norristown, Pennsylvania

Site Description. Norristown is a small urban community in Montgomery County, Pennsylvania, about 12 miles north of Philadelphia. Its transit service area has 3.6 square miles and 35,000 inhabitants (1975). Norristown's high population density (9,722 persons per square mile), its large share of non-white population (17 percent), and its low median income ($9,749 in 1969) distinguish it from most of the other communities in this study. The labor force of 20,500 works mainly in light manufacturing and retail trade.

System Description. The Southeastern Pennsylvania Transportation Authority (SEPTA) operates five local bus routes in the Frontier Division, which includes the Norristown area. Prior to SEPTA operations, service was provided by a small private company. Most of their nine routes were paired to lower operating costs, but little coordination existed to facilitate non-paired route passenger transfers. SEPTA acquired the system in 1976, and decided to institute a completely new system.

A timed transfer focal point was established at Main and Swede Streets in central Norristown. Local routes provide service to area shopping centers, schools and employment sites. Four of the five local routes arrive there five minutes before the hour, wait eight minutes, and leave three minutes after the hour. Additional service is offered during the peak hours, arriving at 25 minutes after the hour and departing eight minutes later. Bus arrivals are also coordinated with the departure times of the high-speed rail line to Philadelphia. Exhibit 2.8 sketches the Norristown transit service, and shows the coordinated bus and high-speed line schedule for the morning peak period.

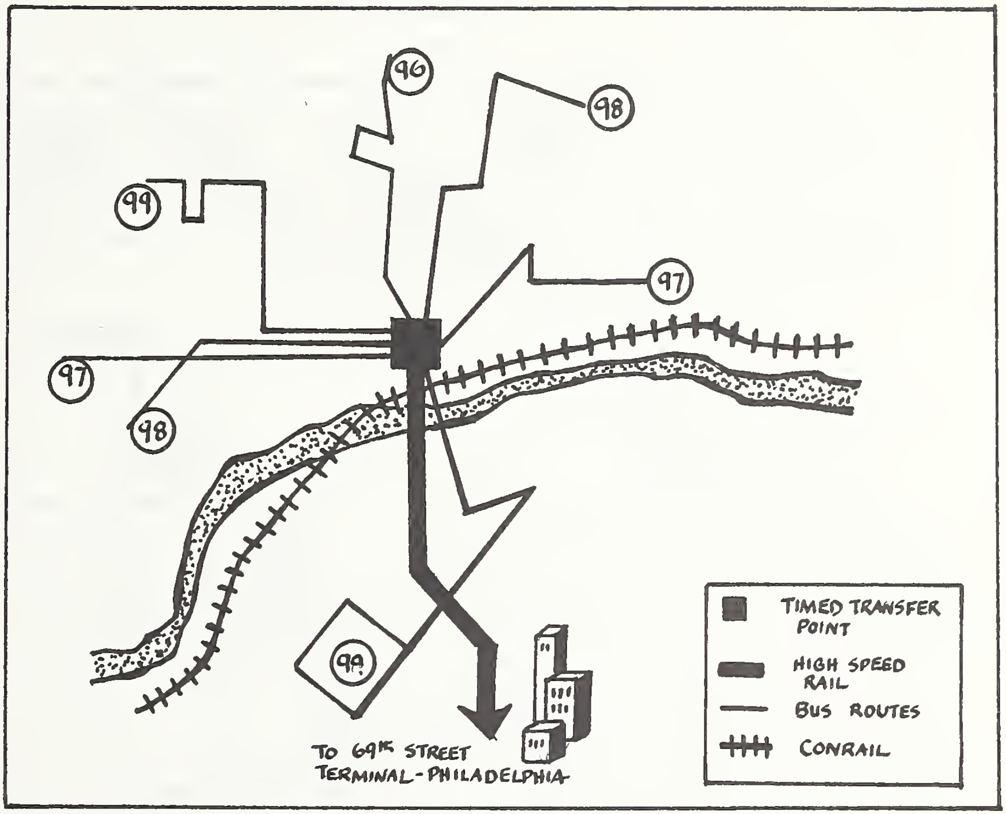
2.2.8 Sacramento, California

Site Description. Florin Center is a suburban development eight miles south of the Sacramento CBD. This low-density suburban area covers 13 square miles, with a population of 37,000 people (2,880 persons per square mile). The Mall, two area hospitals, downtown government offices, and the U.S. Army Depot offer employment for a major part of the area's labor force of 10,400 persons. Commercial activity is strongly concentrated on Florin Mall and along major arterial roads. Auto ownership is high, with practically 90 percent of all households owning at least one automobile.

System Description. Transit service is provided by the Sacramento Regional Transit District (SRTD). Prior to 1979, nine bus routes served Florin Center: two fed into Florin Center, six linked Florin Center with the downtown area, and one served activity centers near the downtown area. These routes were slow, with midday travel times between Florin Center and the CBD ranging from 43 to 50 minutes. On September 4, 1979, SRTD initiated a timed transfer system at Florin Center. Florin Mall

Exhibit 2.8

THE NORRISTOWN FOCAL POINT SYSTEM AND SCHEDULE



Schematic Representation : Not drawn to scale

(A.M. PEAK PERIOD)

DEPARTURES	BUS ARRIVALS			
HIGH-SPEED LINE TO PHILADELPHIA	ROUTE ⑨⑥	ROUTE ⑨⑦	ROUTE ⑨⑧	ROUTE ⑨⑨
6:00		5:55		
6:30, 6:45		6:25		
7:00, 7:15	6:55	6:55, 6:55*	6:55, 6:55*	
7:30, 7:48		7:25, 7:25*		
8:03, 8:18	7:55	7:55, 7:55*	7:55, 7:55*	7:55, 7:55*
8:33, 8:48		8:25		8:25
9:03	8:55	8:55, 8:55*	8:55, 8:55*	8:55, 8:55*

* EASTBOUND AND WESTBOUND BUSES ON ROUTES 97 AND 98; NORTHBOUND AND SOUTHBOUND BUSES ON ROUTE 99.

was chosen as the transfer point because of its importance as an activity center and its strategic location. It is easily accessible from the street system and freeways, and provides sufficient space for transit facilities. Four new feeder routes (Routes 54, 55, 56 and 57) pulse at the mall. Passengers can transfer among them and to route 50, a limited stop express route to downtown Sacramento (see Exhibit 2.9). The buses are distributed over two pulses, one-half hour apart. Routes 54 and 56 leave Florin Mall on the hour, while routes 55 and 57 leave on the half-hour. Route 50 has 30-minute headways with additional service during the peak hours. This express service has improved travel times between downtown and Florin Center.

2.2.9 Tacoma, Washington

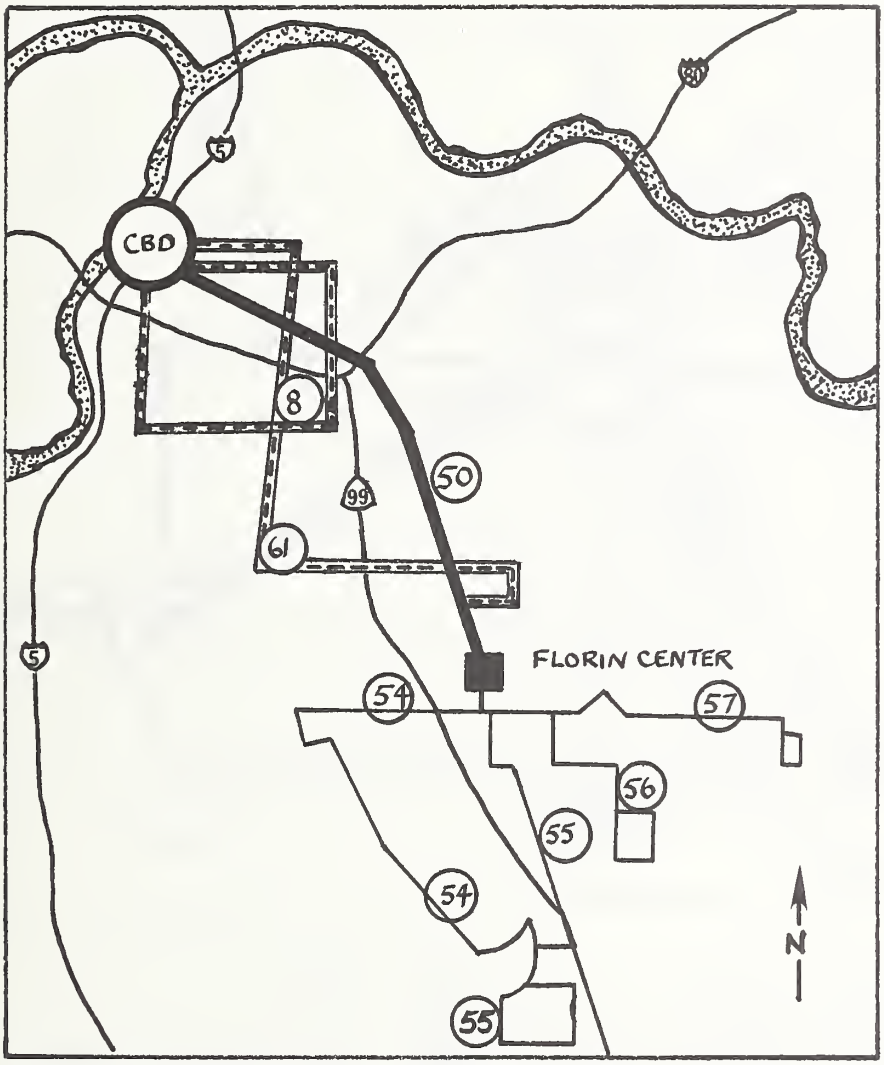
Site Description. Tacoma, Washington, located on the southern tip of Pudget Sound, 25 miles south of Seattle, houses 157,800 of Pierce County's 454,000 population (1977). Widespread automobile access resulted in the decentralization of residential, employment, education and shopping activities, however, some activities are concentrated along major arterial travel corridors. Tacoma's downtown remains the major employment center (9,000 employees), but the Tacoma Mall, downtown Puyallup (an adjacent community), Tacoma Community College, and the Fort Lewis and McCord military bases, located in the southwestern part of the district, employ and attract a large number of area residents. In 1970, the median household income averaged $9,859, somewhat less than other areas included in the study. The Pierce County Public Transit Benefit Area (PCPTBA) provides transit service to a 120 square mile area that includes the City of Tacoma and several surrounding communities. Land use in the PCPTBA service area follows the typical development pattern of low-density suburban and rural residential areas. Population density averages 2,758 persons per square mile.

System Description. The Tacoma Transit System was an outgrowth of the old streetcar network, with radial routes centered on the CBD. To serve the changing demands of residents within the new low-density Public Transit Benefit Area (PTBA), a comprehensive transit plan was developed. A key element of the plan was timed transfer at seven major activity centers. Three types of routes -- local feeder, community, and intercity -- serve the activity centers. Local routes meet at the centers every 30-minutes during the off-peak and every 15-minutes during the peak. Community or crosstown routes and schedules are designed to connect and pulse with local routes at the transit centers, and provide local and express peak-period service to other transit centers. Intercity routes connect five of the transit centers with areas outside the Pierce County service region. A park-and-ride lot is also planned at one transit center. Exhibit 2.10 shows the PCPTBA and identifies the type of routes serving each transit center and the location of the park-and-ride lots.

The new Pierce County PTBA expanded operations in June 1980. Timed transfer services began in September 1980. Since September,

Exhibit 2.9

THE SACRAMENTO (FLORIN MALL) FOCAL POINT SYSTEM

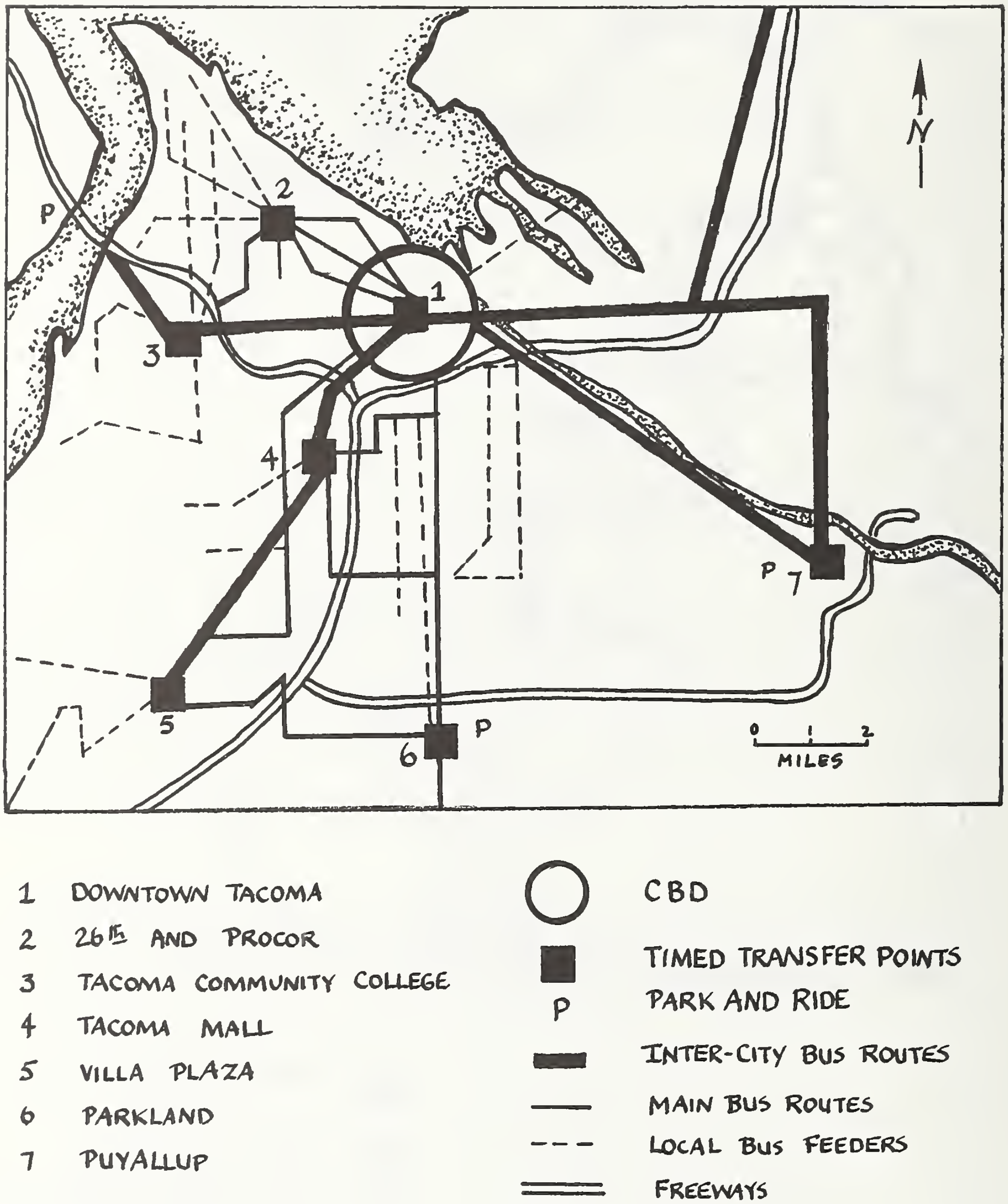


Schematic Representation: Not drawn to scale

■	TIMED TRANSFER POINT
▬	MAJOR BUS ROUTE
▭	OTHER AREA ROUTES, NOT TIMED TRANSFER
—	LOCAL FEEDERS
(50)	BUS ROUTE NUMBERS
—⑤—	MAJOR HIGHWAYS

Exhibit 2.10

THE TACOMA (PIERCE COUNTY) TIMED TRANSFER SYSTEM



ADAPTED FROM: PARSONS, BRINKERHOFF, "PIERCE COUNTY TRANSPORTATION BENEFIT AREA AUTHORITY," 1979.

Pierce County has continued to phase in their fixed-route multiple-focal point timed transfer system. By 1982, the entire Pierce County PTBA fixed-route transit system should be using multiple point timed transfers.

2.3 TRANSIT ALTERNATIVES

An examination of the sites that implemented timed transfer shows that before these services began, a few communities (Sasketoon, Sask., Tacoma, WA) had conventional fixed-route services, one site (Ann Arbor, MI) had demand-responsive paratransit services, while most communities (outlying portions of Vancouver, B.C.; Westside of Portland, OR; Jasper Place in Edmonton, Alb.) had little or no previous transit services. Practically all sites used timed transfer to expand services to new areas. The central issue is why did these sites select timed transfer services as a replacement for existing services or instead of other transit alternatives, such as conventional transit or paratransit?

To understand this selection process, one should understand the unique features, markets, capabilities and limitations of different transit alternatives. Timed transfer systems seem to occupy a niche in the spectrum of transit systems that begins with fixed route transit serving densely populated downtown areas and ends with no transit or low level demand-responsive paratransit systems serving sparsely populated rural areas. The following sections define conventional transit and paratransit systems, discuss the radial and grid configurations, which are the two major types of conventional systems, and identify the potential niche for timed transfer systems.

2.3.1 Conventional Transit

Conventional transit can be defined as regularly scheduled fixed-route intraurban passenger transportation services, such as bus or rail services. Standard buses can carry up to 70 passengers (45-50 seated; 20-25 standees), articulated buses can carry up to 100 passengers and light rail vehicles can carry up to 200 passengers. Conventional transit is particularly well-suited to: (1) areas with high population densities, such as central cities, or (2) corridors with a high travel demand, where it can attract many riders. Conventional transit becomes less attractive as ridership densities drop and it is usually too costly to provide a high level of conventional fixed route service to low density suburban and rural areas.

The heaviest users of conventional transit are usually commuters, travelling to and from work during the morning and afternoon peak periods. In fact, large differences between peak and off-peak ridership can create severe difficulties for transit operators who must maintain vehicles and labor to meet peak demands. Most conventional transit operators try to provide direct, no-transfer service and thus design fixed routes, stops, headways, and schedules according to individual route criteria. Although this practice provides little coordination within the system, it allows maximum operating flexibility.

The two major conventional transit system route configurations are the radial and the grid pattern. Exhibit 2.11 identifies the major characteristics, the advantages and the disadvantages and illustrates the basic design and routing patterns using these two route configurations.

Radial Systems are usually outgrowths of earlier streetcar or fixed route systems. Streetcar tracks were laid to provide access to the downtown core, which in earlier times was the center for all major employment, retail, cultural and social activities. As cities grew and expanded, new transit lines fingered outward to follow the patterns of urban growth. Even after World War II, when buses generally replaced streetcars, and transit systems were no longer physically confined to streetcar routes, most transit operators maintained their earlier configurations. This repeating pattern of urban development and transit extension evolved into radial system configurations, a route pattern centered on downtown with spokes radiating out into outlying areas.

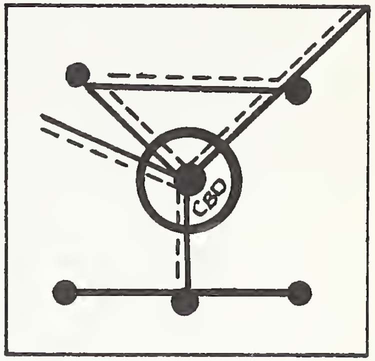
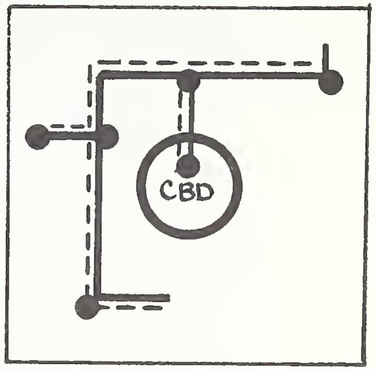
Few long radial routes that extend into low density areas, however, ever attract enough riders to justify their high operating cost. Radial systems generally provide direct, no-transfer travel to the central city. Passengers seeking to travel between two non-CBD locations must travel downtown and transfer to an outbound line. Thus, travelers with access to an alternative form of transportation would not likely use radial transit service between two relatively close, but outlying points because of the long, inconvenient route via downtown.

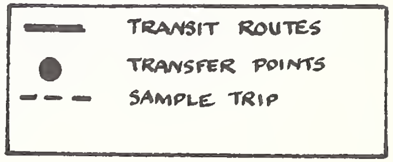
In some cases, crosstown or circumferential routes are added to a radial system, to provide transit access between outlying communities. (In Exhibit 2.11, two crosstown routes bisect the upper and lower portion of the illustration.) Presumably, transit riders can shorten their trips by transferring to crosstown routes, without having to travel into the CBD. But, most crosstown routes traverse low demand density areas, they cannot attract sufficient patronage to warrant frequent service, and it is difficult to coordinate schedules between all radial and crosstown routes. As a result, passengers transferring from radial to crosstown routes usually face long and uncertain waits.

Grid Systems are entirely different from radial systems. Instead of focusing on a single activity center, such as the CBD, the grid configuration provides comparable service to all areas. The basic grid system is most easily understood by users because it consists of relatively straight and evenly spaced parallel routes bisected by another set of straight, parallel routes. Passengers have region-wide mobility within the service area, allowing any traveler to reach any point in the system, with no more than one transfer. This system works best where there are few geographic and topographic barriers and where there is a grid street and highway network that is suitable for transit operations.

Exhibit 2.11

CONVENTIONAL TRANSIT: ROUTE CONFIGURATIONS

SYSTEM TYPE	MAJOR CHARACTERISTICS	ADVANTAGES	DISADVANTAGES	DESIGN
RADIAL	• Downtown oriented system. • Main routes fan out from city center to outlying areas. • Some crosstown routes may be added to basic system (e.g., crosstown route across top and bottom of illustration).	• Direct access to CBD. • Eliminates need to transfer, for downtown travel. • Encourages peak, commute travel to and from downtown. • Easier to tailor route frequencies to demand. • Fairly easy to understand. • Lower cost.	• Depends on strong CBD and CBD desired travel patterns. • Downtown transfer required for most non-CBD trips, discouraging outlying local travel, especially during off-peak. • Inconvenient, circultous travel required for non-CBD trips.	
GRID	• Region-wide mobility system. • Evenly spaced intersecting routes. • Routes at ½ mile intervals for average acceptable walking distances within service area. • Service at 10 minute frequencies to insure short transfer times.	• Passengers can access any point in service area. • Direct service or only one transfer service between any 2 points in service area. • Equal service to all areas and at all times. • Easily understood by users.	• Requires a grid arterial street system with a minimum of geographic or topographic barriers. • Large number of routes required. • Moderate frequency service required on all routes. • Passenger transfers often required, which may involve long waits, even on trips to CBD. • Difficult to account for differing demand densities. • Higher potential cost.	



The major disadvantage of the grid configuration is that many trips require a transfer. Grid system passengers can often face long and/or uncertain transfer waits unless transfer connections are scheduled or high frequency service is provided on all routes. Unfortunately, scheduling of timed transfer connenctions on a grid system is virtually impossible because of the large volume of routes. And grid systems require high demand levels to support frequent service on the large number of routes. Therefore, grid systems are generally restricted to central cities where population and transit demand densities are highest. And because of the large demand required on grid system routes, it is not practical to provide grid routing in suburban or medium-density areas.

2.3.2 Paratransit

Paratransit can be defined as intraurban passenger transportation services which are available to the public, are distinct from conventional transit and can operate over the highway and street system.[5] Paratransit systems include dial-a-ride, route and checkpoint deviation bus services, jitney services, rent-a-car operations, carpools, vanpools and exclusive-ride and shared-ride taxi services. Paratransit vehicles include automobiles, vans, limousines, or minibuses which can carry between 5 and 30 passengers.

Paratransit services are often designed for special users, such as the elderly or handicapped. Paratransit systems often provide doorstop services, for 100 percent service area coverage. Unfortunately, such personalized services are costly, and paratransit's flexible routing, scheduling and dispatching options frequently create service reliability problems. The issue of on-time reliability is particularly important if paratransit systems are to be coordinated with other transportation modes and services.

Although paratransit may be relatively costly, in low population and transit demand density markets paratransit may achieve lower costs per passenger than conventional transit. Paratransit, however, cannot usually provide service at high demand levels because of the low vehicle capacity and the personal nature of the services. Thus, paratransit vehicle productivity usually remains quite low. Paratransit systems are designed to be more flexible than conventional transit systems and are best suited to lower density areas where local trips are scattered.

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[5] Kirby, R.F. et. al., Paratransit: Neglected Options for Urban Mobility, Washington, D.C., 1974.

2.3.3 The Timed Transfer Niche

In central cities, transit services are fairly frequent (i.e., headways of under 10-15 minutes) so that little would be gained by attempting to synchronize schedules to facilitate transfers. As conventional transit services expand outward, route separations in grid systems increase and crosstown connections in radial systems grow less frequent. The frequency of service decreases and most transfers become time consuming and inconvenient. At the other end of the spectrum are rural or very low density areas that are usually served by no transit services. In some low and medium-density areas, flexible paratransit services may be implemented.

Timed transfer appears to be an effective means of serving medium density small cities and suburbs that fit in between these transit alternatives. Exhibit 2.12 graphically illustrates this continuum of transit alternatives, ranging from grid fixed-route transit, to radial routes with crosstown services, to timed transfer, to demand-responsive paratransit, to no transit services. The top portion of this same exhibit compares the key features of conventional transit, paratransit and timed transfer systems.

As demonstrated in Portland, timed transfer can bring local crosstown service to suburban areas and connect with long urban trunk routes. Ann Arbor made a successful change from paratransit to fixed-route timed transfer services as demand grew. And as patronage increased in Boulder, their timed transfer system evolved into a more conventionally scheduled system.

2.4 NATURE OF THE MEDIUM DENSITY MARKET

Timed transfer is identified primarily with medium density population and transit demand markets. This section distinguishes medium density markets from low and high density markets in order to identify where timed transfer has its greatest potential. A number of the unique characteristics of the medium density market, such as dispersed population, higher levels of income and automobile ownership, employment and commuting patterns and transit demand densities are discussed.

2.4.1 Population Density

Medium density markets can be thought of as areas with population densities ranging from 1,000 to 10,000 inhabitants per square mile. Medium density developments are typically found in:

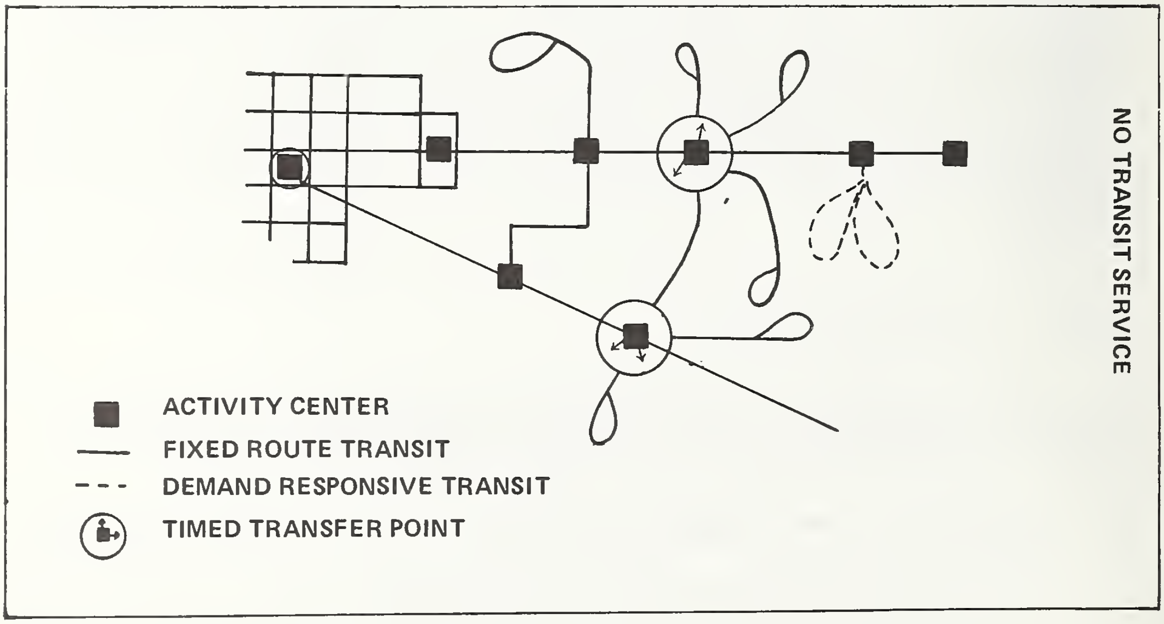
- independent urban communities with more than 50,000 inhabitants; and

Exhibit 2.12

COMPARISON OF CONVENTIONAL TRANSIT, PARATRANSIT, AND TIMED TRANSFER FEATURES

(Comparing systems with the same overall service level over the same area)

Feature	Conventional Fixed-Route	Paratransit	Timed Transfer
Areas Served	Best performance in high-density areas.	Better comparative performance in low-density areas.	Better comparative performance in medium-density areas.
Trips Served	Best for long trips in corridors.	Best for scattered local trips.	Best for interfacing local cross-town and long, corridor trips.
Riders Served	Primarily commuter oriented.	Draws varied patronage, especially elderly, disabled and young.	Primarily suburban patronage, especially commuters, students and shoppers.
Peaking Behavior	Morning and afternoon work trip peaks.	Often midday peaks.	More consistent ridership throughout day, with some morning and afternoon work trip peaks.
Ridership Growth	Usually patronage develops slowly.	Usually patronage develops rapidly.	Patronage has developed fairly rapidly on existing systems.
Reliability	Easier to maintain — planned service quality, with fewer constraints.	Difficult to maintain — no schedule and few constraints.	Most important to maintain — planned schedules and fixed constraints.
Coverage	Different residences and businesses are nearer or farther from routes.	Often available equally to all service area points.	Different residences are nearer or farther from routes or transfer points.
Cost	Least expensive if high passenger volumes	Generally, more costly than conventional, due to route and scheduling requirements and lower passenger volumes.	Generally highest cost per passenger



- fringe or suburban areas surrounding metropolitan centers.

Rural communities, scattered urban settlements or areas with population densities of less than 1,000 persons per square mile and major urban cores, central cities or areas with population densities of more than 10,000 persons per square mile are not generally considered medium density areas.

The medium density market, as represented by this population density, is large and growing. From 1950 to 1970 suburban areas grew at four times the pace of central cities. Between 1970 and 1977, suburban area populations grew 12 percent while central city populations declined 7 percent for all Standard Metropolitan Statistical Areas with over one million residents. And preliminary data from the 1980 U.S. Census indicate the greatest population increases are occurring in low and medium density areas, that are both independent and part of metropolitan regions. The new population growth areas, in the western and southern portions of the U.S., also have significantly less dominant central cities and substantially higher medium density developments.

The most attractive range for timed transfer services appears to be 3,000 to 6,000 persons per square mile. The median number of persons per square mile in the three case studies examined in this report are 4,000 in Ann Arbor, 4,250 in Boulder and 6,000 in the Westside of Portland.

2.4.2 Income and Auto Ownership

In addition to population density, a number of other socio-economic factors characterize medium density areas. Exhibit 2.13 contains census data for metropolitan areas and documents some major differences between high density, city and medium density, urban fringe residents. The urban fringe population is characterized by:

- a primarily white population with a higher level of education;
- a larger number of driving age residents and fewer older people;
- a higher income level, with few persons below the poverty line; and
- a greater availability of automobiles.

Both Ann Arbor and Boulder are dominated by a higher education, University atmosphere. In all three study sites the median annual income was above $10,000 during the 1970's. And in Boulder and in the Westside of Portland, only six percent of all households did not own an automobile.

Exhibit 2.13

PROFILE OF CITY VS. SUBURBAN RESIDENTS

	Central Cities	Urban Fringe
Population by Race (White/Non-White)[1]		
1950	87%/13%	94%/6%
1970	77%/23%	94%/6%
1978	75%/25%	93%/7%
Average years of school for population 25 years and older (1970)[2]	10.6	11.7
Age of head of household, 2+ persons[3] (1977)		
Under 65	85.6%	88.5%
65 or older	14.4%	11.5%
Median household income (1977)[1]	$12,059	$16,579
Percent of persons below the poverty level (1977)[1]	15.4%	6.8%
Percent of occupied housing units with car available (1977)[1]		Central Cities and Urban Fringe
No car	26.5%	16.9%
One car	45.2%	45.3%
Two cars	22.6%	29.6%
Three or more cars	5.7%	8.2%

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[1] Statistical Abstract for the United States 1979 . . . p. 17 (No. 16), p. 459 (No. 751), p. 462 (No. 759), p. 650 (No. 1105).

[2] B. Schwartz (Ed.), The Changing Face of the Suburbs . . . p. 20-21.

[3] U.S. Bureau of the Census, Annual Housing Survey, 1977.

2.4.3 Employment and Commuting

Over the last 30 years, the suburbanization of employment and commercial activities followed the decentralization of the population into medium density areas. Between 1960 and 1970 the greatest increases in employment were in the white collar suburban markets and more recent research has shown further net migrations of the work force from metropolitan and central areas to nonmetropolitan and noncentral areas.[6] This has resulted in a decreasing amount of travel to and from the CBD and a marked increase in the level of traffic in outlying areas.

Exhibit 2.14 illustrates this trend by showing the different commuting trip patterns between the central city and the suburban ring in 1960 and 1970. In 1960, almost two-thirds of the U.S. commuters traveled to the CBD and less than one-third traveled between suburbs; by 1970, just over one-half traveled to the CBD while travel between suburbs grew to 38 percent. Recent estimates indicate less than 10 to 20 percent of the total trips made in an urban region are CBD-oriented.[7]

2.4.4 Transit Demand

Although diffuse travel patterns are characteristic of medium density areas, the combination of the size, density and characteristics of the service area will influence the demand for transit service. Medium density areas can pose serious problems for transit systems if insufficient passenger demand is generated to support local services. Extensive surveys indicated U.S. paratransit systems had a median demand density of 10 passenger-trips per 1,000 residents per day in 1978.[8] At the other extreme, the New York City Transit Authority can have a demand as great as 550 passenger-trips per 1,000 residents per day.[9]

The demand density for fixed-route timed transfer bus systems examined in detail in this report ranged from about 35 to 150 passenger-trips per 1,000 residents per day. The three timed transfer

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[6] U.S. Department of Transportation, Transportation Systems Center, Implications of Selected Societal Trends for Urban Transportation Policy and Research, Cambridge, MA, January, 1981, p. 29.

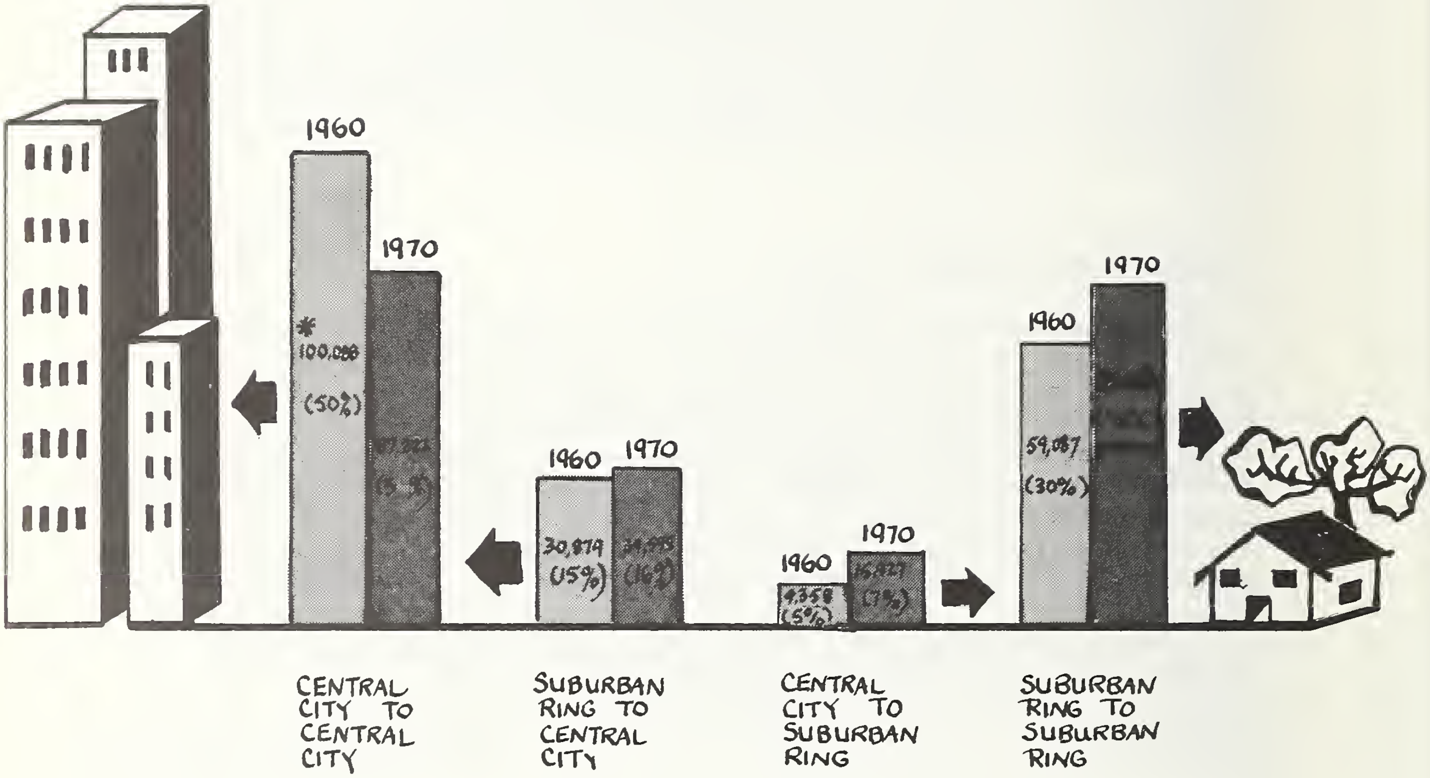
[7] Schneider, Jerry, et al., Planning and Designing a Transit Center Based Transit System, September, 1980, p. 1.

[8] Billheimer, John, et al., Paratransit Handbook, Vol. I, p. 3-17.

[9] APTA, Operating Statistics Report, 1980, p. B-08.

Exhibit 2.14

COMMUTING TRIP PATTERNS



▨ – 1960

■ – 1970

Numbers reflect 1,000's of employees & % of total commuting for each year.

case study sites had demand densities of:

	Daily Pass. Trips/1,000 Residents
Ann Arbor	39
Boulder	96
Portland	148

By comparison, the paratransit services that preceeded timed transfer in Ann Arbor averaged 28 rides per capita. And Boulder averaged 133 rides per capita with its later growth in population and change to a more conventional transit system.

2.4.5 Summary

Medium density areas differ from high or low density areas, in terms of their populations, socio-economic characteristics, travel patterns and transit demand. Over the last thirty years, these areas have continued to grow dramatically, in both resident and employment population. This population shift has diverted travel away from the CBD and made crosstown trips an increasingly important travel pattern.

Although most residents or workers in medium density areas have relatively high incomes and depend on automobiles for their travel, timed transfer transit systems have gained their greatest popularity in such medium density communities. This is especially true in the rapidly growing less densely developed western portions of the U.S. and Canada. According to census data, the total U.S. suburban population is about 83 million persons. Using the Ann Arbor, Boulder and Portland demand density data, if timed transfer can serve 50 passenger-trips per 1,000 residents per day, there may be a substantial and growing market for timed transfer.

2.5 CONCLUSIONS

Eight timed transfer sites and systems were discussed in this chapter and three more are examined in Chapter 5. Exhibit 2.15 summarizes the characteristics of the areas served by these eleven systems. Exhibit 2.16 lists the key features of the systems themselves.

The different timed transfer applications cited in this chapter demonstrate that timed transfer can be and is being used by several transport modes in a variety of settings and situations. These range from:

1. Individual small communities to medium-size cities to one or more suburbs within a large metropolitan area;

Exhibit 2.15

SERVICE AREA CHARACTERISTICS

Site (Date of Implementation)	Size (sq. miles)	Population	Density (Persons/ sq. miles)	Household Auto Ownship (%)	Persons in Labor Force	Median Income	Economic Activity	General Description
Ann Arbor[1] (October '79)	45	179,000	3,978	0 11.3 1 52.3 2+ 36.4	82,000	$12,294	University Research Manufacturing	Two adjacent medium-size growing communities
Boulder[2] (March '78 December '78)	19.5[a]	83,000[a]	4,256	0 6.1[b] 1 44.2 2 36.7 3+ 13.0	41,600	$19,600[b]	University Government Technological	Medium-size University Community Limiting Expansion
Portland[3] (June '79)	27[a]	162,000[a]	6,000	0 6.4[a] 1 35.5 2+ 58.2	71,606[a]	$10,458[b]	Services Manufacturing Retail Trade	Suburban Communities Adjacent to Major City
Edmonton[4] (1964)	120	435,000	4,000	NA	151,125	NA	Industrial Business Commercial University	Central City and Surrounding Communities
Eugene[5]	NA	225,000[a]	NA	NA	84,000[b]	$ 9,995[b]	University	Medium-size University Community
Nassau County[6] (1976)	298[a]	1.43[a] million	5,034[b]	0 8.3 1 42.4 2 41.1 3+ 8.2	650,400[a]	$14,625[c]	Government Services Retail	Large County Suburban Area
Norristown[7] (March '77)	3.6[b]	35,000[a]	9,722	NA	20,555[b]	$ 9,749[b]	Light Manufacturing Retail	Suburban Community Adjacent to Major City
Sacramento[8] (Sept. '79)	12.85[a]	36,975[a]	2,880	0 10.7[b] 1 44.7 2 36.5 3+ 8.1	10,415[a]	$ 9,708[b]	Retail Government College	Suburban Community Adjacent to Major City
Tacoma[9] (Sept. '80)	120[a]	33,000[a]	2,758	NA	NA	$ 9,859[b]	University Port Military Bases	Central City and Surrounding Communities
Vancouver[10] (Fall '73)	40	90,000[b] (Vancouver 1,082,352 in 1979)	2,250	0 7 1 51 2+ 42	(Vancouver 245,000 in 1975)	NA	Retail Services	Suburban Communities Surrounding Metropolitan Area

Exhibit 2.15

NOTES

NA = Not Available

[1]ANN ARBOR

Service area characteristics are based on 1970 Census Data.

[2]BOULDER

[a]Service area size and population are based on 1979 estimates by Boulder City Planning Office.

[b]Autos/HH and median income based on *Annual Housing Survey:* 1976, for Denver SMSA, not including Central Denver.

[3]PORTLAND

[a]Service area size, population, auto ownership and labor force data are based on 1977 CRAG estimates, separated by census tracts, for the Westside service area.

[b]Median income based on 1970 Census Data for the Portland SMSA.

[4]EDMONTON

Population and labor force data based on Census Data, in J.J. Bakker, T.O. Clement Transit Trends in Edmonton, September 1974; and on 1971 data from Edmonton.

[5]EUGENE

[a]Population based on 1977-1978 data from Lane County Transit District in "Transit Development Program 1979-1982."

[b]Labor force and median income based on 1970 Census Data for Eugene.

[6]NASSAU COUNTY

[a]Service area size, population and labor force data based on 1975 estimates for Nassau County, "Nassau County Data Book," 1978.

[b]Densities in Nassau County vary greatly, with higher density areas, (the Northwest and Southwest portions of the County) receiving proportionately higher levels of transit services.

[c]Median income and auto ownership based on 1970 Census Data for Nassau County.

[7]NORRISTOWN

[a]Population based on 1975 estimates from "State, Counties and Subcounty Areas, 1976," for Norristown.

[b]Service area size, labor force and median income data based on 1970 Census Data for Norristown.

[8]SACRAMENTO

[a]Service area size, population and labor force data are based on Sacramento Regional Area Planning Commission, "A Multi-Destination Timed Transfer Transit System," June 1978 for the South Sacramento — Florin suburban area.

[b]Household Auto Ownership and Median Income based on 1970 Census Data for Sacramento County.

[9]TACOMA

[a]Service area and population based on estimates by the Pierce County Public Transportation Benefit Area Authority, 1977.

[b]Median income based on 1970 Census Data for Pierce County.

[10]VANCOUVER

[a]Unless otherwise noted, service area characteristics refer to Coquitlam, a suburban area northeast of downtown Vancouver.

[b]Population and auto ownership data are based on Bureau of Transit Services, "The Impact of New Bus Services in the Coquitlam Area," October, 1974.

Exhibit 2.16

KEY SYSTEM CHARACTERISTICS

Site	Number of Timed Transfer Points	Approximate Fleet Size	Number of Routes in Timed Transfer Network	Number of Buses at each Meet			Headways (minutes)	
				Average	Minimum	Maximum	Peak	Off-Peak
Ann Arbor[1]	7	32[a]	13	5	2	12	15	30
Boulder[2]	4	28	10	4	3	6	15	30
Portland[3]	2	86	9	6	4	8	20	30[b]
Edmonton[4]	13	468	67[a]	6	2	12	15	30
Eugene[5]	1	67	22	10	5	13	30	45
Nassau County[6]	5	322	23[a]	6	5	7	NA[b]	30/60
Norristown[7]	1	20	4[a]	4	1	7[b]	30	60
Sacramento[8]	1	NA	5	3	2	4	30	60
Tacoma[9]	7[a]	185	NA[b]	NA[b]	2	NA[b]	15	30
Vancouver[10]	3	48[a]	12	4	2	10	30	30[b]

NOTES

[1] Ann Arbor:	Based on data from 1979-1980.	[a] Does not include dial-a-ride vehicles, used for elderly and handicapped services.
[2] Boulder:	Based on data from 1978-1979.	
[3] Portland:	Based on data from 1979-1980.	[b] 60 minute headways on Saturday and Sundays.
[4] Edmonton:	Based on data from 1975.	[a] Timed transfer routes during peak (48 routes operate during off-peak).
[5] Eugene:	Based on data from 1978.	
[6] Nassau County:	Based on data from 1980.	[a] Does not include Long Island Rail routes. [b] Headways range from 10-60 minutes, depending on the route.
[7] Norristown:	Based on data from 1977.	[a] Does not include high speed rail route. [b] Three of the four timed transfer routes are divided into east/west or north/south buses.
[8] Sacramento:	Based on data from 1979-1980.	
[9] Tacoma:	[a] Seven points are planned for operation during 1981. [b] Timed transfer system is currently being implemented — the total number of routes and the number of buses at each meet has not yet been determined.	
[10] Vancouver:	Based on data from 1973.	[a] Based on number of vehicles in Coquitlam service area. [b] 60 minute headways on Saturdays and Sundays.

NA = Not Available

2. Areas that previously had conventional grid or radial fixed route transit services to areas that previously had dial-a-ride or paratransit services to areas that had no previous transit service;

3. Single focal point, downtown "pulse" operations, to systems with several outlying transfer points, to timed transfer networks with as many as thirteen focal points;

4. Off-peak only or primarily one directional peak period services to all day, all directional services;

5. Intra-city timed transfer systems to local transit systems that coordinate transfers with inter-city regional routes; and

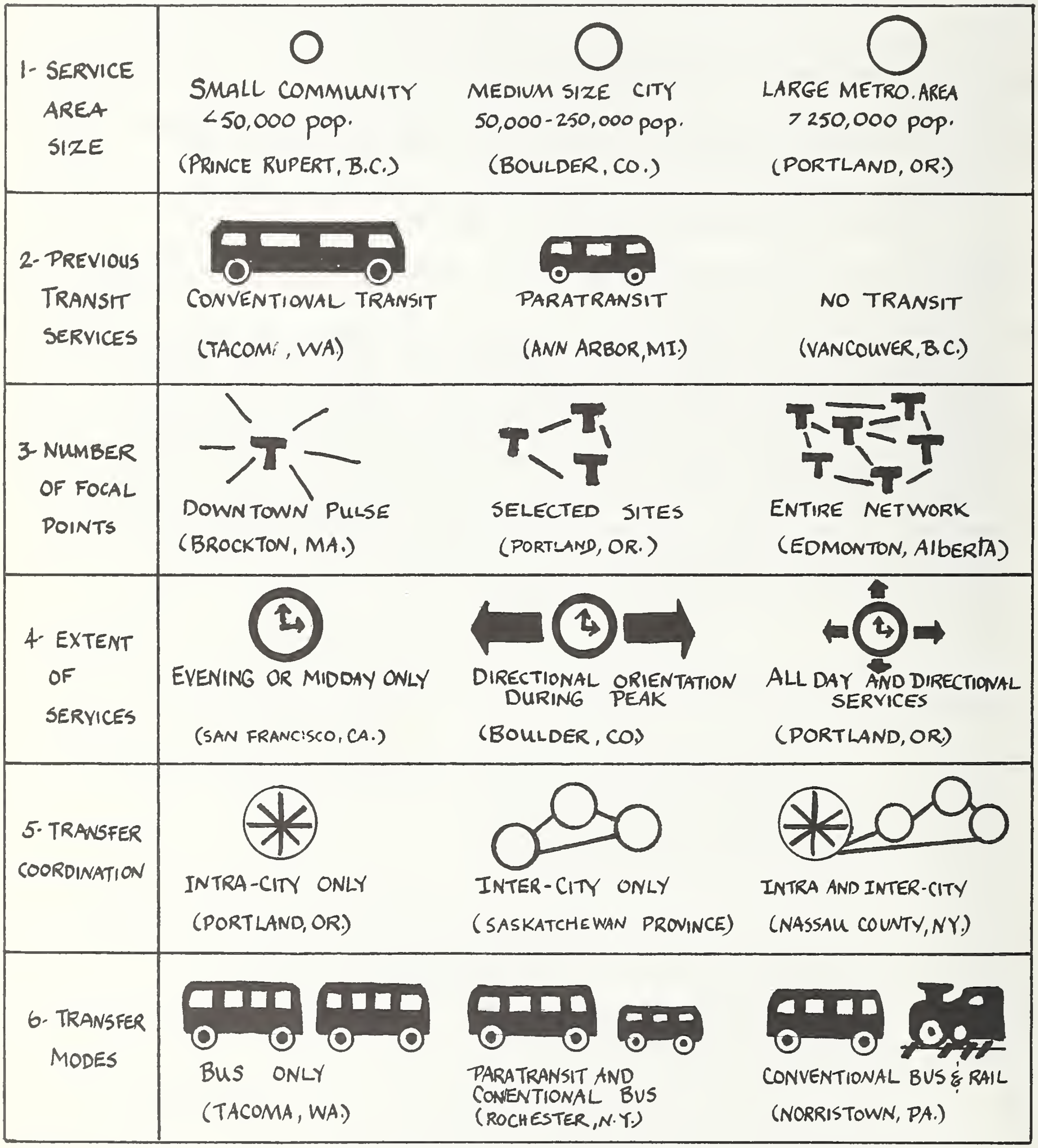
6. Bus-to-bus connections to multi-mode connections, linking conventional buses with light rail or heavy rail vehicles.

Exhibit 2.17 highlights this wide range of possibilities and identifies an example of each situation.

As discussed in this chapter, although timed transfer has been implemented in different size and types of service areas, most timed transfer systems are operating in medium density population and transit demand areas. Similarly, while different types and levels of transit services can preceed timed transfer, most sites operated relatively low levels of conventional transit services prior to timed transfer. And, although the features of timed transfer systems can vary widely, the remainder of this report focuses on intra-city bus-to-bus timed transfer systems that have a selected number of transfer points and provide multi-directional services.

Exhibit 2.17

RANGE OF APPLICATIONS AND EXAMPLES OF TIMED TRANSFER TRANSIT SYSTEMS



FEATURES	APPLICATION AND (EXAMPLES)		
1- SERVICE AREA SIZE	SMALL COMMUNITY <50,000 pop. (PRINCE RUPERT, B.C.)	MEDIUM SIZE CITY 50,000-250,000 pop. (BOULDER, CO.)	LARGE METRO. AREA >250,000 pop. (PORTLAND, OR.)
2- PREVIOUS TRANSIT SERVICES	CONVENTIONAL TRANSIT (TACOMA, WA.)	PARATRANSIT (ANN ARBOR, MI.)	NO TRANSIT (VANCOUVER, B.C.)
3- NUMBER OF FOCAL POINTS	DOWNTOWN PULSE (BROCKTON, MA.)	SELECTED SITES (PORTLAND, OR.)	ENTIRE NETWORK (EDMONTON, Alberta)
4- EXTENT OF SERVICES	EVENING OR MIDDAY ONLY (SAN FRANCISCO, CA.)	DIRECTIONAL ORIENTATION DURING PEAK (BOULDER, CO.)	ALL DAY AND DIRECTIONAL SERVICES (PORTLAND, OR.)
5- TRANSFER COORDINATION	INTRA-CITY ONLY (PORTLAND, OR.)	INTER-CITY ONLY (SASKATCHEWAN PROVINCE)	INTRA AND INTER-CITY (NASSAU COUNTY, NY.)
6- TRANSFER MODES	BUS ONLY (TACOMA, WA.)	PARATRANSIT AND CONENTIONAL BUS (ROCHESTER, N.Y.)	CONVENTIONAL BUS & RAIL (NORRISTOWN, PA.)

3. IMPACTS ON TRANSIT PROVIDERS, USERS AND THE COMMUNITY

Timed transfer has had various impacts on different groups. This chapter examines the major impacts of timed transfer from the perspectives of the transit provider, the transit user and the community. For some impacts, case study examples are given and/or guidelines are suggested. This information may be particularly helpful for those interested in developing timed transfer systems.

3.1 TRANSIT PROVIDERS

3.1.1 APTA Opinion Poll

A survey was conducted to solicit the perceptions and attitudes of transit providers, who are operating timed transfer services, or who have knowledge or interest in the timed transfer concept. The American Public Transit Association's (APTA) Suburban Issues Subcommittee[1] of the Policy and Planning Committee distributed the questionnaire to each of its members. APTA forwarded the completed questionnaires to SYSTAN for tabulation and analyses. A copy of the questionnaire is contained in Exhibit I in Appendix B.

Over 75 percent of all respondents "strongly agree" or "agree somewhat" with the following statements:

- Few transit riders will transfer more than twice per one-way trip;
- Transit systems should provide direct service whenever possible; and
- Reliable service is the single most important factor for attracting riders to transit.

Most of the suburban transit operators feel that timed transfer networks have the greatest potential for medium size, multi-modal, suburban off-peak systems. They also feel that timed transfer provides a better

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[1] APTA's Suburban Issues Subcommittee was formed in 1980 to focus on suburban transit issues on an active project oriented basis. The Subcommittee is composed of approximately 50 members, divided into subgroups focusing on shopping centers, transit centers, pricing/ resource distribution, land use and service development. Most Subcommittee members are transit operators and several are operating timed transfer services.

level of service and is cheaper than paratransit in low-population density areas.

All respondents agreed that the most important operating issue in timed transfer systems is on-time reliability. Operators most familiar with timed transfer reported that such systems can improve on-time reliability by about 25 percent over a conventional fixed-route system. Although an overwhelming number agree that methodologies can be developed to overcome scheduling problems, the majority feel that schedule "meets" are missed primarily because of traffic congestion. The four most efficient and effective methods for assuring "meets," cited by the respondents are:

1. Schedule additional transfer point hold time;

2. Inform and train drivers;

3. Install radio dispatch communication; and

4. Adopt a discretionary policy for additional transfer hold times.

They believe that timed transfer bus services can increase average route layovers by about 35 percent when compared with conventional bus services, and most agreed that buses should never be held more than five minutes beyond their scheduled departure time to accommodate timed transfers.

The respondents overwhelmingly agreed that transit centers provide psychological reassurance of connecting services and that passengers feel more secure if there is a major transfer structure at timed transfer points. However, they disagreed strongly when asked whether the capital costs required to implement timed transfer systems are significant. Operators are evenly divided on the type of transfer center needed to influence the success of the system. Most transit operators appear to separate the timed transfer scheduling concept from the need to provide major passenger transfer facilities. Some operators, however, consider the transit centers to be synonymous with timed transfer systems.

When asked to compare the same level of conventional fixed-route bus services with timed transfer bus services, in terms of equivalent coverage, almost three-fourths of the respondents felt that timed transfer would increase operating costs and 85 percent felt that timed transfer would increase ridership. However, the respondents felt there would be not much difference in the number of vehicles or the labor required to operate either type of system. Overall, a majority felt that timed transfer would produce a slight improvement in productivity.

The respondents feel there is not enough general information on the timed transfer concept or on the costs of implementing and operating timed transfer. There is also little information on how to guide the selection of timed transfer service areas and system planning and scheduling. And practically no information is available on selecting the number of timed transfer points to be used and the number of bus routes that can be coordinated within one system.

3.1.2 Managers/Supervisors

3.1.2.1 Conservative vs. Aggressive Management

Most transit managers are primarily concerned with maintaining a stable ridership and cost structure. This conservative outlook results from declining patronage, rapidly rising costs and a scarcity of operating subsidies. Transit managers fear that shifts in routing or scheduling may decrease patronage. Hence, most managers are highly sensitive and generally opposed to any radical changes in services. When service changes are necessary, individual routes and/or schedules are typically extended or cut-back. This process has produced inefficient, radial bus route configurations that may serve high, medium and low density areas.

Running counter to the conservative management philosophy is the rather aggressive outlook of timed transfer service managers. A couple of timed transfer managers offered such comments as "Be brave -- try it" and "Do it!" on their questionnaires. This aggressive philosophy comes from managers who understand timed transfer system capabilities. This outlook may, however, be inappropriate or difficult for managers of CBD oriented systems that focus on peak period or limited destination service.

New transit managers also seem to have the greatest interest in implementing timed transfer services. This may come from mandates for change, a desire to have an impact on service or a willingness to accept greater risk in a new environment. In Ann Arbor, Michigan, fixed route timed transfer services were implemented after a new transit board was elected and a new manager was hired. Both the board and the manager were openly opposed to earlier paratransit services. Similarly, Tacoma Transit's new Director was interested in exploring different types of services. In contrast, when the scheduling function shifted from Boulder to Denver, Colorado, the RTD-Boulder timed transfer service reverted to a more conventional system. And, after one of the developers of the Edmonton timed transfer system moved to Portland, Oregon, he became a major motivating force behind Tri-Met's timed transfer services.

3.1.2.2 Phased System Approach

Before designing timed transfer systems, transit managers feel it is necessary to look at all routes and schedules as an interrelated network system, rather than as independent routes. Tri-Met looked at its entire system when planning timed transfer service for the Westside.

They redesigned all routes and schedules in the Westside service area and adjusted other parts of the system. The design process took one year from initial planning that began in May 1978 to timed transfer operations that started in June 1979. Monitoring and adjustment continued for almost a year thereafter.

One strategy for reducing the complexity of this design approach is to incrementally or progressively implement the system. Timed transfer can initially be tested in a small service area. If successful, other service changes can be introduced. This strategy was used in developing Portland's Westside service and Sacramento's Florin Mall service. Because of the success of the initial phase, Tri-Met has already expanded timed transfer services to other areas of Portland. Pierce County (Tacoma, Washington) phased the implementation of their expanded timed transfer services over approximately one year. Nassau County developed and implemented its timed transfer services over a four year period.

Incremental implementation, however, does not relieve management of the need to take a network view of the system and to understand how timed transfer relates to the rest of the system. Timed transfer requires a massive overhaul of all routes and schedules. Even if timed transfer services are planned for only a portion of the community, other routes may need to be rescheduled.

3.1.2.3 Strong Cooperative Leadership

Timed transfer providers believe a strong manager is one of the most important criterion for success. Management must be committed to the timed transfer concept and like the system itself, management should function as a coordinated team. An effective transit manager needs to work closely with:

1. planners, to evaluate area needs, demand levels and system resources and to identify appropriate service areas and levels of service;

2. schedulers, to provide the basic structure and headway information for the timed transfer network;

3. marketing personnel, to provide clear schedule and transfer information to customers; and

4. road supervisors and drivers, to convey and emphasize the importance of adhering to schedules, and maintaining reliable services and to understand operating behavior under different conditions.

Each of these parties must also work together if the timed transfer system is to work. For example, the road supervisors are especially important in overseeing vehicle and driver activities and in identifying operational problems. If transfer connections are missed because drivers are making additional unscheduled stops, road supervisors must remind and, if necessary, discipline these drivers. If meets are not made because the schedulers have not allowed sufficient time to complete runs, the driver and supervisor must be able to discuss and rectify these problems with the scheduling department. In Portland, Route 57, the major trunk service between downtown and the Beaverton Transit Center, consistently missed the Beaverton timed transfer connections. Analysis showed that Route 57's schedule was too tight, especially during the PM peak period, and that drivers on connecting lines were not conscientious about insuring the meets. To improve reliability, Tri-Met's schedulers added more running time to Route 57, to enable passengers to make all scheduled connections. In addition, Tri-Met's Road Operations Manager issued a reminder to all drivers about the importance of making the transfer connections. Exhibit 3.1 shows the Tri-Met Manager's reminder statement to drivers.

3.1.2.4 Public Support

A predominant characteristic of timed transfer systems seems to be a high degree of public participation and active citizen support. Management must be willing to work closely with citizens and decisionmakers. Initially, the manager must work with the community to explain the timed transfer concept, the objectives of the system, and to identify possible problems. Local decisionmakers will often be involved in this process. With adequate preparation, strong public support is possible.

Tacoma

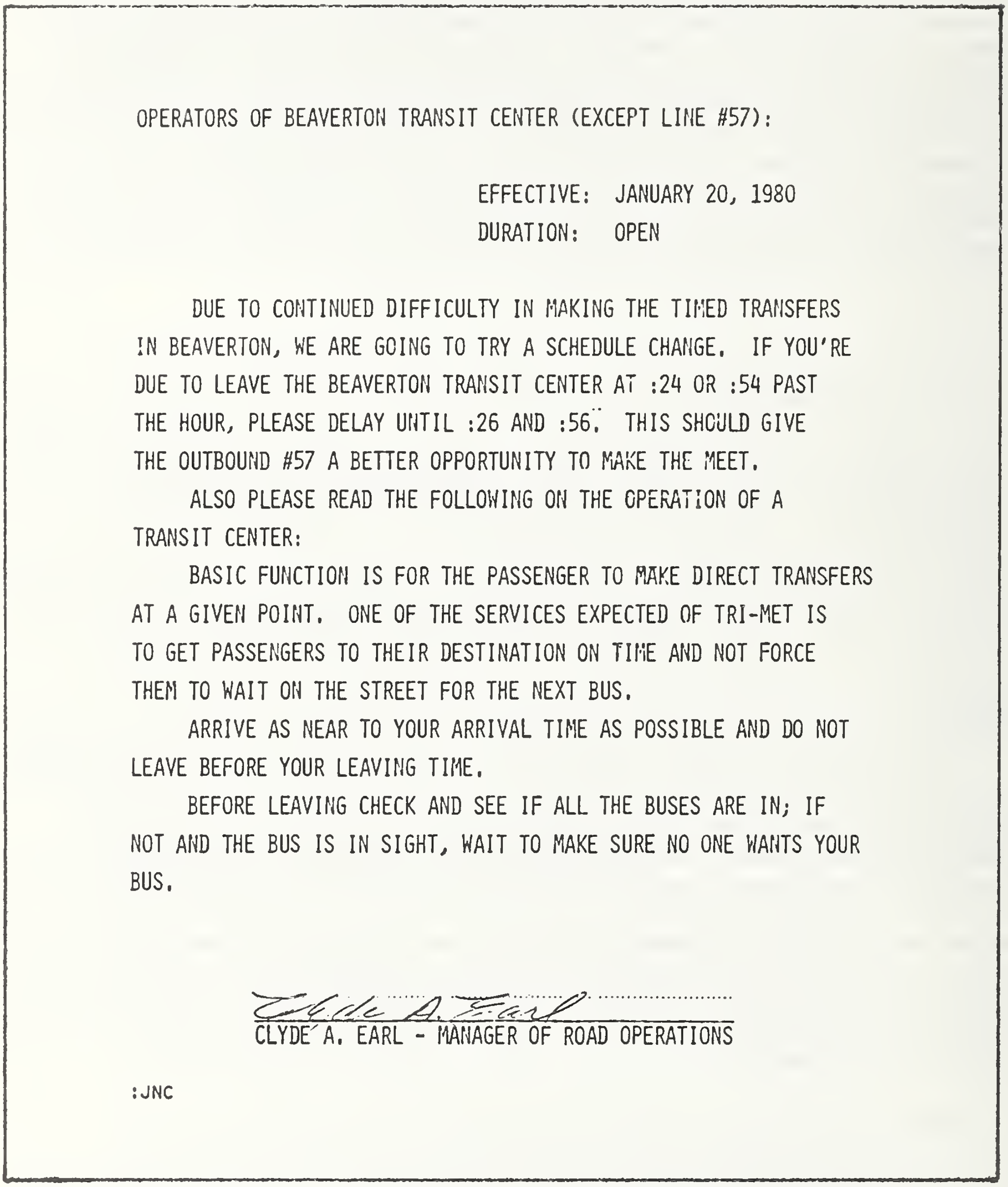
On November 6, 1979, residents of Pierce County, WA, demonstrated their support for improving public transportation by voting for an increase in local sales tax. The newly formed Pierce County Public Transportation Benefit Area (PCPTBA) staff then distributed and mailed over 60,000 workshop information brochures to Pierce County PTBA residents. PCPTBA estimates that over 800 people attended the community workshops, to help to identify the systems' objectives and service area needs. The PTBA also received about 100 informational telephone calls on the proposed system. After the system was partially implemented more community workshops were held to identify major transit center sites and facility requirements.

Portland

In Portland, local neighborhood associations and ad hoc citizen transit organizations were actively involved in planning the Westside "Direct Connection" services. Tri-Met placed placards on existing Tri-Met routes and sent 68,000 informational brochures to registered voters in the region, inviting comments on the proposed services. Interested citizens attended planning meetings, testified to the Tri-Met

EXHIBIT 3.1

REMINDER STATEMENT TO TRI-MET DRIVERS



OPERATORS OF BEAVERTON TRANSIT CENTER (EXCEPT LINE #57):

EFFECTIVE: JANUARY 20, 1980
DURATION: OPEN

DUE TO CONTINUED DIFFICULTY IN MAKING THE TIMED TRANSFERS IN BEAVERTON, WE ARE GOING TO TRY A SCHEDULE CHANGE. IF YOU'RE DUE TO LEAVE THE BEAVERTON TRANSIT CENTER AT :24 OR :54 PAST THE HOUR, PLEASE DELAY UNTIL :26 AND :56. THIS SHOULD GIVE THE OUTBOUND #57 A BETTER OPPORTUNITY TO MAKE THE MEET.

ALSO PLEASE READ THE FOLLOWING ON THE OPERATION OF A TRANSIT CENTER:

BASIC FUNCTION IS FOR THE PASSENGER TO MAKE DIRECT TRANSFERS AT A GIVEN POINT. ONE OF THE SERVICES EXPECTED OF TRI-MET IS TO GET PASSENGERS TO THEIR DESTINATION ON TIME AND NOT FORCE THEM TO WAIT ON THE STREET FOR THE NEXT BUS.

ARRIVE AS NEAR TO YOUR ARRIVAL TIME AS POSSIBLE AND DO NOT LEAVE BEFORE YOUR LEAVING TIME.

BEFORE LEAVING CHECK AND SEE IF ALL THE BUSES ARE IN; IF NOT AND THE BUS IS IN SIGHT, WAIT TO MAKE SURE NO ONE WANTS YOUR BUS.

Clyde A. Earl
CLYDE A. EARL - MANAGER OF ROAD OPERATIONS

:JNC

Board at public hearings and worked with the marketing director on customer information needs.

Ann Arbor and Boulder

Similarly, active student and elderly groups in Ann Arbor and Boulder participated in community hearings and meetings concerning the proposed changes in each cities' transit services. The Ann Arbor Transit Authority Board debated the proposed service changes for almost six months, with considerable public participation. In Boulder, public transit meetings were held to find out where people lived, and where and when riders wanted to travel. Schedulers worked with road supervisors and drivers to understand traffic, physical roadway and other operating conditions, to avoid potential scheduling problems. A preliminary schedule was then field tested by drivers and supervisors to compare running times, passenger route checks and expected passenger loads, stops, and schedule adherence. Based on these findings, schedulers revised the initial schedule.

Edmonton

Edmonton Transit has developed a special public participation process for planning timed transfer services. They first hold a public meeting to explain the timed transfer concept and the routes and schedules proposed for service. Citizen comments are invited. Detailed routings are developed from this input and presented to the public. Another public meeting is held to discuss the proposed service changes. The plan is then adopted or rejected by Board decision at that meeting.

3.1.3 Transit Planners

Like transit managers, most transit planners are not accustomed to analyzing bus services as a regional connected network. Planners spend most of their time patching up or modifying existing routes. Older transportation planning tools and most mathematical programs or algorithms used for planning transit systems analyze routes one at a time. There has, however, been some recent work in examining the overall network and in developing regional macro-based transit models.[2]

Most transit planners are also oriented to designing direct no-transfer services. This orientation comes from planners' sensitivity to the results of numerous passenger opinion surveys; on most conventional transit systems passengers place a high negative value on the "need to transfer." Almost two-thirds of the APTA opinion survey respondents agreed that transferring imposes severe penalties on passengers; no respondents strongly disagreed with this statement. Unfortunately, this outlook has been interpreted by transit planners to mean that people will not use transit if a transfer is required. This attitude posed an institutional barrier to Tri-Met timed transfer service planners. Several of British Columbia's (Vancouver and Victoria) planners also experienced an initial resistance to designing transit services that forced passengers to transfer.

Another institutional barrier cited by some planners was their traditional orientation toward designing transit services for high-density areas, downtown streets and for typically low-income, autoless and transit dependent users. Urban transportation planners may not have an understanding of the suburban and medium-density travel market and the characteristics of its users. Tri-Met service planners sought technical advice from local city and county planning jurisdictions; and suburban community traffic engineers helped identify whether existing streets, intersections, and traffic could accomodate the proposed services.

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[2] U.S. Department of Transportation, Improved Urban Transportation Planning Systems (UTPS), Technical Notes #1-80, Office of Public Affairs, Washington, D.C., February, 1980.

Jones, Paul S. and Carolyn Fratessa, A Method for the MacroAnalysis of Regionwide Public Transportation, SYSTAN, Inc., U.S. DOT, April, 1980.

Hsu, Jen-de and Vasant H. Surti, A Systems Approach of Optimal Bus Network Design, Illinois Institute of Technology, U.S. DOT, September, 1975.

General Motors, TNOP: Transit Network Optimization System, Transportation Systems Center, Warren, Michigan, 1980.

Kocur, George, "A Unified Approach to Performance Standards and Fare Policies for Urban Transit Systems: Analytical Results," Dartmouth College, U.S. DOT, April, 1981.

Sharp, G.P. and P.S. Jones, "Introducing Vehicle Scheduling into the Design of Optimum Public Transit Networks," Operations Research Society of America (ORSA) Spring Meeting, Milwaukee, Wisconsin: 1973.

3.1.4 Schedulers

3.1.4.1 Conventional vs. Timed Transfer

One of the most difficult impacts of timed transfer is the institutional barrier that confronts the timed transit scheduler. Most transit schedulers are used to designing conventional routes and developing runs and schedules according to individual route and line requirements, efficiency criteria and labor agreements, with a minimal emphasis placed on the coordination of system routes and schedules. Timed transfer services require an entirely different approach.

Timed transfer schedules are directed toward passenger travel opportunities and clocked headway meets, with major emphasis placed on scheduling transfer connections. To understand the differences between these opposing philosophies, interviews were conducted with several schedulers at each timed transfer site. The Regional Transit District (RTD) schedulers were most helpful because the Boulder operation changed from a timed transfer system to a more conventionally scheduled system.

Exhibit 3.2 compares the major differences between conventional transit and timed transfer transit scheduling strategies, cited by the different RTD schedulers. In conventional systems, transit schedulers must fully understand service policies and labor contract provisions; they must be able to handle large amounts of data and work within strict deadlines. In timed transfer systems, transit schedulers are subject to these same constraints, and, in addition, they must understand the interrelations that link the network and they must know how to design clock headways, provide for overlapping recoveries, and adjust routes to these schedules.

3.1.4.2 Lack of Guidance

None of the schedulers interviewed for this study received any specific guidelines on how to develop timed transfer headways, routes or schedules. Most transit systems used "trial-and-error" procedures to schedule timed transfers at focal points. Portland and Tacoma schedulers received some general guidance from discussions and on-site visits with Edmonton, Vancouver and Victoria schedulers. Tacoma hired an experienced conventional scheduler, to aid its existing schedulers. In all cases, scheduling and some routing changes were necessary after each system was implemented to alleviate specific operational problems.

3.1.4.3 Computerized Scheduling

To expand their data handling and scheduling capabilities, Portland, Edmonton and Boulder use RUCUS, the computerized RUn CUtting and Scheduling package. Ann Arbor and Tacoma have no current plans for using computerized scheduling. In Portland, route scheduling parameters

Exhibit 3.2

COMPARISON OF SCHEDULING STRATEGIES

Features	Conventional Transit System	Timed Transfer Transit System
• Major Objective	• Maximize route efficiency.	• Maximize travel opportunities and maximize system efficiency.
• Major Constraint	• Labor union contract.	• Clocked headways.
• Evaluation Methodology	• Individual route analysis.	• Total network analysis.
• Basic Guidelines	• Minimize route running time; • Minimize recovery/layover time; • Minimize vehicle requirements.	• Minimize differences in route running time module; • Provide sufficient recovery to insure reliable service. • Maximize transfer connections.
• Data Requirements	• System Policies • Union contract rules; • Ridership; • Number of vehicles; • Capacity of vehicles; • Route running time; • Maximum load points; • Frequency of service/headways;	• System Policies; • Union contract; • Location of major transfer points; • Schedule module/clocked headways; • Route running times (locals, circumferentials, trunks); • Ridership/Max. load points; • Number of vehicles; • Capacity of vehicles.
• Scheduling Procedures	• Identify route demand, based on maximize load point; • Identify number of vehicles required, based on capacity; • Build headways, based on peak/off-peak ridership; • Adjust peak schedules to major employment start/finish times; • Coordinate connecting route schedules if possible.	• Identify service area/route demands; • Relate demand to clocked headways for route at transfer points (e.g. 10, 15, 30 minutes); • Identify route running times based on headway multiple-route recovery time; • Build routes (locals, crosstowns, trunks) based on travel time between transfer points, speed, stops, distance, etc.; • Adjust peak schedules to major employment start/finish times; • Identify number of vehicles required, based on position.

are set by Tri-Met schedulers. RUCUS is then used to develop the drivers' paddles -- to indicate each driver's pull-out time, route schedule, stops, and recovery times. The Edmonton Transit System developed a computer program to evaluate scheduled arrival times at transfer nodes and eventually expanded this capability into a Master Schedule System (MSS). This program was developed in conjunction with RUCUS to provide a computer base for all schedules.[3]

These experiences suggest that greater dissemination of existing timed transfer scheduling experiences and guidance are needed. Automated data handling and scheduling techniques may hold promise for timed transfer schedulers.

3.1.5 Transit Operators

3.1.5.1 Driver Training

A timed transfer system generally requires greater training, cooperation, accountability and involvement from its bus drivers than a conventional system. All of the timed transfer sites that were surveyed provided some type of special driver training. The training, the timing and the requirements varied.

The Portland Tri-Met system provided special training and instructions for its Westside drivers before the system was installed. This training included an explanation of the timed transfer concept, emphasizing the importance of driver discipline; distribution of maps, schedules and information bulletins; and the driving of timed transfer routes. This training was not mandatory and Tri-Met could not provide special training for extra-board drivers or drivers during later sign-ups. RTD-Boulder and RTS-Sacramento developed similar initial driver training sessions but also had follow-up sessions to highlight instances where schedules and meets were not working. When Ann Arbor expanded and switched from dial-a-ride to fixed-route services, all AATA drivers received training on operating line haul services, with emphasis on schedule adherence and timed transfer coordination.

To overcome some of the problems of maintaining consistent and effective timed transfer operations, operators have suggested a mandatory initial and continuing driver education program. Timed transfer driver instructions might include: an introduction to the timed transfer concept; the specific operating requirements and schedule; the importance of operator discipline in maintaining the schedule; and the need for cooperation among drivers and road supervisors.

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[3] Stewart, Scott E. "An Overview of Transit Scheduling Experiments: A Working Paper," UTRB, CSTA, Montreal, 1979.

3.1.5.2 Large vs. Small Systems

A timed transfer system appears to pose greater difficulties for large transit properties, where: (1) all drivers do not operate timed transfer routes; (2) an individual route driver may not know the connecting transfer route drivers or the operational complexities of the connecting route; or (3) drivers do not know their passengers' trip patterns. In small transit properties, most drivers will be involved in timed transfer; drivers usually know each other; drivers are familiar with each others' routes and their related operational problems; and drivers know many of their passengers and their travel patterns.

Operators of small transit systems may also have personal pride in maintaining reliable passenger services, a pride that is reinforced through driver peer pressures. For example, several of Boulder's transit operators, who had been with the system in 1973 when only five routes operated from three timed transfer points, felt personally responsible for providing a high level of services and for making all passenger transfer meets. In this small system, drivers would ask passengers if anyone needed to transfer and request the connecting route's driver to hold the bus at the transfer point. As the Boulder system expanded, new drivers were hired, routes were added and ridership increased substantially, making it considerably more difficult to maintain the informal transfer meets.

3.1.5.3 Cooperation and Involvement

There is a great need for cooperation between drivers, planners, and schedulers. Because drivers are directly responsible for the passenger services and have on-street experience in operating route services, their input can be invaluable to future planning and scheduling changes. In fact, many of the drivers surveyed in Ann Arbor, Tacoma and Sacramento indicated they wanted to be more involved in the system's planning process.

3.1.6 Summary

Most of the issues that concern transit providers who are not involved in timed transfer operations, are based on their traditional views and perceptions of transit services and how they should operate. Traditional transit providers view each route separately and try to maximize patronage on each route. Little attention is given to transfer opportunities or to passenger trips that require transfers. Conversely, timed transfer providers view routes as elements of a system and try to maximize line interactions at transfer points. Similarly, timed transfer systems' management and operation staff also need to be highly coordinated.

3.2 TRANSIT USERS

This section examines the major impacts of timed transfer services on transit passengers. Data was obtained from interviews with timed transfer operators, from the existing literature and from transit users themselves.

The major impacts on timed transfer passengers are:

1. Overcoming resistance to transferring, developed from conventional transit system experiences;
2. Recognizing the difference between actual and perceived convenience of the timed transfer service; and
3. Understanding the timed transfer system.

3.2.1 Resistance to Transferring

In conventional transit systems, the need to transfer can be a severe deterrent to passenger use of public transportation. Passenger resistance is reflected by the frequent complaints about transfers and by low bus transfer rates. Historically, passenger transfer complaints include:

- long wait times;
- variation in wait times;
- long walks and/or interference with traffic;
- uncertainty of transfer connection being completed;
- poor or nonexistent transfer facilities;
- poor or nonexistent information on transfers;
- additional transfer charges; and
- complicated transfer policies.

Exhibit 3.3 shows the transfer policies, charges and information that were available to Los Angeles' passengers on Route 44-Beverly Blvd. during the 1950s. Although transit properties no longer have such complex transfer requirements, this example captures some of the rationale for passengers' historical resistance to transfers.

Exhibit 3.3

44 — BEVERLY BLVD.

FARE & TRANSFER ISSUING INSTRUCTIONS

IN-TRIP EAST	ZONE	FARE	CHECK	PUNCH TRANSFER (DO NOT ISSUE ZONE CHECK)	GOOD TO AN WITHIN ZONES
SANTA MONICA TO FAIRFAX	WEST ZONE 3	10¢	NONE	WEST ZONE 3 — 10¢	WEST ZONE 3
		15¢	ORANGE	WEST ZONE 3 — 15¢	WILSHIRE 2 — HOLLYWOOD 2
		20¢	WHITE	WEST ZONE 3 — 20¢	HOLLYWOOD 2 — GRIFFITH 2 — WILSHIRE 2 — CRENSHAW 2 — INNER ZONE
		25¢	NONE	WEST ZONE 3 — 25¢	COLLECTED ONLY TO HUNTINGTON PARK 2 VIA LINES 84 OR 85 AND 50
NOTE: COLLECT ORANGE CHECKS AT FAIRFAX, IF NO CHECK COLLECT 5¢ TO WESTERN AVE., ISSUE WEST ZONE 3—15¢ TRANSFER ON REQUEST. 10¢ TO INNER ZONE, ISSUE WHITE CHECK OR IF TRANSFER IS REQUESTED, ISSUE WEST ZONE 3 — 20¢ TRANSFER.					
FAIRFAX TO WESTERN	HOLLYWOOD 2	10¢	NONE	HOLLYWOOD 2 — 10¢	HOLLYWOOD 2
		15¢	WHITE	HOLLYWOOD 2 — 15¢	HOLLYWOOD 2 — WILSHIRE 2 — GRIFFITH 2 — INNER ZONE
		20¢	NONE	HOLLYWOOD 2 — 20¢	COLLECTED ONLY TO HUNTINGTON PARK 2 VIA LINES 84 OR 85 AND 50
NOTE: COLLECT WHITE CHECKS AT WESTERN AVE., IF NO CHECK COLLECT 5¢, ISSUE HOLLYWOOD 2 — 15¢ TRANSFER ON REQUEST.					
WESTERN TO 9TH & OLIVE	INNER	10¢	NONE	ARRIVING POINTS (15¢ COUPON DETACHED)	INNER ZONE
		15¢	NONE	ARRIVING POINTS (15¢ COUPON ATTACHED)	INNER ZONE — ANY 2nd ZONE
OUT-TRIP WEST					
9TH & OLIVE TO WESTERN	INNER	10¢	NONE	ARRIVING POINTS (15¢ COUPON DETACHED)	INNER ZONE
		15¢	ORANGE	ARRIVING POINTS (15¢ COUPON ATTACHED)	INNER ZONE — ANY 2nd ZONE
		20¢	RED	HOLLYWOOD 2 — 15¢	WEST ZONE 3
NOTE: COLLECT ORANGE CHECKS AT WESTERN AVE., IF NO CHECK COLLECT 5¢ TO FAIRFAX, ISSUE INNER ZONE TRANSFER (15¢ COUPON ATTACHED) ON REQUEST. 10¢ TO WEST ZONE 3, ISSUE RED CHECK OR IF TRANSFER IS REQUESTED, ISSUE HOLLYWOOD 2 — 15¢ TRANSFER.					
WESTERN TO FAIRFAX	HOLLYWOOD 2	10¢	NONE	HOLLYWOOD 2 — 10¢	HOLLYWOOD 2
		15¢	RED	HOLLYWOOD 2 — 15¢	HOLLYWOOD 2 — WILSHIRE 2 — WEST ZONE 3 — OR INNER ZONE VIA LINE 85 AT ROSSMORE AVENUE
		20¢	NONE	HOLLYWOOD 2 — 20¢	COLLECTED ONLY TO HUNTINGTON PARK 2 VIA LINES 85 AND 50
NOTE: COLLECT RED CHECKS AT FAIRFAX, IF NO CHECK COLLECT 5¢, ISSUE HOLLYWOOD 2 — 15¢ TRANSFER ON REQUEST.					
FAIRFAX TO SANTA MONICA	WEST ZONE 3	10¢	NONE	WEST ZONE 3 — 10¢	WEST ZONE 3

Reference: LA Transit Lines, "Fare and Transfer Instructions", 1950.

3.2.2 Actual vs. Perceived Convenience

Various transit surveys have been conducted to identify the primary modal attributes which determine traveler mode choice. Door-to-door travel time, reliability and convenience are generally cited as the most significant attributes, with less emphasis placed on cost, comfort, safety and amenities. Passengers generally want to minimize travel time and to maximize reliability and convenience.

Passenger perceptions of these attributes, however, are often related to other variables. For example, attitudinal studies show repeatedly that perceptions of travel time depends upon travel time reliability as well as actual elapsed travel time. Arriving on time is often more important than minimizing elapsed travel time, especially for work trips. Surveys also indicate that passenger time spent in walking, waiting and transferring is generally more onerous than vehicle riding time.[4]

These three attributes -- travel time, reliability and convenience -- are particularly significant in timed transfer systems. Individual passengers may perceive timed transfers as adding additional travel time, due to their particular trip patterns, to the unreliability of the service or to the inconvenience of physically transferring.

- Travel times for some users may increase (e.g. trips to downtown) because of route diversions and time delays at one or more timed transfer points; while

- Travel times for some users may decrease (e.g. crosstown trips) because transfers between local crosstown and radial routes are coordinated.

Suburban transit operators noted that they would not expect overall travel times to change. Whether travel times do change depends on the actual routing and scheduling and overall passenger trip patterns. In the case studies, overall travel times improved slightly with the implementation of timed transfer.

Transit operators also noted that in conventional transit systems, if buses do not adhere strictly to their schedules, passengers may be inconvenienced by arriving at their destination a few minutes late. These delays often go unnoticed by many passengers. However, in timed transfer systems, if buses do not adhere to their schedules and thus miss their connections, most passengers will notice and many passengers may be seriously inconvenienced. This is especially important during off-peak periods, when stranded passengers may have to wait up to 30 or 60 minutes for the next connection. Should this happen more than once

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[4] Wachs, Martin, "Consumer Attitudes Toward Transit Service: An Interpretive Review," AIP Journal, January, 1976.

or twice, these passengers will likely find an alternative, more reliable, means of travel. However, if timed transfer is properly executed, passengers may find timed transfer services to be more reliable than conventional transit. In fact, in Portland, transit users felt reliability was an especially positive feature of the timed transfer service.

The inconvenience of physically transferring between two vehicles may also influence passengers' acceptance of timed transfer services. Unfortunately, little research has been done in the area of passenger transfer behavior and attitudes. One mode choice study conducted logit, probit and discriminant analyses, based on a random sample of 471 work and non-work trips in Philadelphia.[5] "Avoid transferring vehicles" ranked fourth out of 33 modal attributes that helped determine traveler mode choices. Interviews with 2,000 commuters in Washington, D.C. showed that 30 percent objected to any transfers and 51 percent objected to transfer policies which would affect their everyday trip-making. Other studies in Paris, France indicate that passengers weight transfer and wait time approximately three times as onerous as they do riding time.[6]

A rural bus transfer study in Yorkshire, England documented transit passengers' strong resistance to transferring. These findings are particularly significant because there was no difference in the total travel time or fare between transfer and non-transfer trips. In fact, a high proportion of travellers delayed or advanced their trip time to times when through service was available or made their trip by an alternative route, in order to avoid the need to transfer.[7]

One strategy for reducing the negative connotations associated with transferring is to eliminate the word "transfer." Tri-Met calls its Westside timed transfer services the "Direct Connection." In Vancouver, passenger transfer facilities and transfer activities are referred to as "exchanges."

These findings seem to indicate that the greatest barriers to timed transfer may be the passenger's perception of transferring in conventional systems and the physical inconvenience of moving from one vehicle to another. Many transit riders have developed negative attitudes toward transferring and expect direct bus-stop-origin to bus-stop-destination service. Timed transfer operators must therefore provide good services and marketing information to counteract passengers' negative perceptions of transferring.

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[5] Hartgen, David, "Attitudinal and Situational Variables Influencing Urban Mode Choice: Some Empirical Findings," Transportation, 1974.

[6] Wachs, Martin, "Consumer Attitudes," AIP Journal, 1976.

[7] Tebb, R.G.P. "Passenger Resistance to a Rural Bus-Bus Interchange," TRRL Supplementary Report 269, TRRL, 1977.

3.2.3 Understanding the System

3.2.3.1 Clear and Simple

One major timed transfer objective cited by several operators was to simplify the transit system's route structure and schedule, for easier passenger comprehension. Before many passengers will board a bus they want to know where, how and when routes will connect with their desired destination. A confusing transit system that is difficult for passengers to understand can inhibit potential users from trying a service and limit potential ridership. A simple, clear and understandable system that is easy for passengers to remember, can encourage riders to try a service.

3.2.3.2 Standardized Routes and Schedules

A timed transfer system must standardize routes and schedules to conform to the system's operating constraints. This standardization can simplify and clarify the system for passengers.

Schedule standardization into clocked headways of 10, 15, 30, 60, or 120 minute frequencies are much easier for passengers to remember than irregular schedules. Most people tend to think in time blocks of 5, 10, 15, 30 or 60 minute intervals and in fact, transit may well be the only scheduled activity people have that does not begin on the hour or quarter-hour, as most meetings and appointments do. Consequently, memorizing a conventional transit timetable is probably foreign to many peoples' thought patterns.[8]

Several passengers however, reported initial confusion over timed transfer's routing. Particularly perplexing was the need to divert routes to transfer centers, the number of transfers required and the interconnectivity of the routes at the transfer points. However, once passengers understand the timed transfer concept, operators felt passengers would be able to more easily use other parts of the timed transfer system. Several riders also commented that once they understood timed transfer services, they found them easier to use.

3.2.3.3 Passenger Information

To help passengers understand timed transfer systems, several operators have emphasized certain types of information, simplified information requirements and varied their methods of disseminating information. Tri-Met developed a Westside system map to identify the major activity centers, transfer points and connecting routes and

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[8] Davis, Frank W. "Bus Transit for a Major Activity Centre," Highway Research Record, Volume 449, 1973.

included this map with each route's timetable. Exhibit 3.4 shows Tri-Met's timetable for Route 52. Passengers can make timed transfers between Route 52 and other Westside bus routes at the Beaverton Transit Center.

Timetables are also used to explain passenger fares, passes, special tickets, and transfer slips and policies, and to indicate paired routes, or buses that change from one route to another at the transfer point. This is especially helpful for new passengers. Exhibit 3.5 shows how the RTD in Sacramento displays its paired Routes 50 and alternating Routes 54 and 55 at the Florin Center timed transfer point.

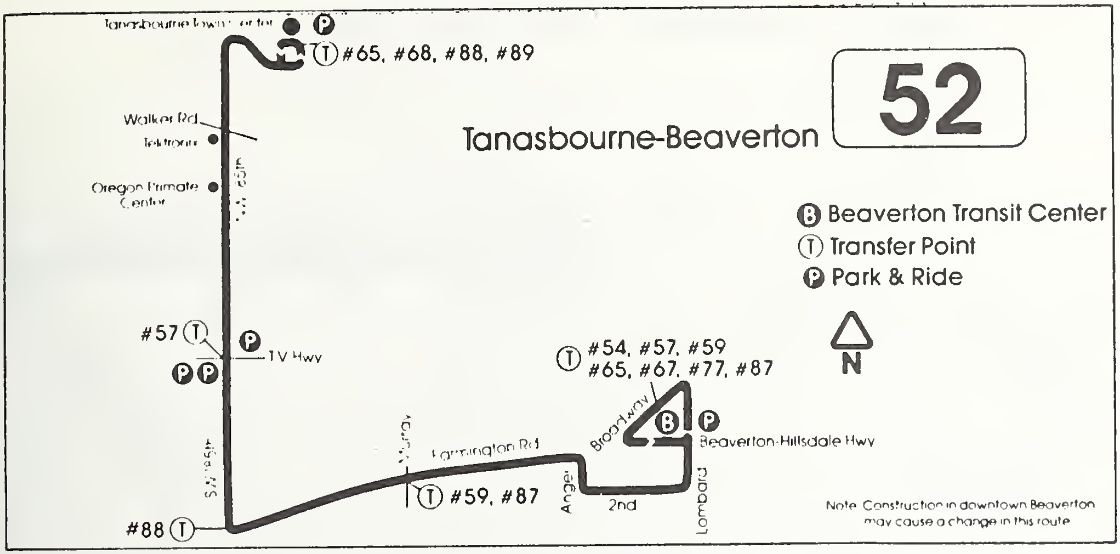
Specific schedule information may not be necessary for very high frequency radial trunk routes. Also, route schedules for repeating local and crosstown routes may not need to show every timed connection; the schedules can simply print :15, :30 or :45 minutes after each hour. Exhibit 3.6 shows Pierce County Transit's repeating 15-minute weekday and 30-minute Saturday timed transfer timetable for the Eleventh Street route.

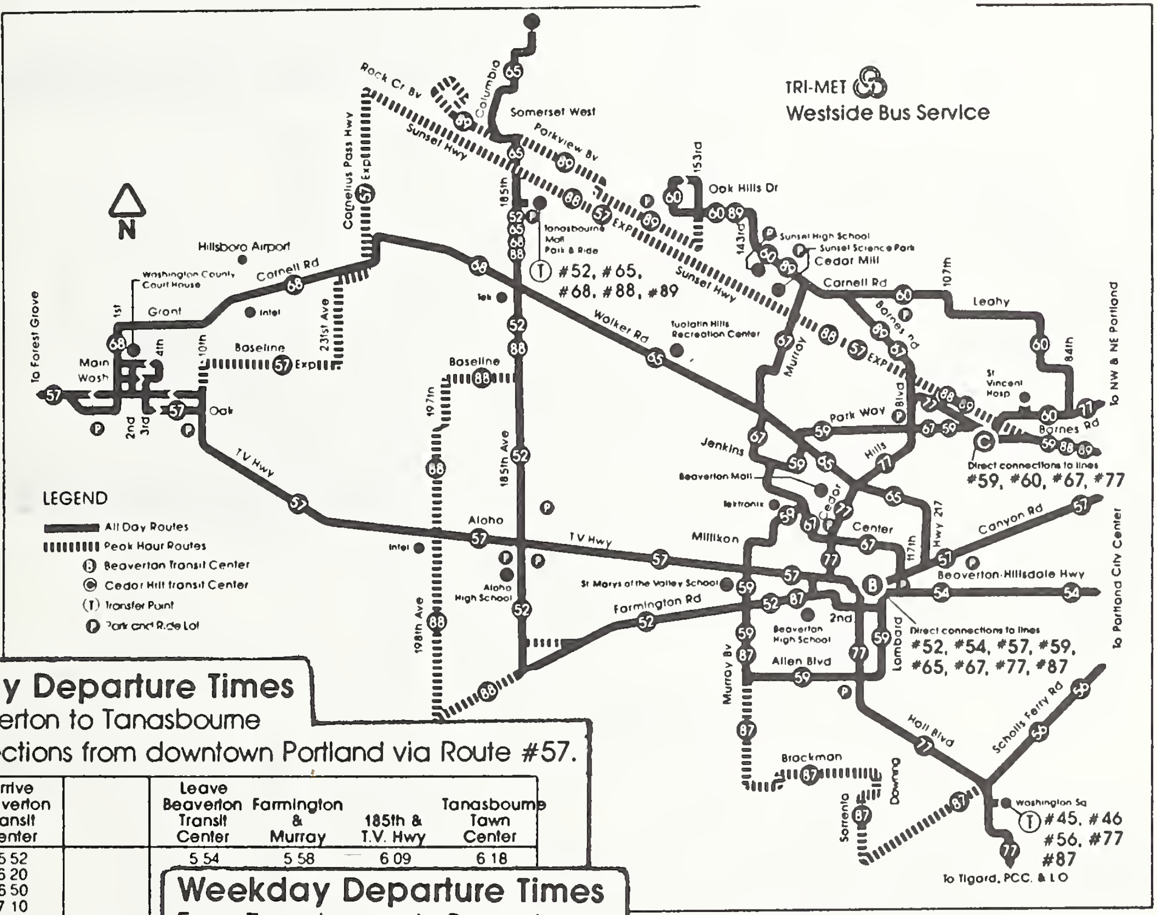
All of the timed transfer operators post information at the timed transfer focal points to help passengers identify connecting routes, bus berthing locations and desired destinations. At least a map of the system, indicating buses that serve the transfer point should be posted. Several operators also post or have extra copies of individual route timetables available at timed transfer points. During implementation or when changes are made, public information or marketing personnel are often posted at the transfer sites to assist passengers in locating their connecting vehicles and to eliminate many passengers' initial confusion.

Each bus is typically assigned a particular berthing space at a timed transfer point, with bus stop information signs clearly posted. Exhibit 3.7 illustrates the downtown Norristown focal point, showing the map of the transfer facility and vehicle assignments. The Ann Arbor Transit Authority also emphasized the importance of clearly displaying the route number and destination on the front and rear of the buses. To minimize passenger transfer confusion, the route information at the transfer point, on the bus stop signs and on the vehicles should be the same as that shown on the individual passenger schedules. For example, Exhibit 3.8 shows a Tri-Met Route 77 vehicle waiting at the Cedar Hills Transit Center; the bus header sign and the bus stop sign are consistent with the adjacent posted map and schedules, which are identical to the individual passenger route timetables.

Exhibit 3.4

TRI-MET TIMETABLE: WESTSIDE ROUTE 52





Weekday Departure Times

From Beaverton to Tanasbourne
with connections from downtown Portland via Route #57.

Portland S.W. 5th & Stark	Arrive Beaverton Transit Center		Leave Beaverton Transit Center	Farmington & Murray	185th & T.V. Hwy	Tanasbourne Town Center
5 32	5 52		5 54	5 58	6 09	6 18
5.59	6 20					
6 29	6 50					
6.49	7 10					
7.05	7 31					
7:25	7 51					
7.55	8 21					
8 25	8 51					
8 55	9 21					
9:25	9 51					
9:55	10 21					
10 25	10 51					
10 55	11 21					

Weekday Departure Times

From Tanasbourne to Beaverton
with connections to downtown Portland via Route #57.

Tanasbourne Town Center	185th & T.V. Hwy	Farmington & Murray	Arrive Beaverton Transit Center		Leave Beaverton Transit Center	Portland S.W. 6th & Salmon
5:52	6.01	6 12	6 17		6.24	6 44
6.22	6 31	6 42	6 47		6:54	7:16
6:39	6 48	7 00	7 07		7:14	7 36
6:59	7 08	7 20	7 27		7:34	7.56
7:19	7 28	7.40	7.47		7:54	8 16
7:49	7.58	8 10	8 17		8 24	8 46
8.19	8.28	8 40	8 47		8 54	9 15
8.52	9 01	9 12	9 17		9 24	9 45

Exhibit 3.5

RTD TIMETABLE: THROUGH-ROUTED LINE 50 WITH 55 AND 54

■ -Indicates Line 50 Terminals.

■ -Indicates Limited Stops, buses stop only at these locations, see timetable for schedule times.

CONNECTING TIMED TRANSFER SERVICE IS PROVIDED TO VALLEY HI, COSUMNES RIVER COLLEGE, ELK GROVE, LINDALE, AND SCOTTSDALE, SEE LINE No. 54-55 & 56-57 TIMETABLES.

DOWNTOWN TO FLORIN CENTER Line 50

Monday thru Friday

SCHED	DOWNTOWN SACRAMENTO 9th & "H" Sts			"Q" Street & 10th St	& 21st St	& 28th St	SACTO MEDICAL CENTER	Stockton Bl & Broadway	& Fruitridge	FLORIN CENTER Main Terminal App.	Chng To Line No.
	9th & "H" Sts	9th & "K" Sts	9th & "N" Sts								
	Lv	Lv	Lv	Lv	Lv	Lv	Lv	Lv	Lv	Ar	
2	600a	602a	604a	606a	609a	610a	614a	616a	620a	625a	55
1	630	632	634	636	639	640	644	646	650	655s	-
3	700	702	704	706	709	710	714	716	720	725	55
2	730	732	734	736	739	740	744	746	750	755	54
1	800	802	804	806	809	810	814	816	820	825	55
4	830	832	834	836	839	840	844	846	850	855	54
3	900	902	904	906	909	910	914	916	920	925	55
5	930	932	934	936	939	940	944	946	950	955	54
1											
2											
3											
4											
1											
5											
3											
2											
1											
4											
3											
5											
1											
2											
7											
3											
4											
1											
8											

CRC TO FLORIN CENTER LINE 55

Monday thru Friday

SCHEO	ROUTE	COSUMNES RIVER COLLFGE E.Steps	METHODIST HOSPITAL	Valley Hi & Mack Rd	Stock-ton & Gerber	66th Ave & Florin Mall Dr.	FLORIN CENTER Main Terminal App.	Chng To Line No.
		Lv	Ar	Ar	Ar	Ar	Ar	
2	55	...	643a	646a	649a	652a	656a	50
1	55	...	713	716	719	722	726	50
3	55	810a	813	816	819	822	826	50
1	55	910	913	916	919	922	926	50
3	55	1010	1013	1016	1019	1022	1026	50
1	55	1110	1113	1116	1119	1122	1126	50
3	55	1210p	1213p	1216p	1219p	1222p	1226p	50
1	55	109	112	115	118	122	126	50
3	55	209	212	215	218	222	226	50
1	55	308	311	314	318	322	326	50
3	55	408	411	414	418	422	426	50

ELK GROVE TO FLORIN CENTER LINE 54

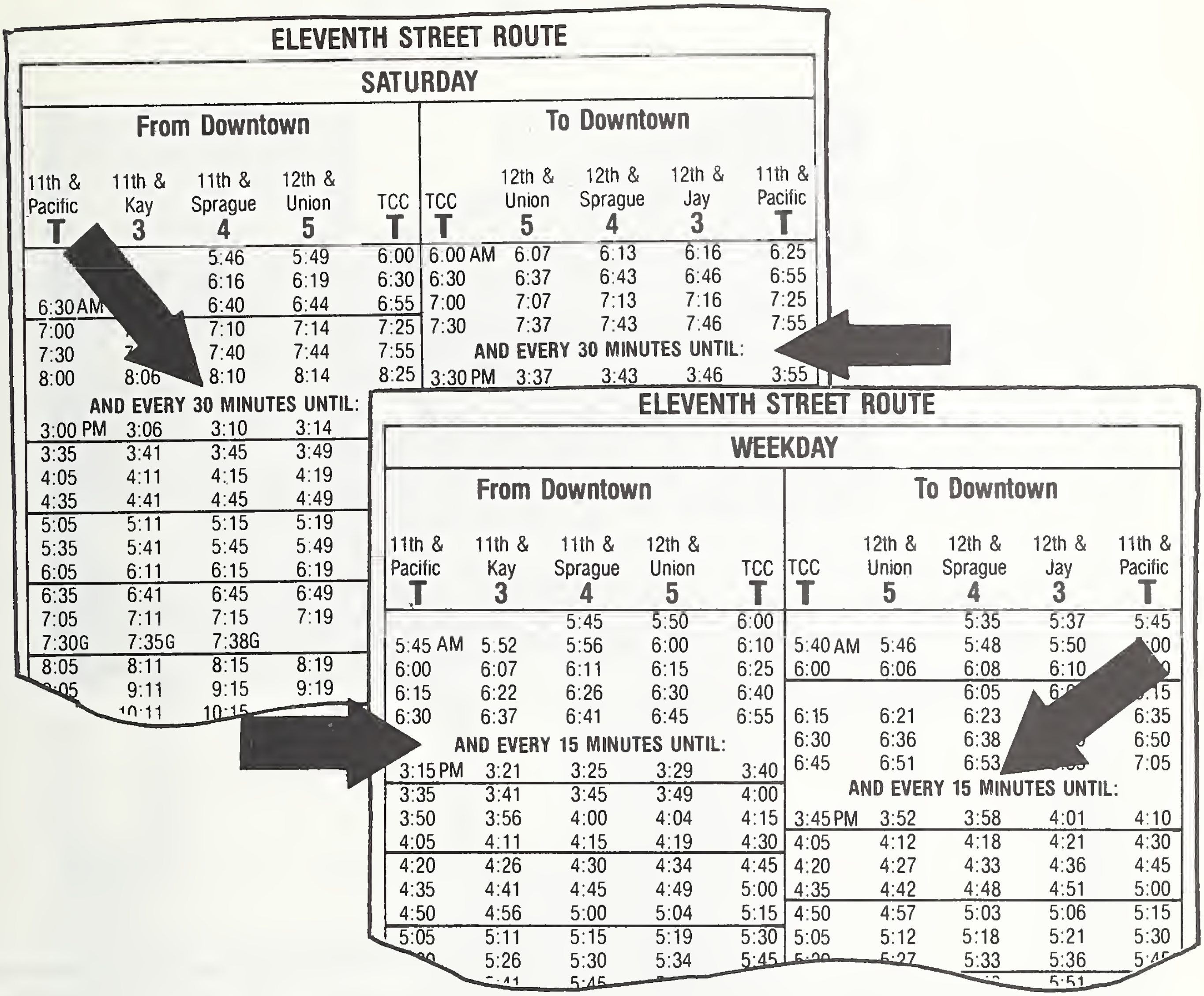
Monday thru Friday

SCHED	ROUTE	ELK GROVE Webb & Grove	Elk Grove & Emer-ald Oak	COSUMNES RIVER COLLEGE East Steps	Valley Hi & Mack Rd	Center Pkwy & Tangerine	SOUTH GATE Florin & Franklin	FLORIN CENTER Main Term. App.	Chng To Line No.
		Lv	Ar	Lv	Ar	Ar	Ar	Ar	
3	54	548a	556a	...	610a	614a	618a	623a	50
5	54	...	...	...	*712	716	721	726	-
4	54	...	...	...	*742	746	751	756	50
5	54	814	824	835	842	846	851	856	50
2	54	914	924	935	942	946	951	956	50
4	54	1014	1024	1035	1042	1046	1051	1056	50
5	54	1114	1124	1135	1142	1146	1151	1156	50
2	54	1214p	1224p	1235p	1242p	1246p	1251p	1256p	50
4	54	113	123	134	141	145	150	156	50
5	54	213	223	234	241	245	250	256	50
2	54	243	253	304	311	315	320	326	50
4	54	413	423	434	441	445	450	456	50
3	54	...	...	605	612	616	621	626	50

MAKES TIMED CONNECTION AT FLORIN CENTER FOR DOWNTOWN SACRAMENTO

Exhibit 3.6

PIERCE COUNTY: ELEVENTH STREET TIMETABLE



ELEVENTH STREET ROUTE

SATURDAY

From Downtown

11th & Pacific T	11th & Kay 3	11th & Sprague 4	12th & Union 5	TCC T
		5:46	5:49	6:00
		6:16	6:19	6:30
6:30 AM	[illegible]	6:40	6:44	6:55
7:00	[illegible]	7:10	7:14	7:25
7:30	[illegible]	7:40	7:44	7:55
8:00	8:06	8:10	8:14	8:25
AND EVERY 30 MINUTES UNTIL:				
3:00 PM	3:06	3:10	3:14	
3:35	3:41	3:45	3:49	
4:05	4:11	4:15	4:19	
4:35	4:41	4:45	4:49	
5:05	5:11	5:15	5:19	
5:35	5:41	5:45	5:49	
6:05	6:11	6:15	6:19	
6:35	6:41	6:45	6:49	
7:05	7:11	7:15	7:19	
7:30G	7:35G	7:38G		
8:05	8:11	8:15	8:19	
[illegible]	9:11	9:15	9:19	
	10:11	10:15		

To Downtown

TCC T	12th & Union 5	12th & Sprague 4	12th & Jay 3	11th & Pacific T
6.00 AM	6.07	6.13	6.16	6.25
6:30	6:37	6:43	6:46	6:55
7:00	7:07	7:13	7:16	7:25
7:30	7:37	7:43	7:46	7:55
AND EVERY 30 MINUTES UNTIL:				
3:30 PM	3:37	3:43	3:46	3:55

ELEVENTH STREET ROUTE

WEEKDAY

From Downtown

11th & Pacific T	11th & Kay 3	11th & Sprague 4	12th & Union 5	TCC T
		5:45	5:50	6:00
5:45 AM	5.52	5:56	6:00	6:10
6:00	6:07	6:11	6:15	6:25
6:15	6:22	6:26	6:30	6:40
6:30	6:37	6:41	6:45	6:55
AND EVERY 15 MINUTES UNTIL:				
3:15 PM	3:21	3:25	3:29	3:40
3:35	3:41	3:45	3:49	4:00
3:50	3:56	4:00	4:04	4:15
4:05	4:11	4:15	4:19	4:30
4:20	4:26	4:30	4:34	4:45
4:35	4:41	4:45	4:49	5:00
4:50	4:56	5:00	5:04	5:15
5:05	5:11	5:15	5:19	5:30
[illegible]	5:26	5:30	5:34	5:45
	[illegible]	5:45	[illegible]	

To Downtown

TCC T	12th & Union 5	12th & Sprague 4	12th & Jay 3	11th & Pacific T
		5:35	5:37	5:45
5:40 AM	5:46	5:48	5:50	[illegible]
6:00	6:06	6:08	6:10	[illegible]
		6:05	[illegible]	[illegible]
6:15	6:21	6:23	[illegible]	6:35
6:30	6:36	6:38	[illegible]	6:50
6:45	6:51	6:53	[illegible]	7:05
AND EVERY 15 MINUTES UNTIL:				
3:45 PM	3:52	3:58	4:01	4:10
4:05	4:12	4:18	4:21	4:30
4:20	4:27	4:33	4:36	4:45
4:35	4:42	4:48	4:51	5:00
4:50	4:57	5:03	5:06	5:15
5:05	5:12	5:18	5:21	5:30
[illegible]	[illegible]	5:33	5:36	[illegible]
		[illegible]	5:51	

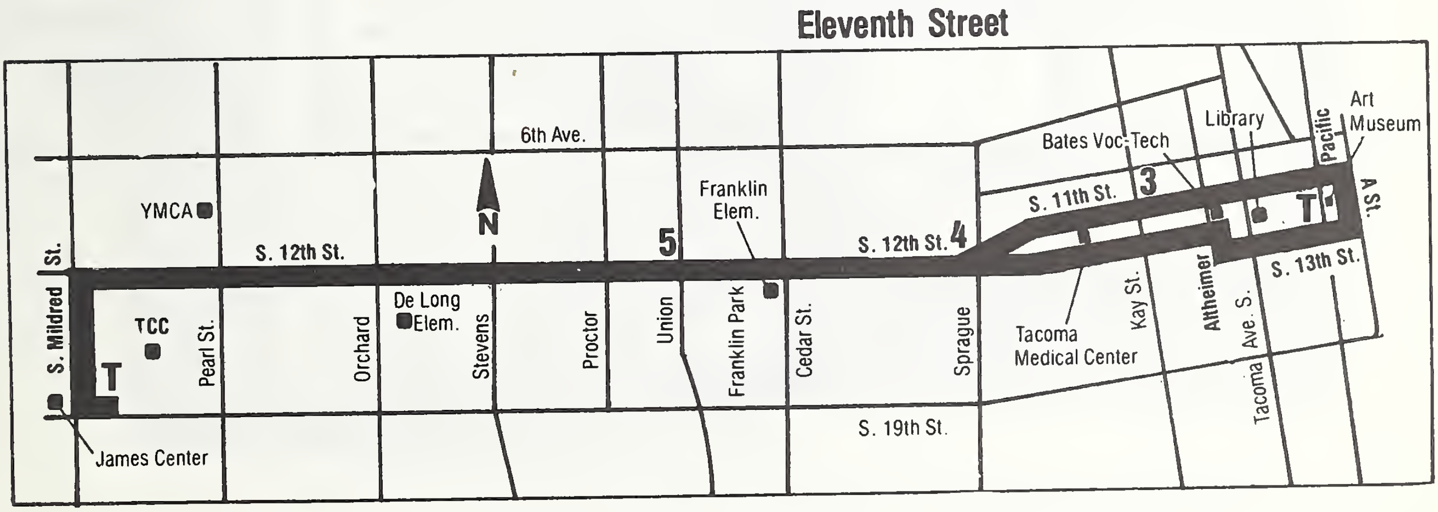
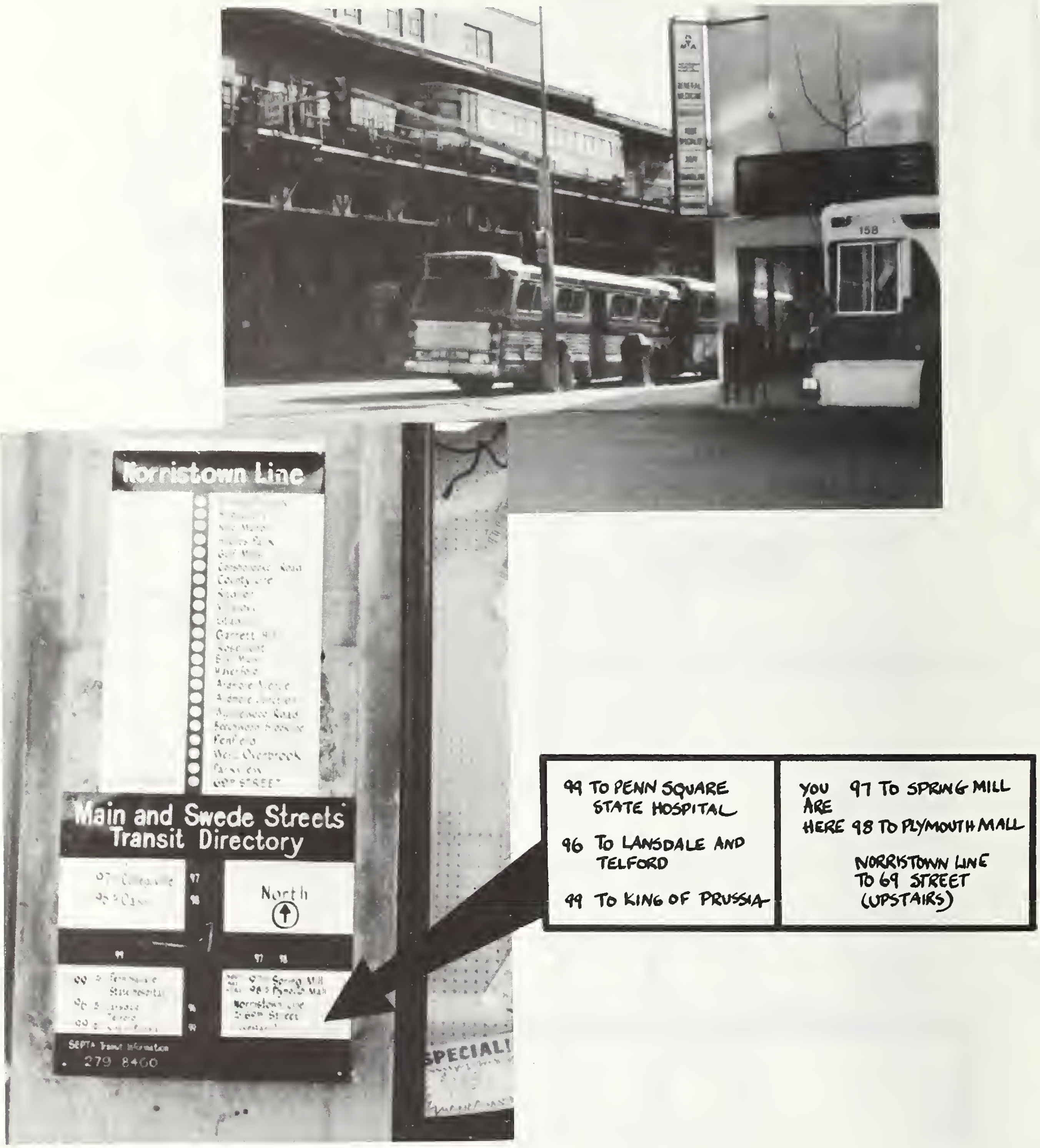


Exhibit 3.7

NORRISTOWN FOCAL POINT & TRANSFER MAP



99 TO PENN SQUARE STATE HOSPITAL

96 TO LANSDALE AND TELFORD

99 TO KING OF PRUSSIA

YOU ARE HERE

97 TO SPRING MILL

98 TO PLYMOUTH MALL

NORRISTOWN LINE TO 69 STREET (UPSTAIRS)

Exhibit 3.8

TRI-MET: COORDINATED INFORMATION AT THE CEDAR HILLS TRANSIT CENTER

3.3 CONCLUSION

In order for timed transfer to attract riders, transit system operators must help users overcome their long-term resistance to transferring, recognize the difference between users' actual and perceived service conveniences and provide clear explanations of how timed transfer systems operate. The issues and problems concerning each of these three areas are discussed and examples are drawn from various case study sites to illustrate how various timed transfer users have recognized and overcome these obstacles. Much can be done with effective marketing and information programs.

3.4 COMMUNITY

A variety of interest groups raised concerns about timed transfer services. This section examines the impacts on downtown businesses, suburban shopping malls, employment centers and regional land developers, in connection with some timed transfer services. Most of this information is based on interviews with representatives from these community interest groups.

3.4.1 Downtown and Regional Businesses

There is a general belief that urban transit services can stimulate downtown economic activity by attracting a captive market to central city businesses. In recent years many urban transit systems have worked directly with downtown businesses to aid central city revitalization. Downtown transit malls are good examples of such cooperation.[9]

On the other hand, timed transfer services can provide convenient transit access to an entire region or to certain areas and activities, such as suburban shopping malls and outlying employment sites, that compete with downtown businesses. Transit systems facing losses in revenue may be forced to decide where cuts in service will be made. This could cause potential conflicts between downtown and regional business interests, with each vying for limited transit service.

After Tri-Met implemented its Westside timed transfer services, local service planners noted a substantial increase in reverse commuting and local suburban off-peak travel patterns. A large number of riders were travelling from downtown and other areas to Westside suburban work sites during the morning peak periods and travelling back from these areas during the afternoon peak hours. Mid-day non-work transit trips increased the most dramatically, with shopping trips most frequently

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[9] Edminster, Richard and David Koffman, Streets for Pedestrians and Transit: An Evaluation of Three Transit Malls, Crain and Associates, February, 1979.

reported during this time of day. Thus far, no change in downtown activity has been attributed to the Westside services.[10]

The Ann Arbor Transit Authority operates timed transfer services to downtown Ann Arbor, downtown Ypsilanti, and to several outlying shopping malls. Based on interviews with area merchants and AATA staff, transit patrons continue to be attracted to the active downtown areas and the shopping malls. No significant economic changes have been noted, due to transit services.

Downtown Tacoma would be the most likely site to be impacted by timed transfer service changes. New Pierce County Transit services provide access to the Tacoma Mall, the Villa Plaza shopping center and downtown Pullayup. To date, no transit-related economic imacts have been noted.

3.4.2 Suburban Shopping and Employment Centers

Although timed transfer transit services can increase mobility to outlying areas, many suburban shopping and employment centers have resisted providing transit access directly onto their property. Suburban activity centers traditionally provide free automobile parking directly adjacent to their buildings because most customers travel to these sites by automobile and are unwilling to walk long distances, especially if they are carrying packages. Since transit passengers also resist long walks with packages, they are less likely to patronize businesses that are remote from transit stops.

The following six objections were raised by suburban activity center managers to buses entering and stopping for passenger pick-ups, drop-offs and transfers in their centers:

1. There is a limited amount of space available and the management is unwilling to sacrifice automobile parking spaces for transit buses;
2. Management does not want transit passengers to use the center's limited parking spaces as a park-and-ride lot;
3. The existing pavement and/or lot geometry cannot accommodate buses;
4. Buses will create additional traffic congestion, especially during the peak periods;

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[10] Gleason, Rick, Westside Service Evaluation, Tri-Met, Portland, Oregon, October, 1980, pp. II-1-II-16.

5. The passengers attracted to transit are perceived as being undesireable clientele; and

6. There is insufficient evidence to prove that transferring transit passengers will enter the major activity center and generate additional revenue.

Timed transfer transit operators presented the following arguments against each of these objections:

3.4.2.1 Limited Automobile Parking

Although shopping mall operators may be unwilling to sacrifice automobile space for transit's access, the International Council of Shopping Centers (ICSC) recently projected a reduction in car size and parking space requirements and an increase in the dependence on mass transit in the near future. ICSC alerted its center managers to be aware of these possibilities and to "make strong efforts to ensure that centers are served adequately by mass transit, where possible."[11] The following examples were also cited by timed transfer transit properties to indicate that there are innovative ways to overcome institutional barriers. For example, the Plymouth Mall merchants granted an easement to the Ann Arbor Transit Authority to develop transfer facilities in their parking lot. The major employer on the Westside of Portland, Tektronix, provides parking spaces, promotes ride-sharing and also provides convenient transit access for their employees. By offering these transportation options, Tektronix no longer needs to guarantee each employee a parking space -- a considerable cost savings.

3.4.2.2 Park-and-Ride Lot

Parking shortages arose at the Lougheed Mall in Vancouver, because commuters would use the shopping center lot as a park-and-ride lot instead of transferring from local routes to downtown express routes. Their automobiles occupied the centers' spaces all day, a problem particularly noted during the peak Christmas shopping season. After posting and enforcing "no park-and-ride permitted" signs, the problem abated quickly.

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[11] ICSC (1979) Schneider [6, p. 7 & 96].

3.4.2.3 Physical Lot Constraints

At the Florin Center in Sacramento, the timed transfer point was initially located in the parking lot next to the front mall entrance. In June 1979, after a new portion of the mall opened, the transfer point was relocated to the rear of the mall and by September 1979 after buses were accused of breaking up the pavement, the transfer point was relocated onto 65th street, alongside the shopping center. Exhibit 3.9 shows the existing on-street transfer site in front of Florin Center in Sacramento and the Plymouth Mall transfer site in Ann Arbor.

3.4.2.4 Traffic Congestion

To avoid creating additional traffic congestion for major activity centers and to help maintain consistent schedules for transit, separate or exclusive transfer and bus circulation areas can be set aside on the site. As the result of a lawsuit brought by environmental groups, the Clackamas Town Center in southern Portland has been working with Tri-Met since 1978 to plan and develop transfer facilities, exclusive bus circulation areas and park and ride lots at this major activity center (Exhibit 3.10). Tri-Met is now operating timed transfer on this site.

3.4.2.5 Undesireable Clientele

Several suburban activity center managers were a little reluctant to mention the fifth cited objection (i.e., transit passengers are undesirable clientele). They are however, afraid transit will bring low-income, young and elderly customers, a market they do not particularly want to attract. They are also concerned that these customers may cause safety and security problems, making their centers less attractive to other users. Several timed transfer transit officials, especially the Canadians, felt this "second-class transit rider syndrome" may be overcome because employees are being attracted to suburban activities by transit.

3.4.2.6 Economic Impacts

The last major objection (i.e., there is insufficient evidence to prove that transferring passengers will generate additional revenue) seems to underlie many of the other objections. Unfortunately, it is extremely difficult to measure the economic impacts that timed transfer services have had on the adjacent major activity centers because:

- Most of the U.S. timed transfer sites do not have local or state retail sales taxes with which to compare retail sales and revenues generated before and after the implementation of timed transfer;

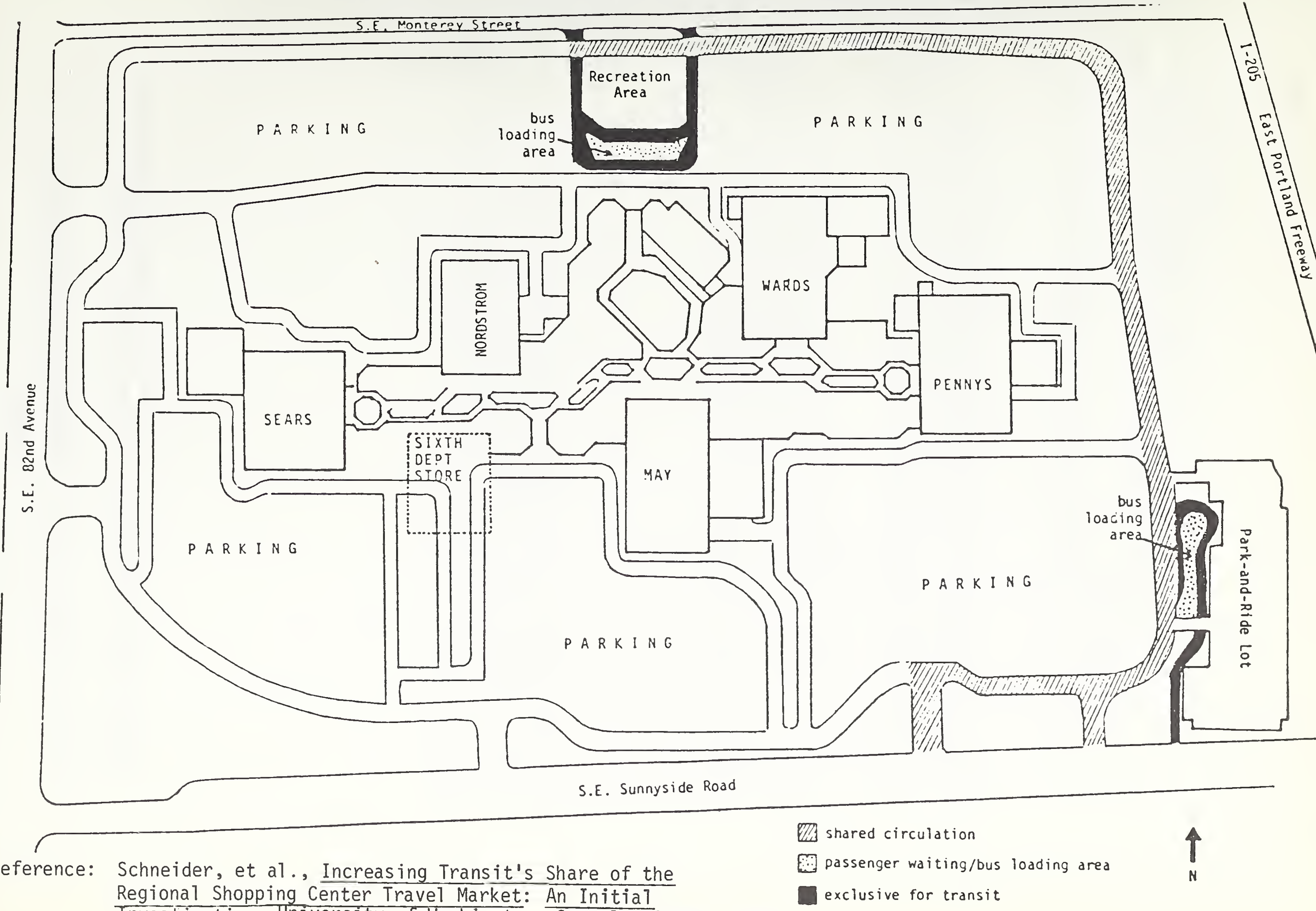
Exhibit 3.9

TRANSFER SITES: SACRAMENTO AND ANN ARBOR

RTD: TIMED TRANSFER ON THE STREET AT FLORIN CENTER, SACRAMENTO

AATA: TIMED TRANSFER IN PLYMOUTH MALL, ANN ARBOR

Exhibit 3.10 — CLACKAMAS TOWN CENTER TRANSFER FACILITIES



Reference: Schneider, et al., Increasing Transit's Share of the Regional Shopping Center Travel Market: An Initial Investigation, University of Washington, Seattle, August, 1979.

- The transit operators did not collect quantitative data on sales levels and economic activity before timed transfer services began;

- Private businesses are reluctant to release any internal financial information; and

- Many of the major activity centers underwent significant changes while timed transfer was being implemented;

Nevertheless, data takers at the Cedar Hills timed transfer point in Portland observed several transit passengers stopping to shop at adjacent stores and later taking outbound buses. There is additional evidence to suggest that timed transfer systems have favorable impacts on suburban shopping and employment centers, especially in the longer operating Canadian systems.

Interviews with Canada Manpower show an increased number of job applications from residents of Coquitlam, especially women, after timed transfer services began in suburban Coquitlam (Vancouver). This seems to indicate that some people are able to accept jobs if transit access is available. At Vancouver's Lougheed Mall, the store managers reported "a definite sales increase"[12] after timed transfer services were implemented in their parking lot. During the same period, a neighboring shopping center reported a decrease in retail sales. Although this latter center is on a bus route, the bus stop is on the street, and major transfer activity does not occur there. The manager of this center surmised that his former patrons were passing up his center because of superior bus access to, and a wider selection of stores at, the regional Lougheed Mall.[13] In Edmonton and Portland, managers of the major shopping centers where timed transfers are operating noted increases in the number of customers using transit. In Ann Arbor and Victoria, the bus schedules and vehicle header signs advertise the individual shopping centers as timed transfer focal point destinations. The shopping center managers believe these notices can be valuable marketing tools.

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[12] Bureau of Transit Services, The Impact of New Bus Services in the Coquitlam Area, Government of British Columbia, Vancouver, October, 1974.

[13] Bureau of Transit Services, New Bus Services in Coquitlam.

3.4.3 Land Uses

The major impact on land use is the difficulty of serving sprawling, lower-density suburban areas with mass transit. The characteristics of the medium-density market and the difficulty of serving it with conventional fixed-route transit are further discussed in Section 2.4. Although it is difficult to change development patterns, suburban areas could be designed to accommodate transit more readily.

Several Canadian cities are coordinating future community development and land use plans with transit service plans. In Edmonton, for example, transit officials are now included in the subdivision design and approval process. New residential developments must meet design specifications to accommodate transit vehicles. The revised planning process has had a direct bearing on Edmonton's timed transfer implementation in at least four new residential areas.[14]

By including transit operators in the planning process, developers, public officials and interested citizens are given a greater opportunity to understand transit's requirements. If transit services are to be provided in new areas, transit requirements can be incorporated into the design of streets, housing and activity centers. These efforts could also help to concentrate major activity centers and to slow the trend of suburban sprawl.

3.4.4 Summary

The impacts on most community groups are based on traditional views of what, where and how transit services operate. In general, local businesses view transit as a necessary service for downtown activities. They do not believe that transit is particularly suitable for suburban shopping centers or other outlying activity centers. In some timed transfer sites these views are changing. Prime examples are some Canadian cities where efforts to coordinate future land use and transit service plans are underway.

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[14] -Lawrence, Lleu, Report from Edmonton.

4. IMPACTS ON SERVICES, RIDERSHIP AND COSTS

This chapter compares the impacts of timed transfer on transit services, ridership and costs in the three case study sites of Ann Arbor, Boulder and Portland. Where possible, recommendations and guidelines are included.

4.1 IMPACTS ON SERVICE

The success of timed transfer services depends on the ability of buses to coordinate their meetings at timed transfer points sufficiently well that transferring passengers can be accommodated and through passengers are not unduly delayed. This section examines the issues concerning timed transfer bus services, analyzes the impacts measured in Ann Arbor, Boulder, and Portland and attempts to develop improvement strategies for enhancing timed transfer services. The analysis focuses on designing routes and schedules, travel times and bus performance.

4.1.1 Designing Routes and Schedules

Timed transfer routing and scheduling combines the design and assignment of bus lines with the location of timed transfer points, individual route and overall network running times, layover times and schedule and headway matching. The configuration of the routes and schedules can severely constrain or ultimately determine the success of timed transfer systems. As the following analysis explains, the extent of the difficulty seems to depend on the complexity of the routes' relationships and the number of transfer points.

4.1.1.1 Issues

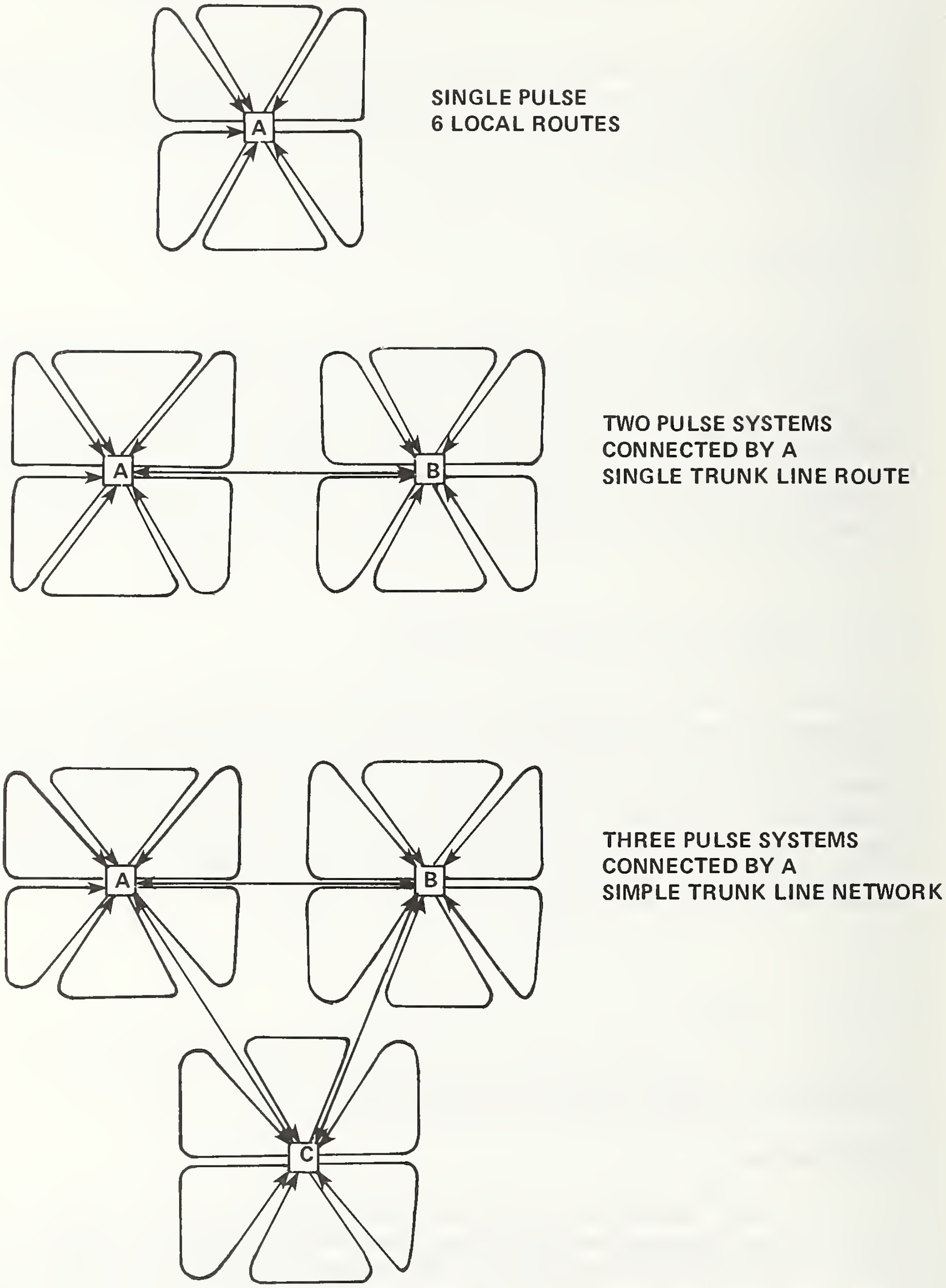
Exhibit 4.1 illustrates three timed transfer systems with increasingly complex route configurations.

Pulse Systems

The first system is a simple single pulse. The six local routes need only be designed so that they have equal round trip times. In many areas, routes can be extended or shortened, diverted or straightened to yield the desired round trip time. Layovers can be scheduled at the transfer point, since it is typically the end of the run. Any headway

Exhibit 4.1

TIMED TRANSFER ROUTE DEVELOPMENT



SINGLE PULSE
6 LOCAL ROUTES

TWO PULSE SYSTEMS
CONNECTED BY A
SINGLE TRUNK LINE ROUTE

THREE PULSE SYSTEMS
CONNECTED BY A
SIMPLE TRUNK LINE NETWORK

can be used so long as it is common to all of the local routes, although it is helpful to use a headway that can easily repeat every hour (e.g. 15, 20, 30, or 60 minutes).

Two-Point Systems

The second system combines two simple pulses with a trunk line route. This configuration imposes new problems and new constraints. The trunk line route must operate so that it is synchronized with the two transfer points. For efficient operation of all buses, the round trip trunk line running time should be the same as or some multiple of the local route round trip times. The trunk line route could be lengthened or shortened, however, this will impact the area served by this route and the riders' travel time. And, since most passengers will want efficient connections with the trunk route, the trunk route's layover time at the transfer points should be minimal.

Three-Point Systems

In addition to the issues cited for two-point systems, routes serving more than two transfer points raise further headway and schedule problems. To illustrate, consider the third system in Exhibit 4.1. Presume that all local routes are designed for a 30 minute round trip time, including layover, and that each leg of the trunk line can be served in 15 minutes. The network might be served by: (1) a shuttle service between the pairs of timed transfer points; or (2) a loop service in both directions around the loop. Both schemes pose difficulties.

First, consider the shuttle service. Let trunk line service depart point A for point B at the hour and half hour. Buses reach B at 15 and 45 minutes after the hour and return on the hour and half hour -- no problems. Shuttle service can depart point B for point C at 15 and 45 minutes after the hour, reaching point C on the hour and half hour. But, what about service between A and C? If buses leave A on the hour and half hour, they reach C at 15 and 45 minutes after the hour -- midway between the pulses. If buses leave A at 15 and 45 minutes after the hour to accommodate the schedule at C, then passengers at A face the same problem. In fact the traveler going from A to C is as well served going via B as using the non-coordinated direct service.

A loop service poses similar problems. If two loop buses leave timed transfer point A on the hour destined for points B and C, the clockwise bus reaches B at 15 minutes after the hour and the counterclockwise bus reaches C at the same time. If each bus continues, the clockwise bus reaches C at 30 minutes after the hour and out of phase with the local service, and the counterclockwise bus reaches B at the same time, also out of phase. Both buses are out of phase when they return to A.

Additional Issues

In addition to the increasingly complex routing and scheduling problems posed above, all timed transfer system planners must consider that:

- There are only a small number of locations that are logical candidates for timed transfer points;
- Only a limited number of streets are available for trunk lines;
- The trunk line network must often tie into a larger areawide network;
- Different headways are often needed for peak and off-peak periods;
- Population and passenger densities are not uniform, further constraining route and frequency flexibility; and
- Major inefficiencies can result by extending or diverting routes to accomodate desired trip times.

Thus, there are many real limits to the design and complexity of any timed transfer system.

4.1.1.2 Case Study Findings

Exhibit 4.2 shows schematic diagrams of the three case study systems: Portland, Boulder and Ann Arbor. Portions of each of the systems are discussed in terms of increasingly complex situations. The numbers in circles identify routes and the numbers along the routes indicate the travel times between the timed transfer points.

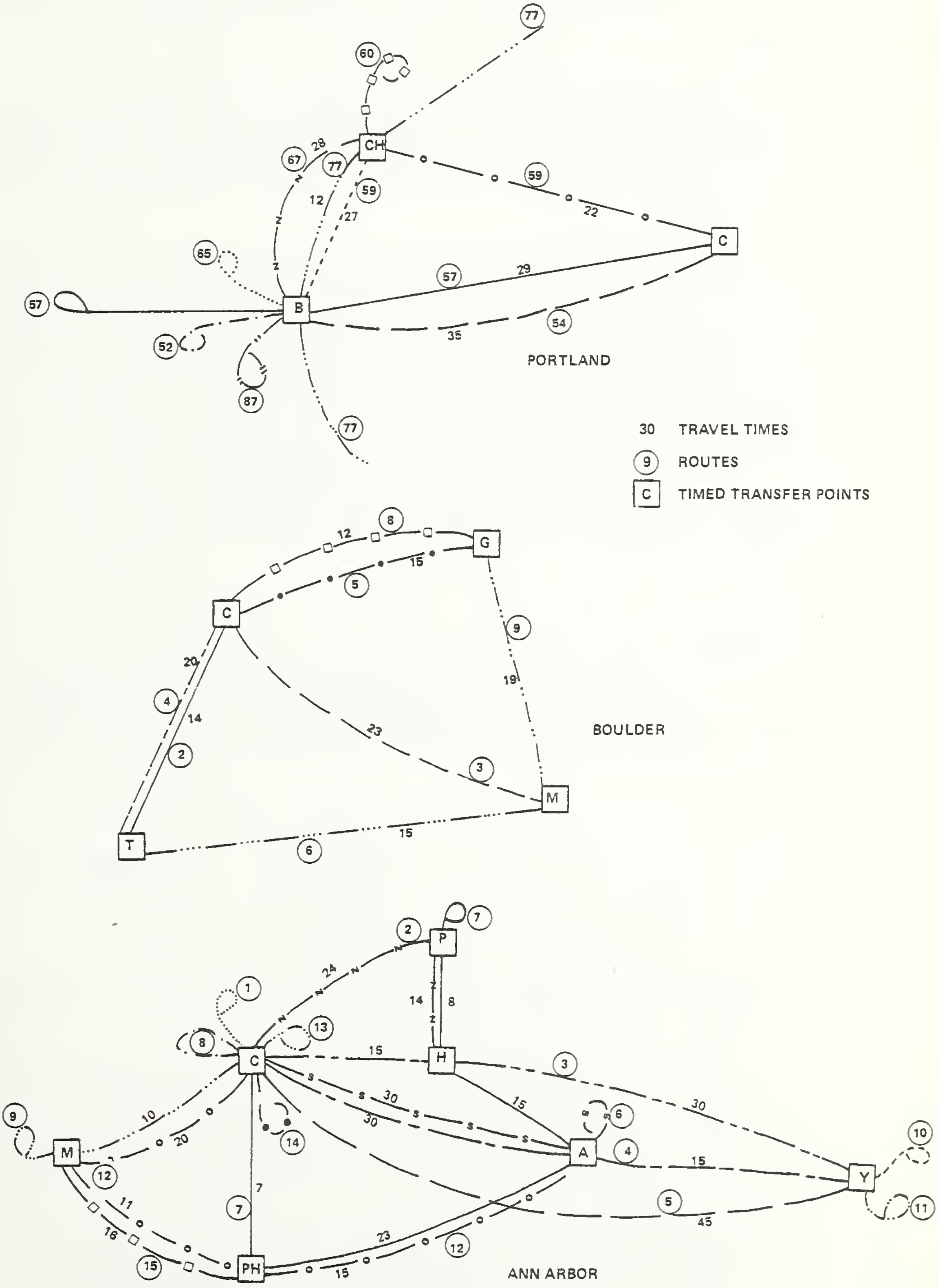
Portland

The Portland timed transfer route structure is the simplest of the three. The trunk routes 54, 57, 59 and 77, which connect the two transfer points and the transit centers with the Portland CBD, are the key to the success of the system. Routes 59 and 77 serve both timed transfer points, but as indicated in Exhibit 4.2, they require different amounts of time to traverse this distance; Route 77 requires about 12 minutes to traverse a reasonably direct path, while Route 59 requires more than twice as long to follow a circuitous path. Since 30-minute meets are generally scheduled, southbound Route 77 buses cannot make all meets at Beaverton and northbound Route 77 buses cannot make all meets at Cedar Hills. Routes, however, that pass through a single timed transfer point, can have their schedules adjusted to make all meets.

Travel times for local service routes are 45 to 50 minutes so that timed transfer point layovers can be added to give an easier to schedule

Exhibit 4.2

SCHEMATIC DIAGRAMS OF TIMED TRANSFER SYSTEMS



one hour round trip time. This also assures that the local buses arrive at the timed transfer points ahead of the trunk line buses and leave after them. The trunk line buses then need to spend the least amount of time at the timed transfer point, a more efficient strategy.

Boulder

The Boulder timed transfer route configuration is slightly more complex than Portland's. There are four timed transfer points and each of the seven routes serve two of the transfer points. Five of the routes meet in downtown Boulder and three routes meet at each of the other transfer points.

As indicated in Exhibit 4.2, it takes each route a different amount of time to travel between the CBD and outlying transfer points. Route 2 takes 14 minutes, while Route 4 takes 20 minutes, due to greater route deviations. Routes 8 and 5 require 12 and 15 minutes, respectively. Route 3 travels from Mohawk and Baseline to downtown in 23 minutes. Although matching all of these route schedules is not possible in downtown Boulder, RTD coordinated schedules at the outlying timed transfer points to facilitate major travel patterns. For example, Routes 5 and 9 can meet at the northern 28th and Glenwood transfer point, Routes 6 and 2 or 4 can meet at the southern Table Mesa and Broadway transfer point, and depending on the time, direction and schedule, Routes 3, 6 or 9 can meet at the eastern Mohawk and Baseline point.

Ann Arbor

With its seven timed transfer points, the Ann Arbor system is the most complex. Several routes follow different paths between the same transfer points and different routes serve the same transfer points in different sequences. As illustrated in Exhibit 4.2:

Route 7 serves Ann Arbor CBD - Pioneer High - Arborland - Huron High - Plymouth Mall
Route 12 serves Ann Arbor CBD - Maple Mall - Pioneer High - Arborland
Route 3 serves Ann Arbor CBD - Huron High - Ypsilanti
Route 4 serves Ann Arbor CBD - Arborland - Ypsilanti
Route 5 serves Ann Arbor CBD - Ypsilanti

The relationships among these routes are very complex. No schedule can permit all routes to participate in all meets.

Priority is assigned to meets at the Ann Arbor CBD and at the Ypsilanti CBD. The other sites vary in their number of route meets. For example, at the northern Plymouth Mall, Route 2 buses going in both directions meet with outbound Route 7 buses at 8 and 38 minutes after the hour and with inbound Route 7 buses at 24 and 54 minutes after the hour. As indicated in the exhibit, some trunk routes have local tails that extend beyond their last timed transfer points (e.g. Route 7). The local service tails vary considerably in trip time, whereas all loop routes have 30 minute round trip times including layovers. This makes it difficult to schedule meets for all outbound and inbound buses.

4.1.1.3 Summary

None of the timed transfer systems examined in this study have all routes, points and schedules coordinated. In fact, each of the case study examples have a different number of timed transfer point and route interactions in their systems. Although routing and scheduling modifications may be possible to make more routes meet at timed transfer points, it may be easier and more practical to operate less than a theoretically perfect timed transfer system. This is because as the number of timed transfer points grows and the number of routes meeting at multiple points increases, the constraints on the routes and schedules become increasingly complex.

The ideal size of a timed transfer system is influenced by the interaction of bus routes serving the timed transfer points and by the number of bus routes that participate in the different transfers. The largest North American system identified is Edmonton, with 40 to 60 routes interacting at thirteen timed transfer points. However, if different routes serve separate transfer points or if little interaction occurs, routing and scheduling difficulties can be eased. For example, there is no interaction between either Beaverton or Cedar Hills and the new timed transfer points implemented on the Eastside of Portland in June 1981. Therefore, operations at Beaverton and Cedar Hills are unchanged. This type of expansion could theoretically continue without limit.

The other major factor that influences timed transfer routing and scheduling will be the local setting. Individual settings will dictate where timed transfer points can be established, where demand warrants transit services or which roadways have sufficient capacity to accomodate transit vehicles. Thus, the routing and scheduling possibilities for different timed transfer operators will vary considerably.

4.1.2 Travel Times

4.1.2.1 Issues

To compare service levels before and after the implementation of timed transfer, an analysis of travel times was conducted. The major issue is whether or not travel times increase because more travelers are diverted to transfer points and spend more time waiting there than they would if they received direct service. The opposite argument is that travel times decrease because timed transfer minimizes transfer wait time, improves significantly the travel times for local and crosstown trips and incorporates faster trunk route services, especially to downtown.

Automobile travel times were used as a reference point, in terms of a ratio, for comparing the alternative transit options. The sample size was 11 to 20 trips in each of the three sites. Different transit options were also available in each site.

4.1.2.2 Case Study Findings

In Ann Arbor, timed transfer fixed-route trips were slightly faster than the same 1979 Dial-a-Ride trips. In Portland, the sample trip analysis suggested the timed transfer service was also slightly better than the conventional low-level services it replaced. However, in Boulder the more conventional transit services were slightly faster than the earlier timed transfer services.

4.1.2.3 Summary

Overall, slight improvements in travel times were achieved with 1) the implementation of timed transfer in two sites and with 2) less emphasis on transfer coordination and more emphasis on efficient services in one site. These findings are compatible with the idea that timed transfer is best suited to medium transit demand areas. At lower demand levels, transit services are slower and less efficient and at higher demand levels, more frequent, faster and efficient transit services are possible.

4.1.3 Bus Performance

Bus performance is a measure of how well the system's routes are operating. Bus performance is extremely important in timed transfer systems, because all participating buses must coordinate their arrivals sufficiently well to accomodate timed transferring passengers. Data were collected in Ann Arbor, Boulder and Portland to determine individual and overall bus route performance in each system.

4.1.3.1 Issues

Two key and related timed transfer bus performance issues are the length of the timed transfer window and the reliability of the system.

Timed Transfer Window

A major bus performance issue is how long must the timed transfer 'window' be to allow transfers to be made? The window is defined as the length of time that the bus is scheduled to wait at the transfer point. In many cases, the timed transfer point is the route's terminus and window time may be route recovery or layover time.

The length of the timed transfer window typically depends on the route's running time, the ability of buses to meet their schedules and the routing and scheduling requirements of the other buses at the timed transfer point. Obviously, bus performance can be improved by increasing the window time or decreasing the route's scheduled travel speed. But, both of these measures work to the disadvantage of passengers - those making transfers and those traveling through transfer points - and of operators - who are trying to provide fast, efficient services and who are trying to keep costs down.

The time actually required for passenger transfers is short. Most buses can be unloaded in 30 seconds or less, walk time between buses is generally short and loading requires one minute or less. In fact, most transfers observed at the timed transfer points in all three sites required less than one minute.

If buses operated precisely on schedule, a two minute window would be adequate to execute a timed transfer. Because they do not operate precisely on schedule, a longer interval is usually needed. How much extra time is needed can vary by individual route, transfer point, time of day or transit system.

Reliability

Related to this is the major issue of bus reliability. Just how long a window is needed depends on the reliability or the variability of the buses. If buses are consistently early or late, schedules can be adjusted to accomodate the difference or routes can be modified to better meet the schedule. When individual occurrences such as accidents cause route delays, often only effective monitoring can prevent one incident from adversely affecting the entire system.

Some other factors that are likely to influence reliability are:

1. Route length -- buses traversing long routes are more likely to encounter unexpected delays than buses traversing short routes;

2. Scheduled trip time -- a loose schedule gives drivers an opportunity to make up for delays; a tight schedule does not;

3. Scheduled layover time -- an ample allowance of layover or window time gives drivers an opportunity to correct for delays;

4. Patronage -- stops to pickup and discharge passengers take time; excessively heavy or light loads will influence schedule performance; and

5. Route -- congested districts, varying traffic densities, railroad crossings or other factors can cause large variations in bus route performance.

Reliability can be measured in terms of on-time performance and the variations from this ideal. On-time performance is determined by each system's route schedules. The parameter used to express bus performance variability is the standard deviation of actual arrival and departure times as compared with scheduled arrival and departure times.

4.1.3.2 Case Study Findings

Exhibits III and IV in Appendix E list actual layover characteristics for routes serving timed transfer points in Ann Arbor and Portland, and performance variability for all routes in Ann Arbor, Portland and Boulder. Actual layover data are not included for Boulder, because timed transfer services were no longer operating when the data were available. The layover characteristics include mean layover time; standard deviation of layover time; and an indication of the range of the layover times. The data are organized by timed transfer point with separate summary data for the connecting point or trunk routes, and provide detailed information about each timed transfer point. The performance variability characteristics include each route's length in miles; trip time; mean layover time; average scheduled speed; mean number of passengers per trip and per hour; and the standard deviation of the actual vs. scheduled arrival and departure times.

The following subsections briefly highlight the major findings in each site and summarize the general distinctions in bus performance for timed transfer systems.

<u>Timed Transfer Windows</u>

In Ann Arbor, all of the mean layover times and standard deviations at the CBD are about the same. Although Route 13 seems to be more tightly scheduled than the other routes, this is matched by better than average schedule performance. All schedules are reasonably tight at Arborland except for Route 7, for which Arborland is the center of five timed transfer points. Ypsilanti seems to serve a schedule adjustment function for the three routes that connect Ypsilanti with the Ann Arbor CBD (Routes 3, 4 and 5). Routes 10 and 11, which are local routes out of Ypsilanti, have longer layovers than the trunk routes with which they exchange passengers. Route 2, which terminates at Huron High School has a long layover time there compared with Routes 3 and 7 for which Huron is an intermediate point.

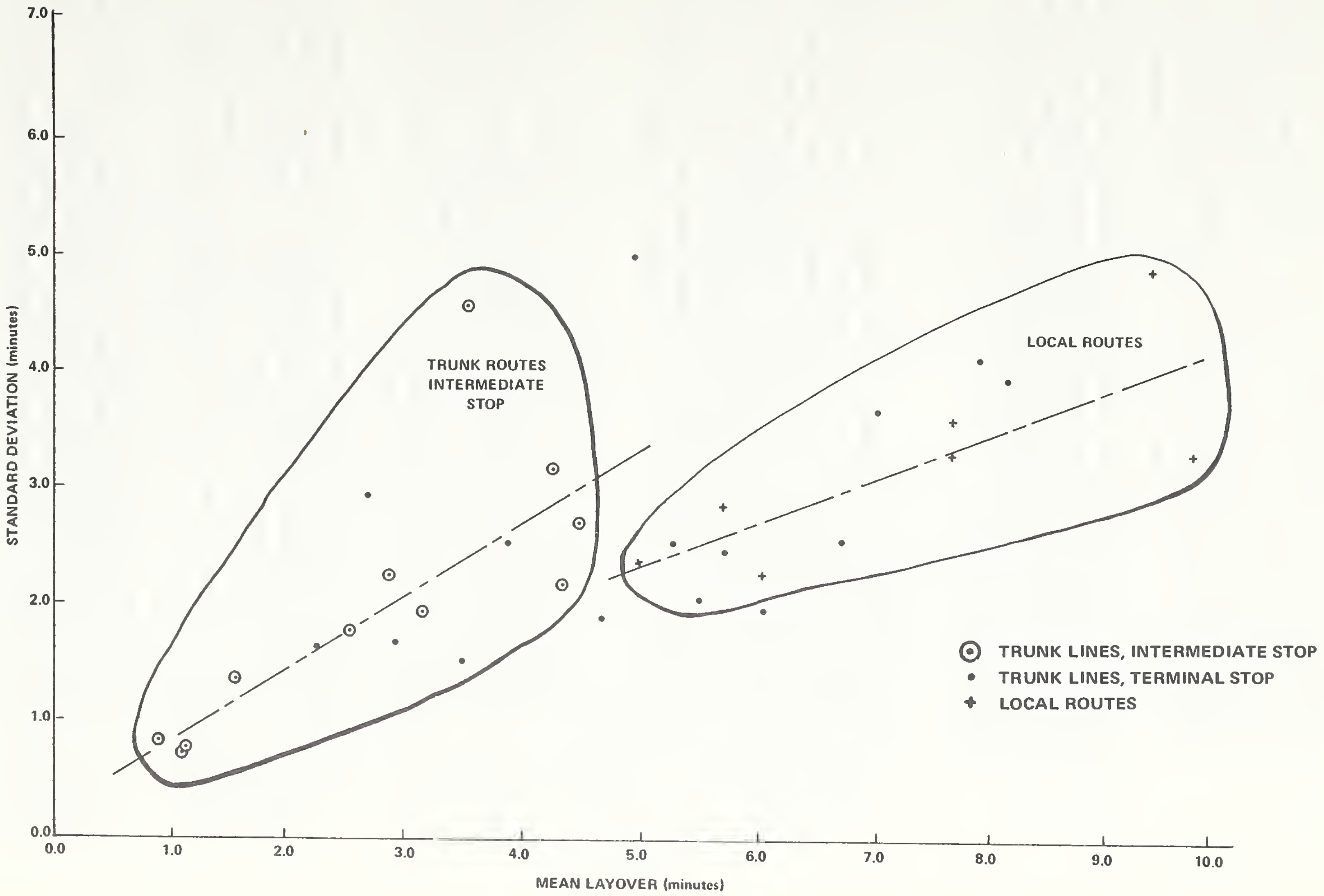
Similar observations can be made about the Portland timed transfer points. At Beaverton, layover times for the local Routes (52, 65 and 67) are considerably longer than those for connecting trunk routes 59 and 77. Routes 54 and 59 have long layover times at Beaverton because it is their terminus. At Cedar Hills, local Routes 60 and 67 have much longer layovers than trunk Routes 59 and 77.

Exhibit 4.3 illustrates the means and standard deviations of layover times for the different categories of bus routes. A close examination of the data reveals three distinct layover patterns:

1. Trunk lines providing service through a timed transfer point have the shortest layovers. They have mean layover times of 2.0 minutes. This value apparently reflects the actual amount of time required for passenger transferring.

Exhibit 4.3

LAYOVER PERFORMANCE OF BUS ROUTES



2. Trunk lines that terminate at a timed transfer point have layover times that depend on their individual routing and scheduling circumstances. Each route needs some slack to accommodate uncertainties along the way. Since it is not generally convenient to allow this slack at a congested downtown timed transfer point (e.g. the Ann Arbor CBD), slack time in the form of long layovers is scheduled at outlying timed transfer points.

3. Local service lines that interchange passengers with trunk lines have longer windows provided at their timed transfer end points. By this means, local service lines reach the timed transfer points ahead of the through trunk lines and follow the trunk lines out. This practice makes it possible to minimize delays for trunk lines.

As mean layover time increases, its relative variability decreases slightly, suggesting that drivers can and do use slack time to improve their schedule performance. Linear relationships developed by regression are plotted in Exhibit 4.3 for both trunk routes at intermediate stops and for local routes. The regression line that best fits the points on the graph for the local routes is distinctly below the one for trunk routes indicating performance is easier to control on short routes that traverse residential areas than on long routes that pass through diverse areas, and routes that pass through congested CBDs.

Reliability

Comparisons between reliability measures in Ann Arbor, Boulder and Portland illuminate some similarities and differences. The basic similarity was that the variability of departure times from timed transfer points was always less than the variability of arrival times. Buses tended to arrive early and to leave on schedule. Since buses are often scheduled to depart at the same time it thus seems easier for the drivers to maintain uniform performance.

Although there was more variation in overall arrival times, the standard deviation of arrival times for a single bus route was not the same at each timed transfer point. Variations in terrain, street geometry, traffic and scheduled speeds introduce variations in bus performance along each route. Drivers' efforts to recover from delays and to increase layover time for personal reasons also influence performance.

To gain further insights into bus performance two types of routes and timed transfer points were compared. First, trunk routes were compared with local routes for all timed transfer points. In Boulder, where a modified timed transfer service was operating, no significant differences were found. In Ann Arbor and Portland, however, the analyses showed:

	Trunk Routes	Local Routes
	(minutes)	
Mean Standard Deviation	2.95	2.57
Sample Variance	0.833	0.327

The large difference between trunk and local route times would occur by chance less than six percent of the time. Thus it is reasonable to state that the reliability of local routes was significantly better than that of trunk routes. This is plausible because local routes typically traverse residential areas where there is little congestion, local routes are shorter than trunk routes and they carry fewer passengers.

An examination of the performance of local routes between the two sites showed no significant difference. However, a comparison of trunk line performance yielded a different result as indicated below:

Performance Comparisons between Ann Arbor and Portland

Service	Standard Deviation of Actual vs. Scheduled Times				$\frac{\bar{x}_1 - \bar{x}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}}$	Significant Difference
	Ann Arbor		Portland			
	Mean	Variance	Mean	Variance		
Local Routes	2.48	0.464	2.67	0.213	0.555	No
Trunk Line Routes	2.84	0.848	3.38	0.654	1.429	Yes (7.6%)
End of Route	2.83	0.736	4.19	0.084	4.49	Yes
Route Midpoint	2.86	1.147	2.97	0.410	0.242	No

Considering all timed transfer points on trunk routes, Ann Arbor buses exhibited less variation in schedule performance than Portland buses. The differences for all trunk route points were marginally significant -- there is a 7.6 percent probability that the measured difference is due to chance.

This difference is clarified when trunk route measurements are divided into: (1) those taken at route midpoints; and (2) those taken at route end points. At route midpoints there are no significant differences between Ann Arbor and Portland, but at route end points there are strong significant differences. Ann Arbor's drivers' performance is also much more variable at route mid points than Portland drivers'. This may be due to more variable traffic congestion, longer routes and more complex schedules.

4.1.3.3 Summary

The operational success of a timed transfer system depends on the ability of buses to coordinate their meetings at timed transfer points, to accommodate transferring passengers and to avoid unnecessary delays for through-passengers. Analysis of case study performance data suggsts that bus routes supporting timed transfer operations can perform reliably with transfer windows of no longer than 6 or 7 minutes. In most cases, the variability of departure times from timed transfer points is less than the variability of arrival times. As discovered for the test sites, buses tend to arrive early and leave on schedule, such that arrival times can change the actual length of the window.

Disaggregating the data into local and trunk route and by timed transfer location illuminates other significant findings. Local routes tend to have much longer transfer windows and are significantly more reliable. Both window times and reliability vary considerably for trunk routes that terminate at a timed transfer point. And trunk routes that provide service through a timed transfer point have the shortest layovers; the widest variations in on-time performance also occur on some of these routes.

4.1.4 Improvement Strategies

Improvement strategies are techniques that transit operators can use to improve timed transfer services. Although there are no established strategies, services can be improved by better scheduling, by closer monitoring of bus operations, by adjusting schedules among transferring buses, or by some combination of the three. These strategies are discussed in this section.

4.1.4.1 Better Scheduling

Bus schedules reflect the amount of time that a bus needs to serve the different segments of a route. Times are generally estimated by driving a bus over the route, simulating stops to drop off and pick up passengers and recording elapsed time for each segment. Many bus systems use different schedules for peak and off-peak service, to reflect the differences in traffic congestion and loading. Times are usually checked periodically to see whether drivers are able to maintain the schedule.

To improve performance through better scheduling, the bus schedulers must understand the variations in bus performance. A careful program of data collection can uncover variations in schedules and local determinants of schedule performance. These may include: (1) time of day; (2) day of week; (3) month of year; (4) location; (5) special events; (6) bus patronage; and other factors. If data are carefully recorded and analyzed, it may be possible to establish route schedules that buses can meet with a high degree of reliability.

As noted in this report, there are also several unique problems and pitfalls in scheduling timed transfer services. Many of these may be avoided by understanding the nature of the problems before designing the system. Operators that are implementing timed transfer systems might consider employing experienced schedulers or meeting and discussing potential problems with experienced timed transfer schedulers.

4.1.4.2 Closer Monitoring

If bus performance is closely monitored and corrected enroute, buses can be expected to arrive at timed transfer points closer to schedule times. To monitor bus performance, dispatchers or supervisors must be able to check bus locations at regular intervals. This can be accomplished by:

1. Putting more supervisors in the field to check bus locations;
2. Requiring drivers to report their positions to dispatchers via radio at regular intervals; or
3. Installing mechanical monitoring devices, such as automatic vehicle monitoring (AVM) systems.

Closer supervision can be achieved by stationing supervisors at intermediate route points. In general, supervisors are assigned fixed locations or specified areas. This tactic is similar to the display of policemen to encourage motorists to observe traffic laws. The supervisor should be able to communicate with the drivers either directly or through the dispatcher. A record should be kept of unacceptable performance so that corrective measures can be taken. Although field supervisors may create a feeling of mistrust, they can develop good communications with drivers, provide on-site support in case of emergencies and help drivers develop and maintain a common objective of improved service. The costs include supervisors' salaries, vehicles and radio or other equipment. All three case study sites used field supervisors, especially during the early stages of timed transfer.

Regular en route reporting can give dispatchers regular information on bus location and give drivers an opportunity to receive timely instructions for correcting buses that are excessively early or late. To use this technique, buses must be radio-equipped, dispatchers must be employed and procedures must be devised to use the information to improve performance. Individual buses can be instructed to wait for connections, but dispatchers must understand the consequences of these delays on other connections. Regular en route reporting can improve communication between dispatchers and drivers and provide an information base for emergency situations. Its cost can be measures in terms of radio equipment, dispatcher staff, confusion on the radio waves, and driver distraction. Ann Arbor used this technique on both their Dial-a-Ride and fixed-route services.

Mechanical monitoring devices, such as AVM, perform the monitoring role without the intervention of drivers or a need for additional dispatching staff to collect data. Equipment is located along bus routes and performance information is transmitted to a central dispatcher. Although still considered a developing technology in this country, there have been more than 30 installations worldwide since 1958. In the United States, AVM systems have been tried in Cincinnati, New York, Chicago, and Los Angeles. AVM equipment is extremely expensive, and has not been employed by any of the studied timed transfer sites.

4.1.4.3 Schedule Adjustments

Schedule adjustments can range from a complete overhaul of existing timed transfer schedules to minor enroute modifications. For example, if buses consistently arrive early at a transfer point, moving the schedule up a few minutes or extending the route may increase the route's efficiency. After scheduling an initially conservative system and operating timed transfer services for over six months, Pierce County (Tacoma), Washington, realized they could make significant adjustments to their schedules; they reduced timed transfer window times and tightened all route schedules. In fact, all of the timed transfer sites implemented some adjustments to their initial schedules, after learning from on-street experience.

For transit systems with varying schedule performance, it may be more advantageous to adjust bus performance just prior to each meet than to try to reschedule the routes. This can be accomplished if buses are radio-equipped and drivers check in with the central dispatcher approximately ten minutes prior to each scheduled meet. The check-in gives the dispatcher an opportunity to alert other drivers to problems, to adjust for buses that are unduly behind schedule and to implement corrective action before the meet occurs. Dispatchers in Ann Arbor spend about one third of their time arranging such meets.

4.1.4.4 Summary

Timed transfer services can be improved by better scheduling, by closer monitoring of bus operations and by adjusting schedules of transferring bus routes. These improvement strategies may be used at varying times and to varying degrees by transit operators. In most instances, the timed transfer sites used at least one of these strategies.

4.1.5 Conclusions

This section identified the impacts on services through a discussion of the increasing complexities and constraints imposed on timed transfer routes and schedules as the number of transfer points and route interactions increases from a pulse two-route system to a seven-point multi-route transfer system. An analysis of timed transfer performance found that as window times increased, so did reliability, with differences associated with different types of routes and transfer points. Finally, three major strategies for improving services are discussed for potential use by timed transfer operators.

4.2 IMPACTS ON RIDERSHIP

This section discusses the key impacts on transit ridership that can result from timed transfer. The impacts on transit users, the actual and proportional changes in patronage and the level, location and direction of transit passenger activity are included. Emphasis is placed on the major findings from the three case studies.

4.2.1 Impacts on Transit Users

4.2.1.1 Issues

Dramatic changes accompanied the implementation of timed transfer services in almost all the sites examined. In most cases, the level of transit services increased significantly, in terms of geographic coverage and/or the hours of service. The issues examined in this section are what marketing efforts the transit operators took to assist users in understanding the new system, the actual changes in user services, and how users perceived the new services.

4.2.1.2 Case Study Findings

Most transit systems, and all three case study sites, initiated major marketing efforts with the initiation of timed transfer services. Boulder advertised the changes prior to implementation and issued new schedules to riders. In Ann Arbor, where services changed from a Dial-a-Ride to a fixed-route timed transfer system, the AATA offered an introductory week of free fares and an ample supply of new route maps and schedules. In Portland, Tri-Met launched an aggressive marketing campaign, which included coordinating the design of route maps, schedules and signs, sponsoring community meetings to explain the new system and assigning staff to the transfer points to assist riders.

In some sites, fixed routes that previously provided transit patrons direct service to downtown were diverted to transfer points, causing delay and inconvenience for these users. Ann Arbor's transit users faced unique changes since door-to-door paratransit services were no longer provided, forcing most riders to walk and wait outside at bus stops and transfer points. In most cases, however, transit patrons received an improved level and quality of services with fixed-route timed transfer. Particularly in Portland, this was because faster trunk route services to downtown were inaugurated and more convenient local and crosstown trips were possible.

Surveys and interviews were conducted in two of the sites on transit passengers' attitudes and perceptions of the services. In Portland approximately three-fourths of the passengers felt timed transfer worked well, met their travel needs and was more convenient than the previous low level conventional services. Boulder transit users perceived improvements in the frequency and directness of services, the convenience of routes and the comprehensibility of the system after the services expanded to a more conventionally scheduled service, with some users noting a worsening of on-time reliability, and total trip time.

Although many passengers need to transfer once in a timed transfer system, surprisingly few need to transfer more than once. This is fortunate, since the Boulder surveys found passengers were fairly accurate in their estimates of waiting time at the first transfer point, but they tended to magnify their estimated waiting times if multiple transfers were required. This may indicate passengers' resistance to transferring.

4.2.1.3 Summary

New timed transfer services have been marketed to transit users via community meetings, advertisements, route maps, schedules and on-site staff assistance. While some user trips are longer and less convenient, most transit users in outlying areas will receive an improved level and quality of service with timed transfer. And users generally perceive timed transfer as more convenient than low level conventional services, although there are still indications of passengers' resistance to multiple transfers.

4.2.2 Impacts on Patronage

4.2.2.1 Issues

In presenting patronage findings resulting from timed transfer service changes, it is necessary to understand and maintain the distinction between unlinked and linked trips. Unlinked trips consider each passenger boarding or segment of the trip as a separate unit. For example, a passenger that does not transfer is counted once while a passenger that transfers twice is counted three times -- once for each route segment of the trip. Linked trips consider only originating passengers as a separate unit -- whether a trip requires no transfers or one, two or more transfers, it is counted as only one trip.

Because timed transfer systems encourage riders to transfer between bus routes, unlinked trip patronage should increase considerably with the implementation of timed transfer service. This can give the false appearance that ridership is actually growing. A comparison using the number of linked trips or originating passengers before and after timed transfer implementation is thus a more accurate measure of the impact on the system's patronage.

In order to accurately interpret timed transfer's impacts on patronage it is also necessary to separate the impacts resulting from timed transfer from the impacts resulting from other factors. For example, in each of the case study sites, the implementation of timed transfer was accompanied by an expansion or change in the level of services. Thus, in addition to examining the total number of passengers using the system before and after the service changed, other measures, such as ratios which can normalize these differences, must be used. The number of passengers per vehicle-hour or per vehicle-mile are ratios intended to measure patronage without regard to the size of the transit system.

In Ann Arbor and Boulder, significant fare changes also occurred, further confounding the patronage impacts of timed transfer. The following analysis attempts to separate these impacts by looking at both the short and long-term patronage trends. It appears that timed transfer may have varying impacts on transit patronage.

4.2.2.2 Case Study Findings

Ann Arbor

Because of the growing demand and the high cost of paratransit services in Ann Arbor, the AATA curtailed Dial-a-Ride (DAR) services, expanded timed transfer fixed-route services and increased fares in October of 1979. To separate the effects of the fare increase, a five-year patronage period was analyzed. Patronage increased from about 6,200 to about 8,400 passenger trips per day between 1976 and 1981, representing a 26 percent growth over five years.

Between 1976 and 1981 the AATA operated almost 600 hours of transit service each weekday. In 1976, however, DAR accounted for 72 percent of these services, while in 1981, 74 percent of the hours were devoted to fixed-route services. Productivity, in terms of passengers per vehicle-hour, averaged 3.3 on Dial-a-Ride and almost 30 on fixed-route services for an overall system productivity of eleven trips per hour. By 1981, Dial-a-Ride productivity had dropped to 1.3 and fixed-route productivity declined to about 20 passenger trips per hour, for an overall system productivity of almost 15 trips per hour. This represents a 27 percent improvement in passenger productivity between 1976 and 1981.

The transfer rate remained quite high before and after fixed-route services were expanded. Almost all Dial-a-Ride trips and one-third of the fixed-route trips required at least one transfer in 1976. Slightly over one-third of the fixed-route trips involved transfers in 1981.

Boulder

In Boulder, the RTD implemented an off-peak free fare demonstration project during the same period that Boulder began operating an expanded level of timed transfer services. This fare experiment as well as other factors increased the demand for transit, confounding the patronage impacts resulting from timed transfer. The analysis attemps to understand these impacts separately by comparing the short and long-term patronage trends in Boulder with those in Denver.

Long-term free fare ridership gains are estimated at about 4 percent of overall RTD post-free fare ridership. However, Boulder's long-term gains were much greater than the overall system's gains. This was because Boulder's patronage increased almost twice as much as Denver's patronage between January and March of 1978, when free fares were implemented in both areas and timed transfer services were expanded in Boulder. Boulder's ridership also continued to increase to its highest level in the Fall of 1978, when both free fares and improved timed transfer services were operating, while Denver's patronage was beginning to level off.

Because of incomplete data, it is difficult to determine the exact patronage impacts of expanded timed transfer services in Boulder. Greater relative increases in patronage occurred in Boulder than in Denver over both the short and the long term. Yet, Boulder's system and population was growing and it is likely that Boulder's student and retired population was more interested and able to take advantage of mid-day free fares and timed transfer services.

Portland

In Portland, before Tri-Met implemented the Westside timed transfer service, the Westside provided about 640 hours and 10,600 miles of conventional transit services and carried about 14,000 originating passengers each weekday. Productivity averaged 22 passenger trips per hour and 1.3 trips per mile. One year after Tri-Met expanded timed transfer services, the Westside provided about 960 hours and 14,900 miles of service and carried about 19,000 originating passengers each weekday. Westside service hours increased one-third, mileage increased 29 percent and patronage increased 26 percent.

Although ridership surpassed Tri-Met's goals, Westside productivity declined slightly. The average number of passenger trips per hour declined ten percent and passenger trips per hour declined five percent. The difference in these productivity measures may be explained by timed transfer's additional layover time requirements.

Longer-term patronage trends indicate comparable growth with the rest of the Tri-Met system. However, patronage on routes that only serve timed transfer points has grown faster than all Westside patronage. Since significantly more passengers are now transferring on the Westside, this also represents an even greater increase in Westside unlinked passenger trips.

4.2.2.3 Summary

Because of the variation in the case study sites, it appears that timed transfer can have varying impacts on transit patronage. Patronage increased 26 percent and productivity increased 27 percent over a five year period in Ann Arbor, when services switched from paratransit to fixed-route timed transfer services. In RTD-Boulder, after expanded timed trasfer services were implemented, ridership increased at a much faster pace and sustained a higher relative patronage level after the elimination of free fares, then in RTD-Denver. And after one year in Portland, patronage increased 26 percent, although productivity dropped five to ten percent.

Thus, it appears that expanded timed transfer services have had positive impacts on transit patronage. It is likely, however, that ridership may have increased in all three sites without timed transfer. In fact, timed transfer was seen as a way to meet the projected increasing ridership demands in each site.

4.2.3 Impacts on Passenger Activity

4.2.3.1 Issues

Timed transfer can have significant impacts on the level, location and directional flows of transit passengers. In most cases, the majority of passenger activity is concentrated at the timed transfer points. However, specific sites may receive more or less activity at varying times of the day. Of particular interest is the off-peak period, when transit services are less frequent, passenger activity is usually quite low, and productivity suffers.

The level of passenger activity data were collected at the timed transfer points on two to three weekdays in Ann Arbor, Boulder and Portland during 1980 and 1981. Data collectors monitored individual bus routes at each timed transfer site and recorded the number of passengers who disembarked, the number of passengers who boarded and the number of riders who were on-board each departing bus. Where possible, transferring passengers were differentiated from originating passengers, and disembarking passengers, who missed a transfer, were noted.

4.2.3.2 Case Study Findings

Passenger activity was heaviest at the transfer sites in downtown Ann Arbor and Boulder. In Ann Arbor, considerable activity also occurred at the Ypsilanti CBD and at Arborland, a shopping mall situated between Ann Arbor and Ypsilanti. Considerably less activity occurred at Boulder's other transfer points. Checks were not conducted in downtown Portland, since the most frequent demands and services occur there and timed transfer is not warranted. A comparison of Portland's two timed transfer sites, however, showed Beaverton, which is served by a total of eight routes, one of which is a major trunk route, has almost three times more activity than Cedar Hills, which is served by four routes.

At the downtown transfer points, a considerable number of passengers originated or completed their transit trip. At the outlying transfer sites, the vast majority of passengers transferred to departing buses. Some passengers were observed disembarking at transfer sites, especially in shopping centers, and returning later to board an outbound bus. Practically all of the transfer activity in all the sites seemed to occur at the timed locations.

It is not surprising that during the morning and evening peak periods, ridership was heaviest inbound to and outbound from the CBD, respectively. In Boulder, most of the crosstown traffic also occurred during the peak periods. In Ann Arbor, however, only a small fraction of the passengers rode all the way to the CBD. And in Portland, there was a considerable amount of off-peak activity on local and trunk routes. In fact, at the Ann Arbor Arborland Mall transfer point, the heaviest passenger activity occurred during the mid-day and evening periods. More riders may be attracted to timed transfer during the off-peak periods because even though services are less frequent route connections are assured.

In all three sites, many passengers stayed on-board some buses at the transfer points. Passenger route carryovers were particularly significant in downtown Ann Arbor, where most routes are paired together. It is assumed that these riders were taking advantage of the route pairings by the operator, and that another route, which would require a transfer, would not have better served their needs.

In contrast, local routes discharged vitually all passengers and took on new loads at the Portland transit centers. During the morning peak, the Beaverton trunk routes picked up almost 40 percent of their bus loads at the transit center and during the evening peak, the trunk routes dropped off over 60 percent of their passengers at this transfer point. Thus, the ability of timed transfer to coordinate inbound local residential services with other local and trunk routes becomes obvious.

4.2.3.3 Summary

Passenger activity is heaviest in downtown locations. In downtown, passengers may be originating, completing or transferring on their transit trip, while in outlying sites, most passengers are transferring and most transferring occurs at timed locations. On some routes many passengers stay on-board the buses to take advantage of paired or through-routing, while on other routes virtually all passengers disembark and transfer. Ridership is still heaviest during the peak periods, although timed transfer seems able to attract a considerable number of passengers during the mid-day and evening periods.

4.2.4 Conclusions

Timed transfer can have significant impacts on transit ridership. In terms of the transit user, effective marketing may help to attract riders. Yet, convenient routes and schedules and a limited number of multiple transfer trips are needed to sustain timed transfer riders.

The greatest volume of passenger activity will focus on the timed transfer points, especially if these occur in downtown locations. Paired or connecting routes can eliminate through-passengers' physical need to transfer. And timed transfer may also improve peak to off-peak ridership ratios.

In terms of unlinked passenger trips, patronage can increase substantially, due to the higher rate of transferring. Actual patronage may also increase, but at a lower rate. Depending on the change in the level and type of services, the number of passengers per trip may vary.

4.3 IMPACTS ON COSTS

The incremental cost of timed transfer service over the service it replaces is highly dependent on specific features of the system design and other site-related factors. A transit operator will primarily have to consider the following aspects in estimating the costs of changing to a timed transfer system:

- The type of transit services currently provided by the system (e.g., conventional fixed-route or demand-responsive transit);
- The capital investment planned for timed transfer points; and
- Service characteristics of the planned timed transfer system such as bus route participation and the size of the transfer window.

Other factors that may contribute to the costs of a system change to timed transfers, but that are not directly attributable to timed transfer services as such are:

- Increases in the overall level of service;
- Fare changes (e.g., increases or free fares); and
- Other changes in operating policies (e.g., levels of supervision).

Each of these kinds of changes was made at one or more of the case study sites and is discussed in their individual analyses (see Chapter 5). The remainder of this section, however, examines only the costs caused by timed transfer system characteristics, i.e. incremental capital and operating costs, and start-up costs incurred during the implementation period.

4.3.1 Capital and Start-up Costs

Capital and start-up costs are presented together, because both represent a commitment a transit system must make at the outset of a timed transfer system, as opposed to the continuous flow of operating costs.

4.3.1.1 Transfer Points

Transit systems that emphasize transfers in their existing services may not have to establish new transfer points. Ann Arbor is an example of this situation. The Dial-a-Ride system required 11 transfer points that could be converted to 7 fixed-route timed transfer points at no extra cost.

In other cases, the minimum investment associated with a new transfer point is the cost of shelters and benches for waiting passengers. In 1979-80, these costs ranged from $6,000 to $12,000 per transfer point at the case study sites.

If many buses have to wait at the transfer point at the same time due to a high degree of route participation, curb modifications and special parking spaces may become necessary. Signs for individual routes and general transit information may also be installed. Costs for these changes amounted to $90,000 in Portland's Westside in 1979.

Very busy transfer points are often located in transit centers and can serve both local and regional transportation purposes. Such transit centers may provide room for passenger waiting areas, bicycle and motorcycle racks, baggage/parcel areas, ticket counters, information centers, restrooms and other facilities for the passengers' convenience. In 1979, the Denver RTD submitted a grant application for a new transit center in downtown Boulder. This center was planned to have all of the facilities listed above, providing 6 to 8 parking spaces for timed transfers of local buses, 6 spaces for regional buses, 3 spaces for short layovers, and 8 spaces for recovery. The following estimated cost breakdown for the Boulder transit center may serve as a guideline for the types and order of magnitude of the costs that may accrue for a major timed transfer transit center:

Land acquisition (former 150"x300" parking lot)	$850,000
Architectural & engineering services	57,828
Construction management	34,697
Construction (5,000-square foot building)	578,275
15% Contingency	228,120
TOTAL	$1,748,920

The Denver RTD had similar plans for several transit centers at the same time, with total costs ranging from $800,000 to $1,500,000 per site.

4.3.1.2 Start-up Costs

In addition to the facilities, other initial efforts are necessary to establish a timed transfer system. Among those, marketing, training and supervision can contribute significantly to the overall costs.

Marketing. As timed transfers are a rather recent phenomenon, passengers will have to be acquainted with it through an intensive public information campaign. New schedules and information brochures must be printed to explain the technical details of transferring, the routing and scheduling changes and the advantages of timed transfers. The continued support of former passengers and the interest of new riders makes marketing an important item for a timed transfer budget. In many instances, other service changes can be advertised simultaneously and the costs shared.

Tri-Met in Portland spent about $50,000 on public information related to the new timed transfer services in 1979. This included on-site information staff during the start-up period. The Ann Arbor Transportation Authority expanded its telephone information center, used newspaper ads, radio spots, information flyers, distributed new timetables and system maps, and offered free service for the first week of timed transfer operations. As a result, the AATA spent more on marketing in October 1979 (when timed transfers were introduced) than in the entire previous year. Not all of these costs can be attributed to timed transfer services, however, because the efforts were partly intended to overcome the ridership effects of a fare increase that was implemented at the same time.

Training. At all of the case study sites, drivers were given initial training in operating timed transfer routes. The extent of this training is described in Chapter 3. The costs associated with it were estimated to be $160,000 for the familiarization of all drivers in Portland's Westside. The amount can be expected to decrease substantially once only new drivers have to be trained.

Supervision. The costs of the extra amount of supervision during system start-up times were estimated to be $110,000 in Portland. These costs cover the additional supervisory effort needed at the transfer points and the dispatching centers in order to coordinate transfer meets during that stage. All of the case study sites reduced these higher timed transfer supervision levels after the initial period. As indicated in the discussion of improvement strategies for timed transfer services (Section 4.1.4), increased supervisory efforts may be advantageous for timed transfer systems. If such a strategy were adopted, the additional operating costs would be determined by the supervisors' salaries and their vehicle operating costs.

4.3.1.3 Other Potential Capital Costs

All of the case study sites expanded their vehicle fleet with the implementation of timed transfer services. The Ann Arbor Transportation Authority replaced many of its Dial-a-Ride vans by regular sized coaches, and Boulder and Portland's Westside increased their fleets by 11 and 27 buses, respectively, at a cost of about $120,000 - 140,000 per bus. It is, however, hardly possible to determine whether expenses for buses are attributable to timed transfer services. The AATA would have had to buy large buses for any conventional fixed-route transit system and Boulder and Portland used their new buses to substantially increase their level of service.

The same argument applies to bus equipment. Buses operating in timed transfer systems are often fitted with two-way radios, so that dispatchers can coordinate meets. All the buses in the case study sites were equipped with radios, but at no appreciable cost. The AATA transferred radio equipment from Dial-a-Ride vehicles to fixed-route vehicles, RTD-Boulder buses were already radio-equipped and in Portland those coaches that had radios were assigned to the Westside service. Other systems planning to implement timed transfer services may not have a radio system, but may also purchase them for reasons other than timed transfers, e.g. general operating improvements and security. Thus, neither the costs for new buses nor that for radio equipment can be principally attributed to timed transfer.

4.3.2 Operating Costs

Timed transfer generates two main kinds of incremental operating expenses: (1) personnel costs, and (2) costs caused by routing/scheduling requirements.

4.3.2.1 Personnel

The employees most directly involved in operating timed transfers are drivers, dispatchers, supervisors, and schedulers. Incremental operating costs associated with the number of drivers depend on whether fewer or greater buses are attributed to timed transfer services. In Ann Arbor, the number of drivers declined from 131 to 104, a development that was directly caused by the switch from Dial-a-Ride to fixed-route services, since the larger buses have a better driver to passenger capacity ratio. Portland and Boulder, on the other hand, had a greater number of drivers after the expansion of their fleets.

The AATA could decreased the number of dispatchers from 5 to 2 after they had reduced the level of Dial-a-Ride services. They estimated, though, that their dispatchers spent about one third of their time coordinating timed transfer meets. Therefore, systems with low levels of dispatcher activity may incur additional operating costs in the form of dispatcher wages after introducing timed transfer services.

As discussed earlier (see Section 4.1.4), additional supervisory and scheduling efforts may help to improve timed transfer system reliability. These measures would add incremental operating costs, as determined by the wages of the additional personnel assigned to the timed transfer operations. Cost estimates for extra supervision and scheduling are not available from the case study sites, because after the initial start-up period they did not employ new personnel for this purpose, but rather reassigned or expanded the responsibilities of existing staff.

In all the sites, annual total costs for personnel increased when timed transfer was compared to earlier personnel costs. Most of the increase was caused by higher annual wage and benefit rates after discounting for the actual change in the size of the staff.

4.3.2.2 Routing and Scheduling Requirements

The coordination of complex meets of routes at timed transfer points can result in operating inefficiencies. Scheduling requirements may affect headways, route miles, bus speeds, running times and layover times. The following analysis of layover and window times demonstrates the impact timed transfer services may have on operating productivity and thus the operating costs of a system.

Layover times serve as driver resting periods and slack time to assure service reliability. In timed transfer systems, they may also be used to allow passengers to complete their transfers. Therefore, two factors determine the incremental cost of timed transfer layovers over layover times in conventional fixed-route systems:

- the size of the transfer window; and
- the extent to which a route's layover time can be scheduled at transfer points.

In Ann Arbor, all layover times could be shifted to the transfer points. Using the scheduled round trip time for each route, layover times were then calculated as a percentage of revenue running time. The system total of 20.8% of layover time represents 69.4 service hours per weekday. The incremental cost of this layover time can be estimated by comparison with conventional fixed-route transit statistics. The Southern California Rapid Transit District (SCRTD) in Los Angeles guarantees its drivers rest periods that equal 10% of their platform time, or 15% of their running time. Taking this norm as a reference, the AATA would have to reduce its layover time to 50 service hours per weekday. Thus, the operating cost that can be attributed to timed transfer scheduling requirements equals

(69.4 hours - 50 hours) x \$39.44/hour x 247 = \$188,988

annually for weekday services, where \$39.44 is AATA's cost/revenue vehicle-hour in the fiscal year 1980, and 247 represents the number of weekdays per year.

The same analysis conducted for Portland's Westside results in layovers of 21.8% of running time, and incremental annual operating costs of $593,141 (using systemwide costs of $44.47/revenue vehicle-hour in 1980). These costs are probably conservative, since additional time may still be needed for driver breaks and all route layovers will not occur at timed transfer points. Nevertheless, this analysis suggests that there are measurable cost effects of timed transfer's routing and scheduling requirements that must be taken into account by transit planners. The exact amount of these additional costs will vary from system to system, depending on the degree of slack in the system prior to timed transfer services, the size of the timed transfer windows, the amount of layover time that can be scheduled at transfer points, additional layovers required, and the costs per vehicle-hour of the individual system.

4.3.3 Comparison of Operating Statistics

The issue of comparing costs of timed transfer systems to the costs of systems they replaced (or were replaced by) is complicated by the extensive changes in the level of service that usually accompanied the introduction of timed transfers. Also, timed transfer services have not always been implemented systemwide. These difficulties must be taken into account in the interpretation of the operating statistics in Exhibit 4.4. The exhibit compares transit performance data for Boulder and Ann Arbor with averages that the American Public Transit Association (APTA) published for transit systems with service area populations of 50,000-200,000.

Analyzing timed transfer performance first, both Boulder's services in 1978 and Ann Arbor's in 1980 were more expensive than the U.S. averages, but Ann Arbor's more so than Boulder's. This fact may be representative of the greater complexity of Ann Arbor's timed transfer network.

On the other hand, the data show the success of Ann Arbor's decision to reduce the level of Dial-a-Ride services: while the U.S. average in costs/bus hour increased by 37.7% (from $16.61 to $22.82) between 1979 and 1980, costs/bus hour in Ann Arbor increased by only 16.4%, and costs/bus mile decreased by about 17%. Comparing Boulder's timed transfer operations with the successive system, one can find a characteristic increase in bus miles per bus hour - a sign of shorter layover times at transfer points. Costs have increased relative to the increases of the U.S. averages; costs/bus mile were 34% higher than the average in 1980 compared to 20% higher in 1978, and costs/bus hour were 13% over the average in 1980 as opposed to 8% in 1978.

Exhibit 4.4

OPERATING STATISTICS OF TIMED TRANSFER AND CONVENTIONAL BUS SYSTEMS

Statistics*	1978		1979		1980		
	U.S. Population Group 50,000-200,000	Boulder Timed Transfer	U.S. Population Group 50,000-200,000	Ann Arbor** Dial-a-Ride	U.S. Population Group 50,000-200,000	Ann Arbor Timed Transfer	Boulder Conventional Fixed-Route Bus System
Bus operators per bus	1.25	NA***	1.36	1.29	1.21	1.13	NA
Passengers per bus mile	1.88	2.2	2.06	1.30	2.11	1.05	NA
Revenue bus miles per revenue bus hour	12.44	11.5	11.60	10.11	12.97	14.17	12.1
Costs per unlinked passenger trip	$0.74	$0.74	$0.69	$2.51	$0.89	$2.58	NA
Costs per bus mile	$1.27	$1.60	$1.43	$3.35	$1.61	$2.78	$2.16
Costs per bus hour	$16.91	$18.38	$16.61	$33.86	$22.82	$39.44	$25.76

* Source: American Public Transit Association, Operating Statistics Report, 1979, 1980 and 1981 (U.S. averages and Ann Arbor); Denver Regional Transportation District, Monthly Performance Reports (Boulder).

** Ann Arbor statistics reflect systemwide averages. Dial-a-Ride and fixed-route timed transfer services each accounted for about two thirds of all services in 1979 and 1980, respectively.

*** NA = not available.

4.3.4 Summary

On balance, one may conclude that timed transfer services are more costly to operate than conventional fixed-route services. The incremental costs that accrue with the introduction of timed transfers depend on the kind of system they replace, the capital investment a transit operator is willing to make at the transfer points, the specific marketing, training and supervisory requirements, and the additional vehicle or equipment costs. Incremental operating costs will include any changes in drivers, dispatchers, supervisors and schedulers and the routing and scheduling requirements may add five to ten percent more service hours.

The three case study sites experienced different economic impacts with timed transfer services. In Ann Arbor, fixed-route timed transfer operations proved to be more efficient than the Dial-a-Ride services they replaced. Tri-Met in Portland offset much of timed transfers' increased costs by attracting a large number of new riders. Results for Boulder are still being debated; the termination of timed transfer services brought about initial cost reductions, but the analysis of Boulder's operating statistics suggests that these reductions have not been permanent.

In addition to the costs presented in this section, other costs and benefits of timed transfer services that are not easily quantifyable may influence a transit planner's decision equally or even more. Among these factors may be perceived convenience by passengers, the desire or need to provide transit service to a medium-density area, or the economic activity generated at transfer points.

5. CASE STUDIES

This chapter contains detailed descriptive and analytical information on the three timed transfer case studies. The three study sites are: Ann Arbor, Michigan; Boulder, Colorado; and Portland, Oregon. These case studies provided much of the documentation for the rest of this report.

5.1 ANN ARBOR

5.1.1 Site Description

Located 40 miles west of Detroit, Ann Arbor is the largest city in Washtenaw County. The Ann Arbor urbanized area includes Ypsilanti, Superior and Pittsfield townships, an area of 45 square miles, with a population of 210,000. Single family residences are dominant in the urbanized area and the mean population density is a moderate 4,000 persons per square mile.

Life in Ann Arbor is dominated by the University of Michigan, whose main campus is adjacent to the Ann Arbor CBD. The University has an enrollment of 35,000 and a staff of over 10,000 persons -- the largest employer in the area. The university's influence is reflected in the age distribution of the population and in the research and teaching orientation of the labor force; Ypsilanti has some automobile-related industry. Both Ann Arbor and Ypsilanti have commercially active CBDs and there are several shopping malls in the surrounding area. Automobiles are the primary mode of transportation since almost 90 percent of all households own at least one automobile.

5.1.2 System History

Since 1968, public transit in Ann Arbor has been provided by the Ann Arbor Transportation Authority (AATA). AATA's service has been characterized by innovation, a strong public conscience, and steadily increasing patronage. Initially, four mini-buses provided conventional fixed route service. By 1971, 18 buses provided service on six routes with 30 minute headways during peak periods. In 1972, AATA began operating a comprehensive, areawide Dial-A-Ride (DAR) service. This service, called Teltran (Telephone and transportation), combined DAR and conventional fixed route services to meet transportation area needs at different times. Eleven local DAR areas, covering the entire city of

Ann Arbor, provided weekday service. Six fixed bus routes in Ann Arbor and between Ann Arbor and Ypsilanti connected the DAR areas. Exchanges between DAR vehicles and fixed route buses took place at eleven different timed transfer points. Evening and weekend service provided comparable coverage with larger DAR areas and fewer fixed bus routes.

Annual AATA patronage grew from 541,000 in 1971 to almost two million by 1979. However, the DAR service was very costly. Fares accounted for only about ten percent of system revenues, relying on state and federal subsidies and a local mileage tax for support. The (1) cost of DAR; (2) changes in attitude at the AATA; and (3) growth in patronage encouraged the AATA to support a more comprehensive fixed route service. On October 1, 1979, the AATA discontinued the Teltran system and initiated an expanded fixed route timed transfer service called "The Ride".

5.1.3 Timed Transfer System

AATA retained the Dial-a-Ride timed transfer concept in the new fixed-route system so passengers could easily transfer between routes. The new system has seven timed transfer focal points: the Ann Arbor CBD at 4th Avenue and William; two shopping centers (Arborland and Plymouth Mall); two high schools (Pioneer and Huron); and the Ypsilanti CBD. The AATA system map in Exhibit 5.1 identifies each timed transfer location and the connecting fixed bus routes.

5.1.3.1 Route Structure

The AATA provides bus service on 18 different routes. The AATA also provides DAR service for elderly and handicapped persons and an Out County DAR service for residents of the smaller communities in Washtenaw County. The characteristics of the fixed bus routes are listed in Exhibit 5.2.

The routes cover most of the Ann Arbor-Ypsilanti urbanized area. Some routes (e.g. Route 4), provide direct service between two points. Others (e.g. Route 6 and Route 7), serve non-CBD oriented trips and downtown. Only one route, 15-South Maple, is crosstown, serving neither the Ann Arbor nor the Ypsilanti CBD.

All but three of the bus routes (Route 6, Route 12, and Route 15), are paired. For example, each bus that enters the Ann Arbor CBD as a Route 4 leaves as a Route 9 and vice versa. By following this regular switch back and forth, inbound Route 4 passengers who wish to transfer to Route 9 need not change buses. Ten percent of the passengers outbound on Route 9, simply remain on board the paired Route 4 bus. In the aggregate, 6.5 percent of the system's passengers take advantage of the paired routings. The pairings are indicated in Exhibit 5.2. All pairings, except one, occur at the Ann Arbor CBD; Routes 3 and 5 are paired at the Ypsilanti CBD.

Exhibit 5.1

ANN ARBOR BUS ROUTE MAP

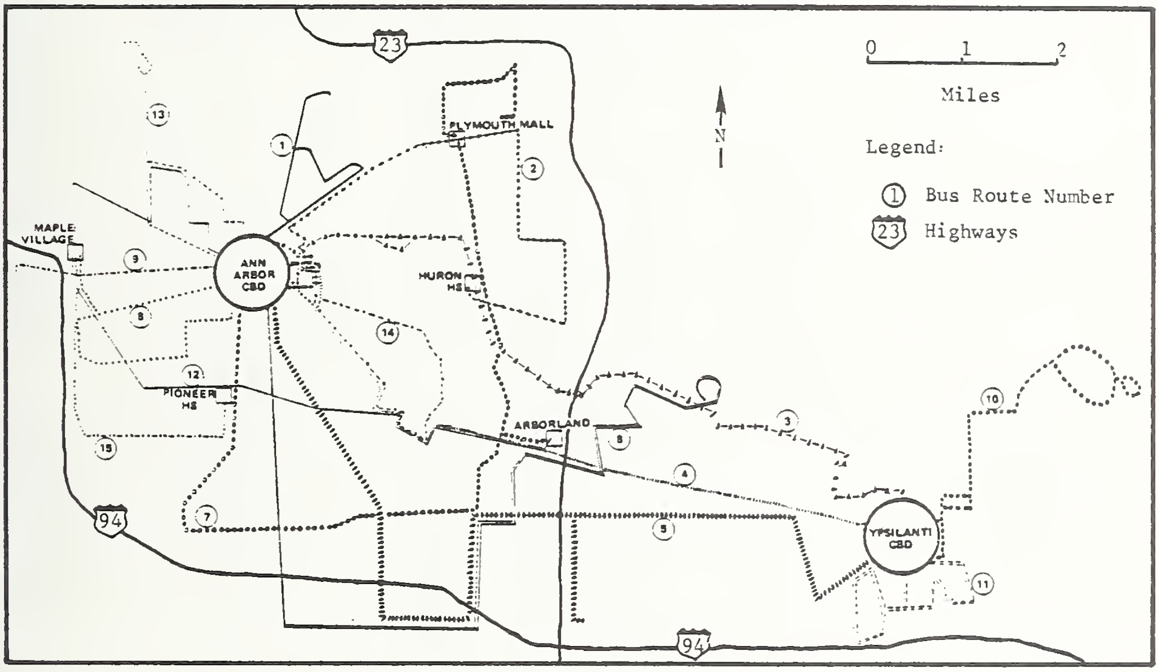
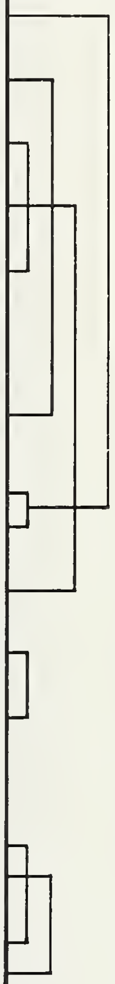


Exhibit 5.2

ANN ARBOR BUS ROUTE CHARACTERISTICS

Route No.	Name	Headway		Round Trip			Patronage			Run Through Pairings
		Peak (min)	Off Peak (min)	Distance (miles)	Time (min)	Avg Speed (mph)	Daily	Per Trip	Per Hour	
1	Pontial	30	30	6.16	30	12.3	380	17.1	34.2	
2	Plymouth	15	30	16.52	75	13.2	667	29.4	23.5	
3	Huron River	30	30	19.19	90	12.8	665	31.1	20.7	
4	Washtenaw	15	30	16.90	90*	11.3	1,648	58.7	42.8	
5	Packard	15	30	25.88	90*	17.3	892	34.8	27.9	
6	State-Ellsworth	30	30	22.42	90	14.9	659	28.2	18.8	
7	South Main-Huron Parkway	15	30	25.58	120*	12.8	907	32.6	16.3	
8A	Liberty-Pauline	60	60	4.81	30	9.6	373	17.4	34.7	
8B	Pauline-Liberty	60	60	4.49	30	9.0	435	19.5	39.0	
9	Jackson	30	30	6.24	30	12.5	397	17.6	35.3	
10	Ypsilanti-Northeast	60	60	8.81	30	17.6	103	10.5	21.0	
11	Ypsilanti-South	60	60	4.86	30	9.7	137	12.5	24.9	
12	Stadium-Miller	30	30	23.24	90	15.5				
13A	Newport-Miller	60	60	6.86	30	13.7				
13B	Newport-North Main	60	60	6.86	30	13.7				
14A	Medford-Geddes	30	60	7.46	30	14.9	57	3.3	6.7	
14B	Geddes-Medford	30	60	7.46	30	14.9	41	2.6	5.1	
15	South Maple	30	30	7.68	30	15.4				



*Some buses cover only a portion of the route

AATA matches route pairs together to maintain reliable service. For example, particularly long or highly variable routes would be paired with short or fairly consistent routes so the driver can correct earliness or lateness on one portion, without allowing these impacts to multiply throughout the day. Over time, if ridership, traffic or other factors alter a route's time or reliability, AATA has the flexibility to switch route pairings to maintain reliable services.

5.1.3.2 Points, Routes and Schedules

AATA adopted a seven point timed transfer program to efficiently serve a wide variety of trips with minimum enroute delays. Nine of the 18 bus routes serve more than one timed transfer point. One route, Route 7, serves five of the seven timed transfer points; one route, Route 12, serves four; and three routes, Route 2, Route 3, and Route 4, serve three timed transfer points.

AATA did not schedule transfers between all possible route combinations at all timed transfer points. The scheduled transfer times for the two major points between 7 AM and 8 AM are displayed in Exhibit 5.3. Exhibit 5.4 schematically illustrates the relationship among the nine routes that serve two or more timed transfer points.

Transfers at the Ann Arbor CBD are synchronized so that 13 buses are scheduled to depart at 15 and 45 minutes after the hour. Four routes, operating on the more frequent 15-minute headways, also meet in downtown Ann Arbor on the hour and half-hour. The two directional versions of Route 8 (8A and 8B) participate alternately in the 13 bus exchanges. Exhibit 5.5 illustrates the 13 bus route assignments at Fourth and William, in front of the AATA Information Center in downtown Ann Arbor.

At the Ypsilanti CBD transfers are synchronized among four routes on the hour and half-hour, with alternate participation between Routes 10 and 11. Some buses do not participate in time d transfers, e.g. Route 12 at Pioneer High School. Others participate only partly, e.g. Route 7 at Pioneer High School at 22 and 52 minutes after the hour.

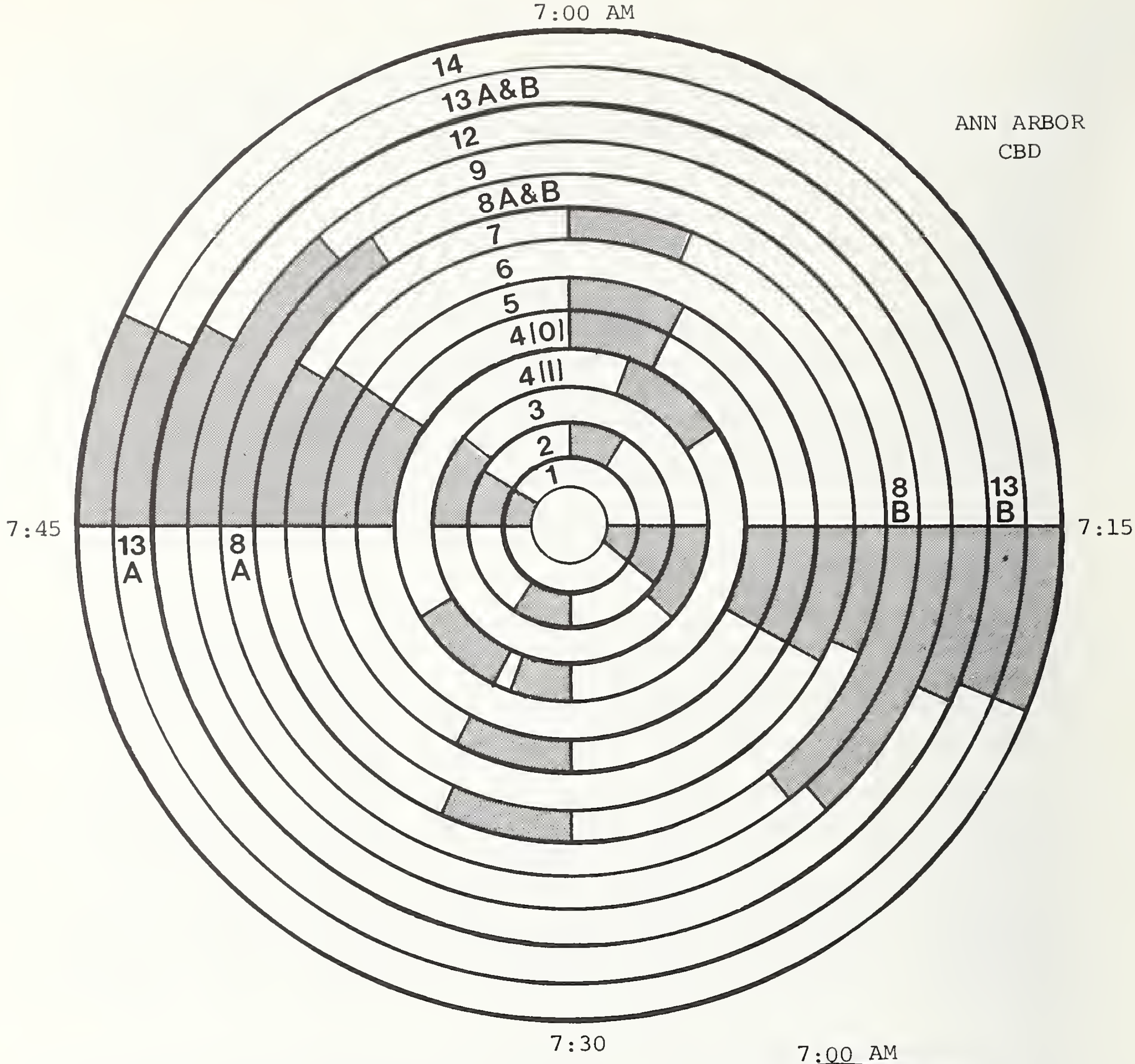
Buses serving routes 7 and 15 at Pioneer High School can exchange traffic in both directions at seven and 37 minutes after the hour. Thus, buses on Route 12 do not have convenient interchanges with either Route 7 or Route 15. The reasons for this difficulty are clear when one considers the many interactions among the different bus routes.

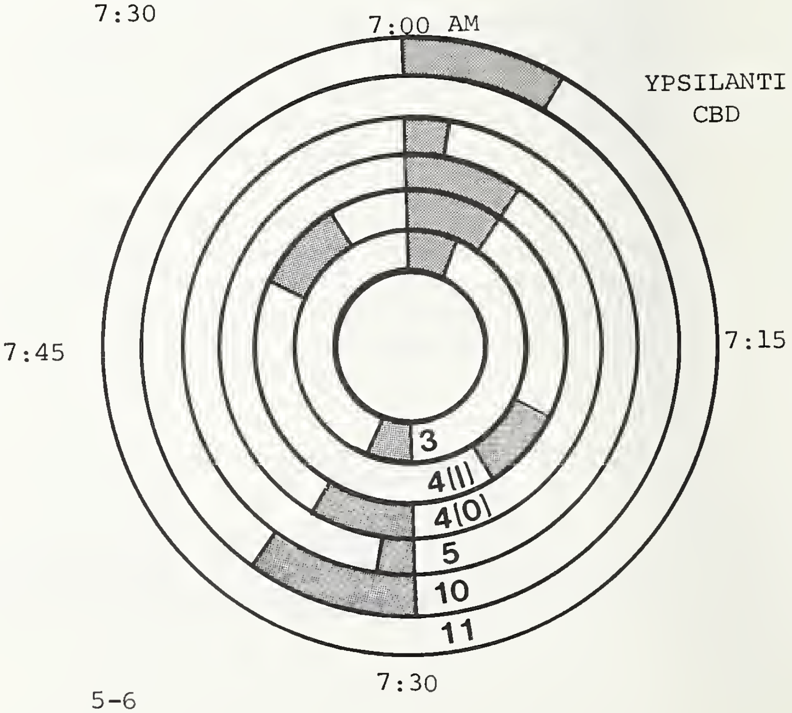
5.1.3.3 System Example

Some of the schedule difficulties can be understood by examining the schedule requirements for one route. Route 7, South Main-Huron Parkway, for example, originates at the Ann Arbor CBD. Buses depart

Exhibit 5.3

ANN ARBOR TIMED TRANSFER SCHEDULES





LEGEND:

▨	Scheduled Timed Transfer Layover Time
4	Route Number
(I)	Inbound to CBD
(O)	Outbound from CBD

Exhibit 5.4

RELATIONSHIPS AMONG ANN ARBOR ROUTES SERVING TWO OR MORE TIMED TRANSFER POINTS

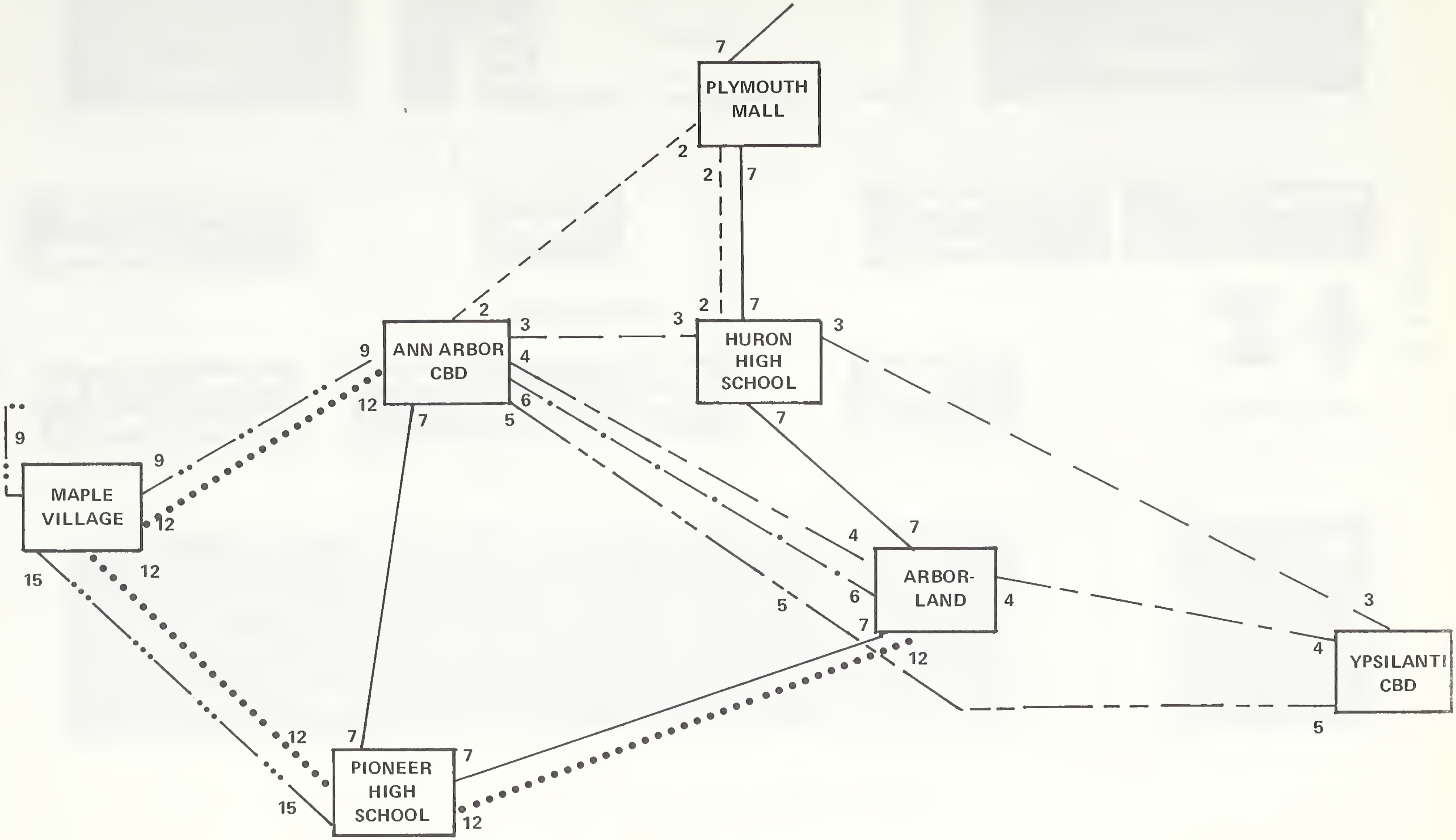
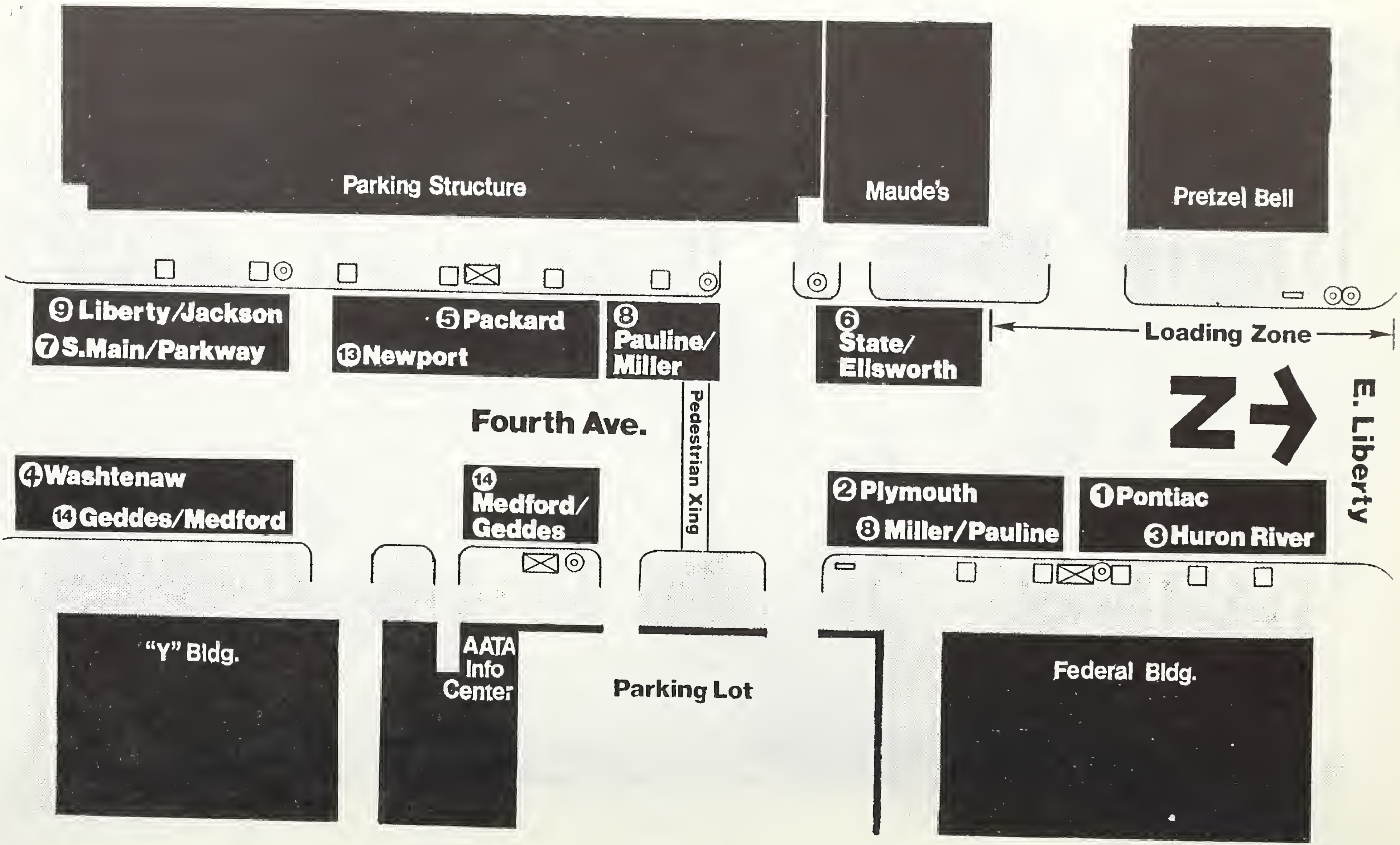


Exhibit 5.5

DOWNTOWN ANN ARBOR TRANSFER POINT



every 15 minutes at 0, 15, 30 and 45 minutes after the hour (Exhibit 5.3). From the CBD, a Route 7 bus travels down Main Street, picking up and discharging passengers. After a scheduled running time of seven minutes, it reaches Pioneer High School, the next timed transfer point. At Pioneer High School the Route 7 bus can interchange traffic with Route 15 at 7 and 37 minutes after the hour. Route 7 passengers can wait 8 minutes for transfers to Route 12 buses that arrive at 15 and 45 minutes after the hour, but transfers from Route 12 to Route 7 or Route 15 are not very convenient. The Route 7 bus then proceeds southwest and east toward Arborland, the next timed transfer point. The scheduled running time from Pioneer High School to Arborland is 23 minutes. At Arborland, the Route 7 bus can interchange traffic:

- At time: 00, with Rout e 4 (outbound and inbound), and Route 12;
- At time: 15, with Route 4 (outbound and inbound), and Route 6 (outbound and inbound);
- At time: 30, with Route 4 (outbound and inbound), and Route 12; and
- At time: 45, with Route 4 (outbound and inbound), and Route 6 (outbound and inbound).

Half of the Route 7 buses terminate at Arborland. On completing their timed transfers, they retrace their route back to the Ann Arbor CBD. The remaining buses, on leaving Arborland, proceed west to Huron Parkway and then north to Huron High School, the next timed transfer point. At Huron High School, passenger interchanges can occur with Route 3 (outbound and inbound) at 0 and 30 minutes after the hour. Transfers to and from Route 3 have a wait of from seven to 23 minutes. From Huron High School, the Route 7 bus continues north on Huron Parkway to Plymouth Mall, the last timed transfer point, which is reached at 8 and 38 minutes after the hour. Here, passengers can interchange with Route 2 (outbound and inbound). From Plymouth Mall, the Route 7 bus continues to the end of the line (Plymouth and Green). It returns to the Ann Arbor CBD over the same route, stopping at all timed transfer points along the way. The timed transfer points are located so that outbound and inbound buses meet at each timed transfer point except at Plymouth Mall. Two to seven minutes of slack time are built into the routes' schedules to facilitate these meets.

5.1.3.4 Summary

In designing workable schedules around the complex route structure, AATA compromised on bus route headways and on timed transfer meets. It was not practical to use the same headway for all AATA bus routes. Clearly, the more heavily used routes required more frequent service.

AATA retained a 15 minute module so that meets could occur between routes with different headways. Heavily used routes (2, 4, 5, and 7) operate on 15 minute headways during peak hours (see Exhibit 5.2). Other routes (1, 3, 6, 9, 12, and 15) have 30 minute headways. The loop routes and Ypsilanti locals (8A, 8B, 13A, 13B, 10, and 11) operate on 60 minute intervals.

The loops (8, 13 and 14) operate in both directions (clockwise and counter-clockwise) so that the passenger who is willing to accept a longer ride from indirect routing can receive bus service more frequently. Because of the differences in bus headways, all possible transfers cannot be made at each timed transfer point for each meet. The result is a timed transfer system that does not meet a theoretical ideal, but does provide excellent service for a large number of trips.

5.1.4 Ridership Impacts

5.1.4.1 Impact on Transit Users

The changes that AATA inaugurated on October 1, 1979 drastically altered passenger services. Although geographic coverage remained essentially the same, door to door Dial-A-Ride service was eliminated for all but the elderly and handicapped and for late night service. Other bus passengers had to walk to and from bus stops and adjust to a fixed route and scheduled bus service.

AATA retained the basic structure of the six fixed bus routes but even these routes were adjusted to complement the eleven new routes. Despite an effective marketing program and generous distribution of new route maps and schedules, most AATA passengers were likely confused when the new services began. To ease the transition, AATA offered free fares for the first week. The following week, AATA increased fares from a base fare of \$.35 to a base fare of \$.50.[1]

5.1.4.2 Impact on AATA Patronage

In April of 1976, the Ann Arbor fixed-route system carried an average of 5,800 passengers and Dial-a-Ride carried an average of 2,500 passengers per weekday. Transfers were coordinated to occur between fixed-route buses, Dial-a-Ride vans or between the two modes. Of the fixed-route riders, almost one-third transferred at least once and four percent transferred at least twice. Of all the trips that began on Dial-a-Ride 88 percent involved at least one transfer and 12 percent

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[1] Regular passengers could retain the \$.35 fare by purchasing 20 tokens for \$7.00. The use of tokens became popular.

required two or more transfers.[2] This resulted in an overall weekday volume of almost 6,200 linked passenger trips.

ANN ARBOR RIDERSHIP

(Before: 4/1976)

5,800 Unlinked Fixed-Route (FR) Trips x Transfer Rate* of (3,944 direct trips + [812 (@ 2 link trips) + 77 (@ 3 link trips)]) = 4,833 FR Passenger Trips

2,500 Unlinked DAR Trips x Transfer Rate* of (300 direct trips + [950 (@ 2 link trips) + 100 (@ 3 link trips)]) = 1,350 DAR Passenger Trips

FR Passenger Trips + DAR Passenger Trips = 6,183 Total Passenger Trips

* Based on Newman, et al., Integrated DAR and FR Transit in Ann Arbor, MI, in 1976, 32% of all fixed-route bus trips involved at least one transfer and 4% required 2 or more transfers; 88% of all trips that began on Dial-a-Ride involved at least one transfer and 12% of DAR trips required 2 or more transfers.

In October of 1979, the AATA curtailed TelTran Dial-a-Ride services and expanded fixed-route services. During the first week of the new service, the AATA offered free fares to all riders and patronage increased significantly to an estimated 49,700 riders. By comparison, a year earlier in October 1978, weekly ridership averaged 37,000. Soon thereafter, ridership dropped to a slightly lower level than it had carried previously. Most of this decline is attributed to the increase in passenger fares from $.35 to $.50.

By April of 1981, the effects of the change in services and the increase in fares had stabilized. As calculated in the formula below, unlinked weekday ridership averaged 10,000 trips on fixed-route services and 300 trips on Dial-a-Ride. Dial-a-Ride was then providing supplemental night and weekend service; Dial-a-Ride services for the elderly and handicapped are not included in these data. According to survey results conducted by the AATA in April 1981, over one-third of all fixed-route bus trips required transfers, although very few required more than one transfer, for a fixed-route weekday trip rate of about 8,200 passengers. The AATA estimates 200 Dial-a-Ride weekday trips occurred, for an overall weekday volume of almost 8,400 passenger trips.

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[2] Neumann et al. Integrated Dial-a-Ride and Fixed-Route Transit in Ann Arbor, Michigan March, 1977.

(After: 4/1981)

10,000 Unlinked Fixed-Route Trips x Transfer Rate** of (6,400 direct trips + [1,700 (@ 2 link trips) + 67 (@ 3 link trips)]) = 8,167 FR Passenger Trips

300 Unlinked DAR Trips x Transfer Rate** = 200 DAR Passenger Trips

FR Passenger Trips + DAR Passenger Trips = 8,367 Total Passenger Trips

** Based on the AATA On-board Rider Survey conducted in April of 1981, 36% of all fixed-route bus trips required at least one transfer and the AATA estimates very few fixed-route trips (about 2%) required 2 or more transfers. The AATA estimates 200 riders make 300 DAR trips per day in 1981.

This analysis indicates the AATA's ridership increased 26 percent between April of 1976 and April of 1981. One must be careful, however, in interpreting the change in patronage solely to improved timed transfer services. First, there are other reasons why transit ridership may have changed during this five-year period. For instance, the energy crisis in the late 1970's attracted some new riders to transit. Second, it is not clear that all DAR riders saw the change as an improvement and thus switched modes. For example, passengers who used DAR for short trips because door-to-door service was available, may not use fixed-route services because the trip now requires walking and waiting outside.

Another means of analyzing patronage, especially from the operator's perspective, is to determine whether the services are being used more productively. A common measure of productivity is the number of passengers carried per vehicle hour. The following calculations compare the number of linked trips per vehicle hour on fixed-route, Dial-a-Ride and total AATA services in 1976 and 1981.

Total Weekday Passenger Trips : Total Weekday Vehicle Hours**** = Passenger Trips Per Vehicle Hour

(Before: 3/1976)

4,833 Fixed Route Trips : 165 Fixed Route Hours = 29.3 FR Trips/Hour

1,350 DAR Trips : 414 DAR Hours = 3.3 DAR Trips/Hour

6,183 Total Trips : 579 Total Hours = 10.7 Total Trips/Hours

+++

(After: 2/1981)

8,167 Fixed Route trips : 420 Fixed Route Hours = 19.4 FR Trips/Hour

200 DAR Trips : 150 DAR Hours = 1.3 DAR Trips/Hour

8,367 Total Trips : 570 Total Hours = 14.7 Total Trips/Hour

===

Total Weekday Passenger Trips: +26% Total Hours of Service: -2% Total Trips per Hour: +27%

**** Includes deadheading time, which is estimated to account for about 10% of total vehicle hours.

In 1976, the AATA operated almost 600 hours of transit per weekday, of which 72 percent were for DAR services. Productivity on DAR averaged 33 passenger trips per hour. Productivity on fixed-route services averaged almost 30 passenger trips per hour for an overall system productivity average of 11 trips per hour.

In 1981, the AATA operated almost the same number of hours of transit per weekday, although fixed-route services now accounted for 74 percent of the system. Dial-a-Ride productivity dropped to 1.3 passenger trips per hour and fixed-route productivity declined to about 20 passenger trips per hour. Overall system productivity increased to almost 15 trips per hour, a 27% improvement from 1976.

5.1.4.3 Impact on Passenger Activity

Timed transfer passenger activity data were collected in February 1981 to understand how and where transfer activity occurred. Data included passengers boarding and disembarking from buses at six of the seven timed transfer points. Exhibit I in Appendix C shows the mean numbers of passengers leaving and boarding each bus for all routes serving the timed transfer points. Separate entries are given for the morning and evening peaks and for the mid-day period.

Activity is heaviest at the Ann Arbor CBD. There is also considerable activity at Arborland and at the Ypsilanti CBD. Activity at the other timed transfer points is sporatic. Analysis of these data suggests some of the directional flow. For example, during the morning peak, ridership on Route 4 is heaviest inbound toward the Ann Arbor CBD, but only a small fraction of the bus passengers ride all the way to the CBD. Passenger activity on Route 8A is heavier inbound during the morning peak and outbound during the afternoon peak. Passenger activity at Arborland is heaviest during the mid-day and evening periods.

On board passenger counts were also made for all buses departing from each timed transfer point. Mean counts for all routes are also listed in Exhibit I in Appendix C. These counts can be compared with the number of boarding passengers to estimate the number of passengers who remain on-board the vehicle at the Ann Arbor CBD to take advantage of the bus route pairings. These data suggest that there are significant carryovers on Routes 1, 3 and 7.

5.1.5 Relative Speed and Quality of Service

5.1.5.1 Impact on Bus Speed

The timed transfer meet requirements influence bus speed over different segments of its route. In some cases, buses need to travel more quickly to meet timed connections and in other cases, a slower speed may suffice. This varies with the number of transfer point meets and the amount of slack built into the route's schedule.

Using Route 7 as an example, the meet requirements dictate the following speeds for different route segments:

Between	Scheduled Running Time (minutes)		Distance (miles)	Mean Speed (mph)	
	Out	In		Out	In
Ann Arbor CBD & Pioneer High School	7	8	1.32	11.3	9.9
Pioneer High School & Arborland	23	22	5.95	15.5	16.2
Arborland & Huron High School	15	15	2.49	10.0	10.0
Huron High School & Plymouth Mall	8	6	1.68	12.6	16.8
Plymouth Mall to Plymouth & Green & return	16		3.93	14.7	

The low speed near the Ann Arbor CBD is dictated in part by traffic conditions. The low speed between Arborland and Huron High School is due primarily to timed transfer schedule requirements. Although there are many influences on mean bus speed (e.g. the number of bus stops, the number of passenger boardings and disembarkings, street conditions, accident rates, congestion, etc.), Ann Arbor provides some evidence that a route's average bus speed decreases as the number of timed transfer points to be served increases (Exhibit 5.2).

5.1.5.2 Alternative Travel Speeds

The utility of the AATA timed transfer service was explored for a set of sample trips that represent travel in the Ann Arbor area. Three or four travel alternatives were examined for each sample trip: (1) automobile; (2) walking for short trips; (3) present AATA timed transfer bus service; and (4) AATA Teltran bus service that existed prior to October 1, 1979. Thirteen sample trips were selected. Trip times, as calculated for each trip and each mode, are listed in Exhibit I in Appendix D. A detailed explanation of this sample trip definition process is contained in Section 1.2.4.

As expected, the automobile is always the fastest mode of transportation. Direct distances are short, parking is readily available at most destinations, and traffic is uncongested except around the Ann Arbor CBD and the main campus of the University of Michigan.

Walking is the slowest mode. In some cases, timed transfer bus travel is direct and reasonably competitive with automobile travel; in other cases it is indirect and therefore slow in comparison with automobile travel. In practically all cases, timed transfer service is comparable or faster than DAR service.

5.1.5.3 Transfers Required

Of the 13 sample timed transfer trips, only five required transfers (38.5 percent), and all occurred at timed transfer points. Three took place at the Ann Arbor CBD and the other two took place at Pioneer High School and at the Ypsilanti CBD. Relatively few transfers were needed because the Ann Arbor CBD and the University of Michigan, within walking distance from the Ann Arbor CBD, were four of the sample destinations. Passengers making four other trips could have transferred, but in each instance, a slightly longer walk was faster than a transfer. No paired route transfers occurred.

In comparison, nine of the same 13 sample trips (69 percent) would have required transfers on the previous DAR system. DAR vehicles provided service within particular areas so that the physical transferring of passengers between zones was often necessary. The DAR system also relied on transfers to and from the fixed-route services, especially for longer trips.

This evidence indicates the timed transfer fixed-route service requires almost one-third fewer transfers than the previous DAR service in Ann Arbor.

5.1.5.4 Convenience of Service

Comparing alternative mode trip times tells only part of the story because it does not consider the convenience of the bus schedule. Bus passengers traveling to work or to fixed time appointments may need to arrive early because no available bus service conforms to their schedules. Other bus passengers with fixed starting times may need to wait at the first bus stop for service. Elapsed transit time, the sum of trip time, walking time and waiting (or early arrival) time can be compared with elapsed total automobile travel time, in terms of a ratio. The relative quality of DAR and timed transfer services can then be compared from this ratio.

The minimum bus/automobile elapsed time ratio for timed transfer service is 2.1. The 1979 Dial-a-ride would have served one sample trip with an elapsed time ratio of 1.5, and one with a ratio of 1.6, because there was little or no waiting or walking time required with this door-to-door service. The cumulative distributions of elapsed time ratios for 1979 DAR and timed transfer bus services are shown in Exhibit 5.6. Overall, timed transfer service (mean elapsed time ratio = 3.06) is slightly better than the 1979 Dial-A-Ride service (mean elapsed time ratio = 3.18).

5.1.6 Bus Performance

5.1.6.1 Driver's Responsibility

For timed transfer to work, drivers must know what is expected of them and they must be motivated to give the desired performance. It is also essential that the schedules be realistic. Standard performance instructions to AATA bus drivers are summarized in Exhibit 5.7. Drivers were reprimanded by the dispatchers and supervisors for leaving timed transfer points ahead of time. Departures between the scheduled time and two minutes late are considered to be on time. Departures as late as eight minutes can be tolerated because drivers can generally make up this amount of time in one round trip.

5.1.6.2 Individual Route Performance - Downtown

Exhibit 5.8 compares the schedule performance for all of the bus routes that serve the Ann Arbor CBD with their actual performance. The vertical bars mark the frequency of arrival at different times before and after the schedule time. The light shaded bars are arrivals and the dark shaded bars are departures. The solid vertical line marks the mean arrival times and the dashed vertical line marks the mean departure times for each bus route.

Almost all arrivals occur before schedule time and all departures occur at or after schedule time. The performance of individual bus routes varies. Route 12 has the narrowest performance range with the earliest arrival five minutes before scheduled time and the latest departure five minutes after scheduled time. Performance on Route 2 is almost as good. With the exception of a few early arrivals, Routes 1, 5, 6, 7, 8, and 9 also have good performance. Routes 3 and 4 have some late arrivals and corresponding late departures. Routes 13 and 14 seem to have the greatest difficulty keeping schedule. Large numbers of buses arrive on schedule and leave three to six minutes late. Mean arrival time for Route 13 is one-half minute late.

On the whole, variations in individual route performance are small. Ninety percent of each route's buses arrive between schedule time and five minutes early while ninety percent depart between schedule time and

Exhibit 5.6

CUMULATIVE DISTRIBUTION BUS/AUTOMOBILE ELAPSED TIMES (ANN ARBOR)

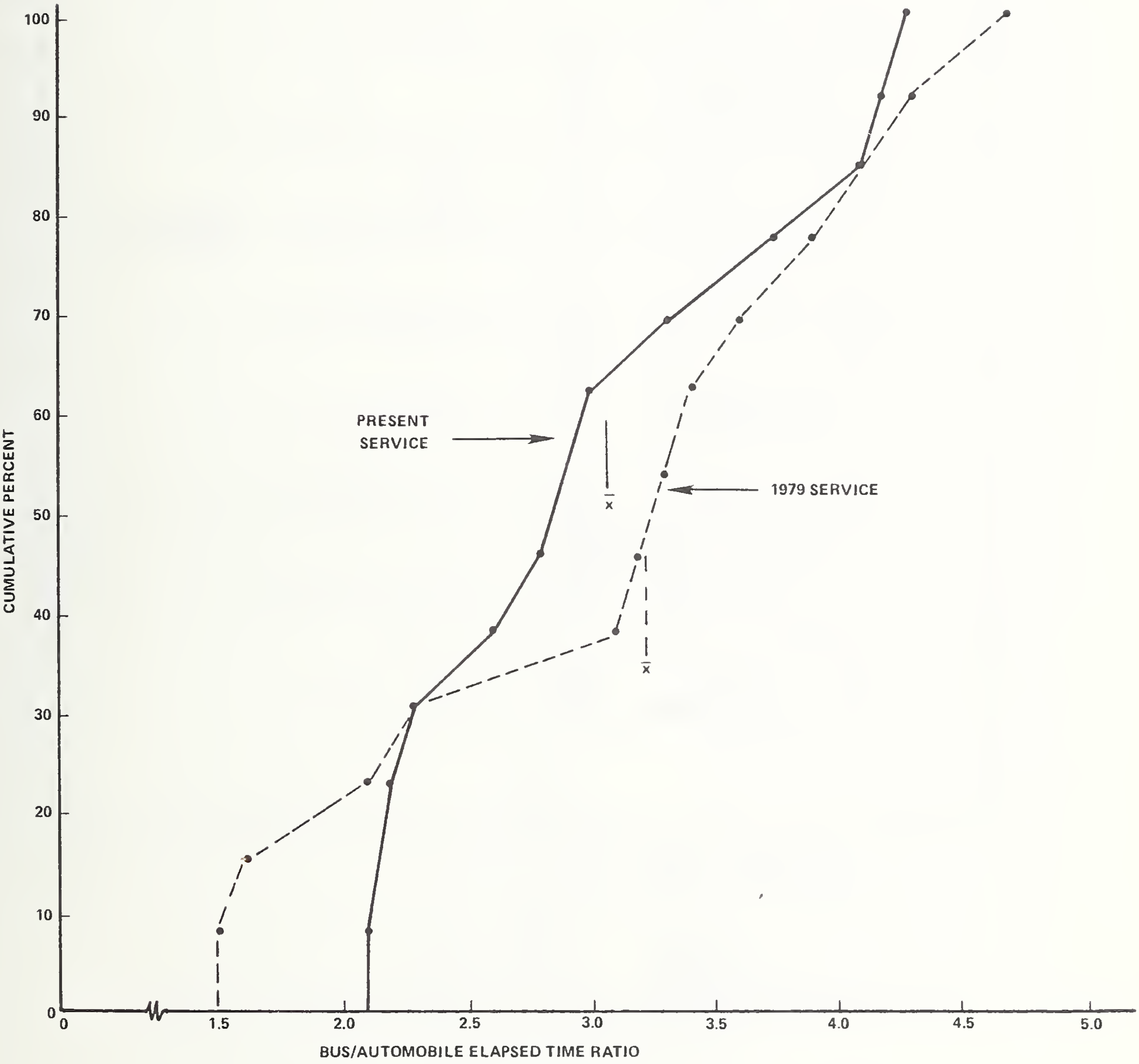


Exhibit 5.7

BUS PERFORMANCE INSTRUCTIONS (ANN ARBOR)

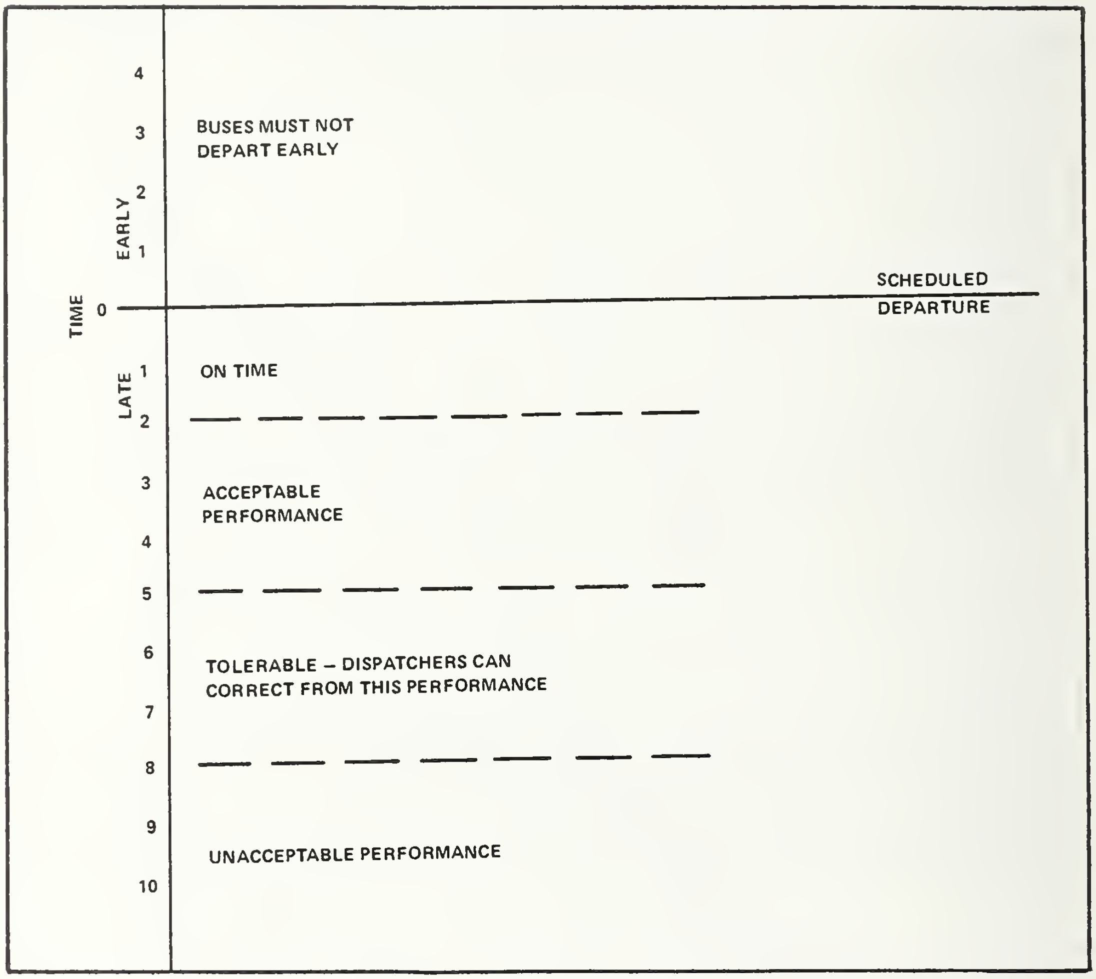
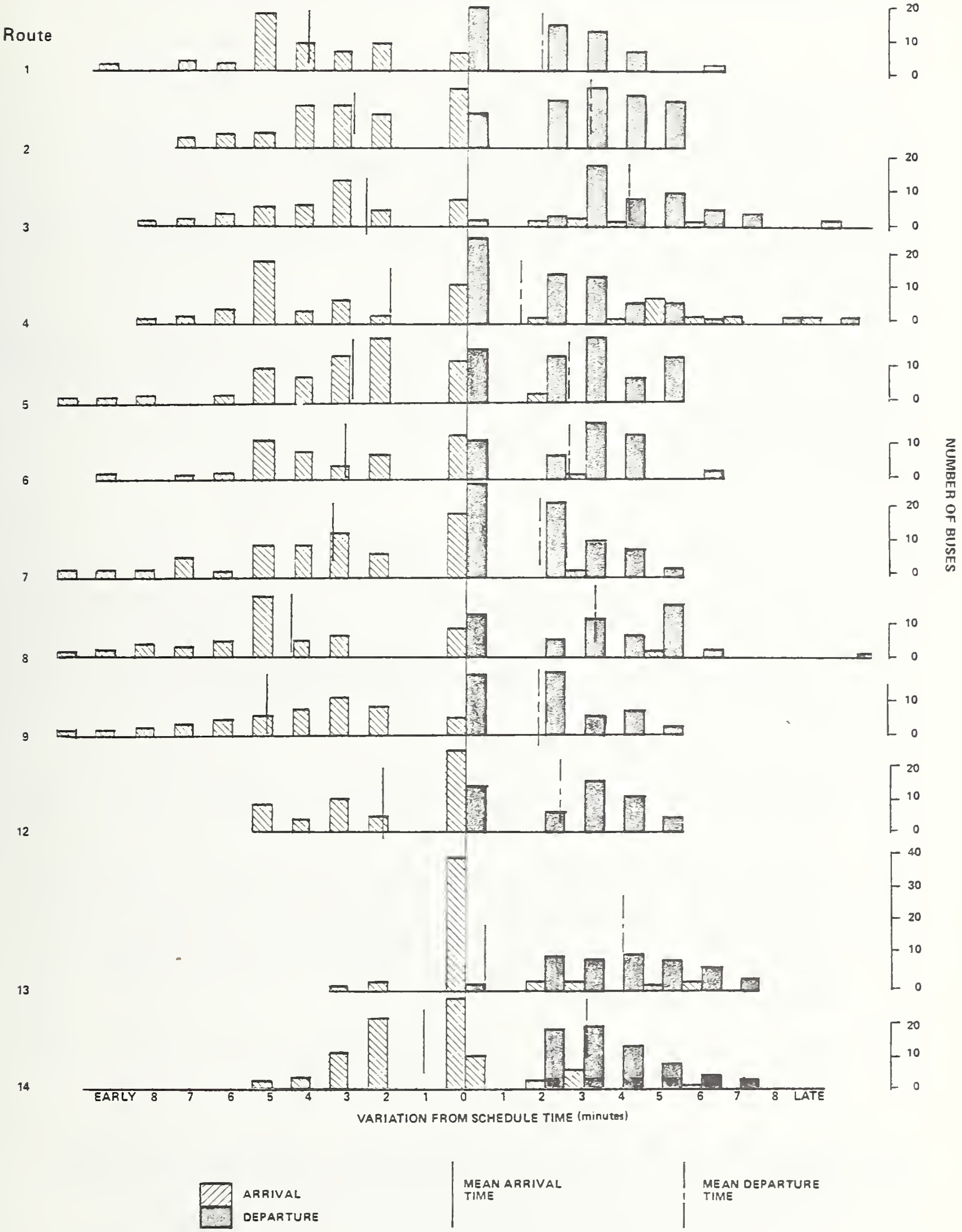


Exhibit 5.8

BUS SCHEDULE PERFORMANCE BY ROUTE (ANN ARBOR CBD)



four minutes late. The predominant number of transfers occur within a nine minute span.

5.1.6.3 Overall Schedule Performance - Downtown

Exhibit 5.9 illustrates the overall distribution of scheduled and actual bus arrival and departure times at the Ann Arbor CBD. The largest number of buses arrived within one minute of the scheduled time. Most others arrived early; few were late. No buses departed prior to the scheduled time and almost all buses departed within three minutes after the scheduled time.

Exhibit 5.9 also shows a cumulative distribution of all layover times. Most fall in the range between three and six minutes. Only four percent are one minute, and none exceed twelve minutes. Short layover times limit the delays imposed on through passengers and improve the quality of bus service, but short layovers require good schedule performance by all buses.

5.1.6.4 Performance at Other Transfer Points

Performance at other timed transfer points is not as consistent as that at the Ann Arbor CBD. Nonetheless, it is good. Exhibit I in Appendix E lists mean schedule performance for all bus routes at the six timed transfer points for which data were collected.[3] Mean actual arrival times preceed scheduled times for all routes except the following:

- Route 4X at Arborland -- these express buses lagged throughout their schedule because of large loads and rush hour traffic. Ten minute layovers at Ypsilanti provided the needed catch up time.

- Route 9 at Maple Village -- the ten minutes allowed to clear the Ann Arbor CBD and travel 2.2 miles to Maple Village are apparently insufficient, particularly if buses depart after scheduled time. Buses leaving the Ann Arbor CBD 1.98 minutes late would need to average 16.5 mph to reach Maple Village on time -- this is apparently infeasible.

- Routes 4 and 5 reach the Ypsilanti CBD a fraction of a minute late -- this does not appear to be a problem.

All departures are after schedule time except departures from Pioneer High School, which are early. Perhaps an adjustment is needed here.

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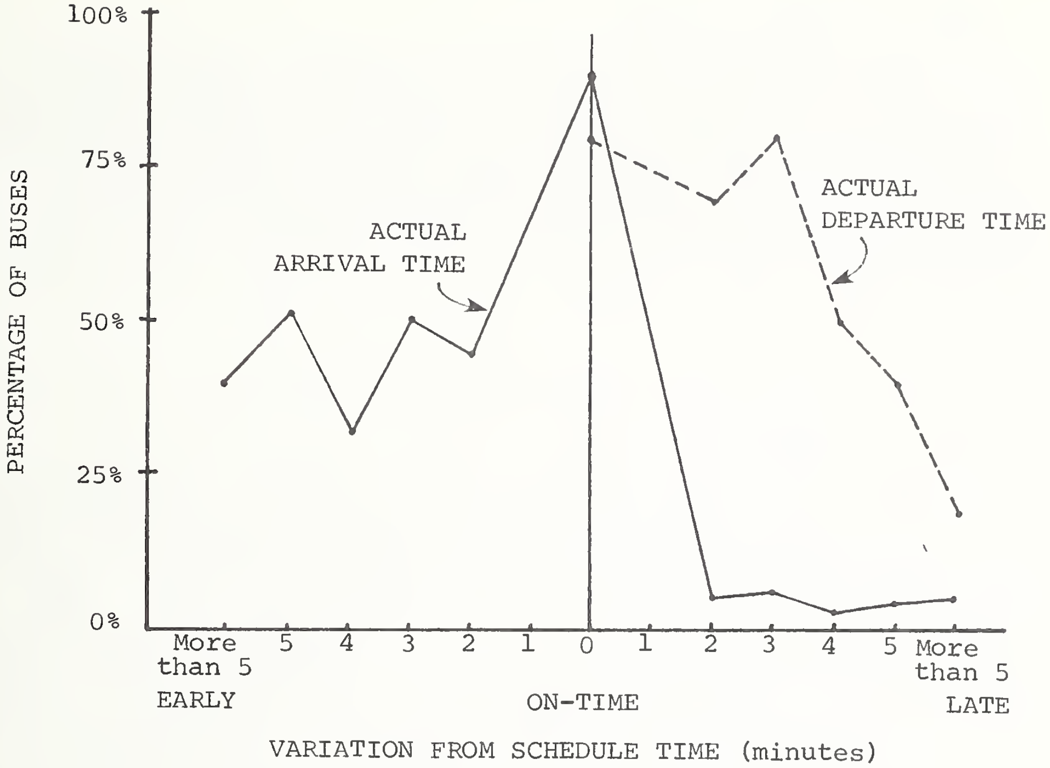
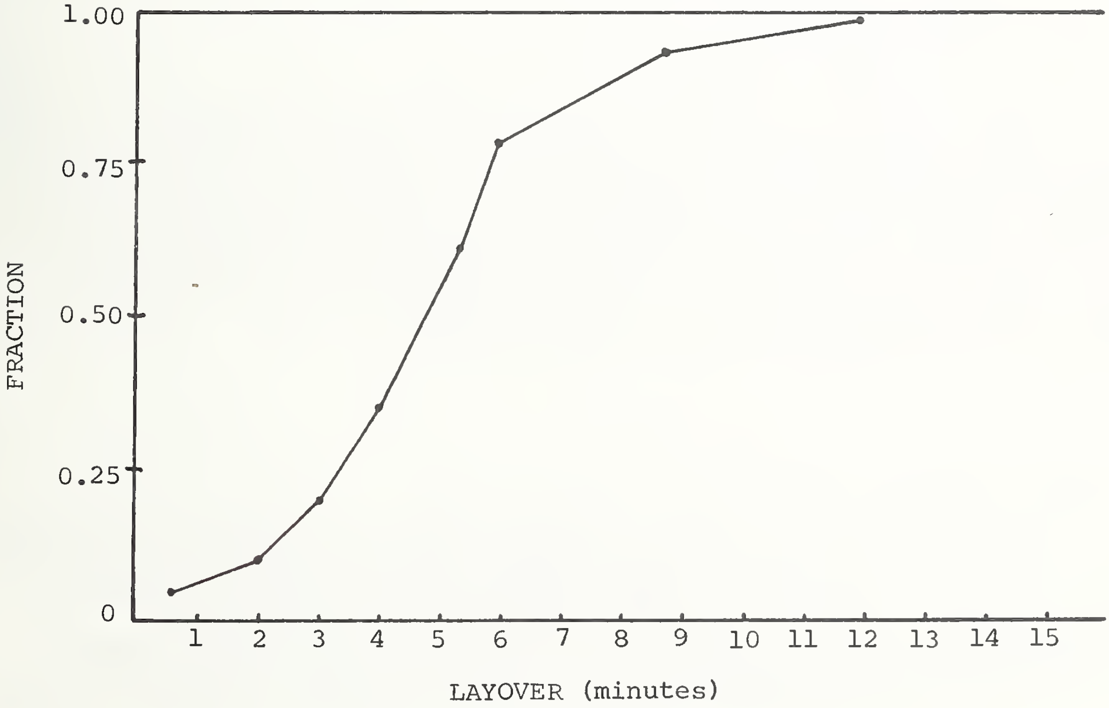
[3] No data were collected at Plymouth Mall.

Exhibit 5.9

BUS SCHEDULE PERFORMANCE (ANN ARBOR CBD)



CUMULATIVE DISTRIBUTION OF LAYOVER TIMES (ANN ARBOR CBD)



5.1.6.5 Missed Transfers

The final performance test for Ann Arbor's timed transfer system concerns the consistency with which passenger transfers are made. During on-site observations, only about five percent of all passengers failed to make their transfers at the timed transfer points. Practically all of the misses occurred during the peak periods, when services are more frequent and stranded passengers have shorter waits. No particular routes or points had a greater number of missed connections.

5.1.6.6 Summary

Individual timed transfers are not completely synchronized but bus performance is good. Buses arrive individually at or before the scheduled times; they discharge their passengers and board originating passengers and passengers transferring from other buses. When all buses that are participating in the timed transfer have arrived and transfers are complete, the buses leave -- not all together, but over a span of two or three minutes. For example, all 13 buses arrived at least one minute early for the 7:15 transfer that occurred at the Ann Arbor CBD on April 7. Transfers were completed so that six buses departed at the scheduled time. Five more left during the next minute and two left individually two and four minutes after the scheduled time. Similar performance was recorded at other times of the day and at other timed transfer points.

5.1.7 Impacts on Costs

5.1.7.1 Site-Specific Factors

Cost reduction was a major incentive for changing the AATA system from a Dial-A-Ride service to a primarily fixed-route, timed transfer system. AATA estimated that because of low vehicle productivity and high operating costs, Dial-A-Ride trips cost almost ten dollars more than the revenue received. In order to further improve the economic position of the system the AATA also implemented a fare increase with the introduction of fixed-route timed transfer services. These changes strongly affected AATA's costs and productivity.

5.1.7.2 Capital Costs

Capital and start-up costs for timed transfer services in Ann Arbor were minimal. Hardly any changes needed to be made to the existing Dial-a-Ride transfer points to be used for fixed-route timed transferring. Most of the Dial-a-Ride vans were replaced by regular size buses, but as the new buses were financed entirely through federal and state subsidies, the local transit agency did not incur any new costs. The two-way radios used in the Dial-a-Ride vans were also transferred to the buses operating on timed transfer routes. The initial training and supervision costs were not fully due to timed transfer services, because most drivers had to be instructed in regular fixed-route services as opposed to demand-responsive services.

5.1.7.3 Operating Statistics

The change to fixed-route, timed transfer service was advantageous in terms of many operating and cost parameters. Exhibit 5.10 lists various operating statistics for both the Dial-a-Ride and fixed-route services in 1979 and 1980.

Annual system costs declined by about 13% while farebox revenues increased about 23% from 1979 to 1980. This improved the total cost to revenue ratio from nine to thirteen percent. Most of the increase in revenue is due to the increase in fares in 1979. Most of this decrease in costs can be explained by the decline in annual revenue bus hours, reflecting the change from more time-consuming demand-responsive services. Associated with this were reductions in personnel costs, as the number of drivers shrank from 131 to 104, and the number of dispatchers decreased from 5 to 2. The total number of revenue bus miles remained almost unchanged, since the reduction in Dial-a-Ride bus miles was balanced by increased fixed-route services. Although the total number of unlinked passenger trips decreased, total average passenger trips per weekday actually increased, reflecting the higher rate of transferring in the earlier system.

The statistics derived from these annual totals reflect the same developments. In terms of passengers, productivity increased with the new services. Costs per bus hour and per bus mile changed in opposite directions, because costs per bus hour increased in spite of lower overall costs, due to the overproportionate decrease in bus hours. On balance, it appears that the change from the demand-responsive to the fixed-route, timed transfer system was economically beneficial. The results suggest that a timed transfer service can be a viable transition for a growing Dial-a-Ride service in a medium-density community.

5.1.8 Conclusion

Ann Arbor Transit Authority converted its Dial-A-Ride based transit service to a fixed-route timed transfer service in the Fall of 1979. Eighteen bus routes serve seven different timed transfer points to give convenient service for a wide variety of trips. As a result, AATA is carrying more riders than with the previous system.

In terms of the quality of service, the fixed-route timed transfer service is slightly faster, requires fewer transfers and has shorter

Exhibit 5.10

TRANSIT COST AND PERFORMANCE

(ANN ARBOR)

<table>
<tr><th rowspan="2">Statistics</th><th colspan="2">1979</th><th colspan="2">1980</th></tr>
<tr><th>Dial-a-Ride</th><th>Fixed-Route</th><th>Dial-a-Ride</th><th>Fixed-Route</th></tr>
<tr><td>Annual System Cost</td><td colspan="2">$7,397,774</td><td colspan="2">$6,428,092</td></tr>
<tr><td>Annual Farebox Revenue</td><td colspan="2">$644,000</td><td colspan="2">$834,000</td></tr>
<tr><td>Revenue/Cost Ratio</td><td colspan="2">8.7%</td><td colspan="2">13.0%</td></tr>
<tr><td>Unlinked Passenger Trips</td><td>707,616</td><td>2,240,784</td><td>204,080</td><td>2,288,656</td></tr>
<tr><td>Revenue Bus Hours</td><td>141,151</td><td>77,349</td><td>59,000</td><td>104,000</td></tr>
<tr><td>Revenue Bus Miles</td><td>1,306,110</td><td>903,890</td><td>813,000</td><td>1,497,000</td></tr>
<tr><td>Passengers per Bus Hour</td><td colspan="2">13.5</td><td colspan="2">15.3</td></tr>
<tr><td>Passengers per Bus Mile</td><td colspan="2">1.3</td><td colspan="2">1.1</td></tr>
<tr><td>Costs per Bus Hour</td><td colspan="2">$33.86</td><td colspan="2">$39.44</td></tr>
<tr><td>Costs per Bus Mile</td><td colspan="2">$3.35</td><td colspan="2">$2.78</td></tr>
<tr><td>Costs per Passenger Trip</td><td colspan="2">$2.51</td><td colspan="2">$2.58</td></tr>
</table>

average travel times than the Dial-a-Ride service that it replaced. The timed transfer system also operates well. Buses are generally on time with the help of dispatchers and meets are made as scheduled at timed transfer points; few timed transfers are missed. The cost of fixed-route timed transfer is also considerably lower than the cost of the Dial-A-Ride service, and more revenues are being collected.

5.2 BOULDER, COLORADO

5.2.1 Site Description

Boulder, Colorado, a city of 83,000 inhabitants, is situated 15 miles northwest of Denver and is part of the Denver Metropolitan Area (DMA). Between 1960 and 1978 the population of the DMA grew at a rate of almost 2.5 times the national average, with most of this growth occurring in the suburban areas. Single family housing is dominant, although in recent years the number of multiple dwelling units increased substantially.

Boulder is the home of the University of Colorado, which with 20,000 students, has a marked influence on the character of the community. The labor force of 41,600 is concentrated in University, government, research, computer and high technology firms. In recent years, employment in technology and service industries has outpaced population growth, especially in the northeast and east sections of Boulder. Boulder's median income was $14,500 in 1970, which was significantly higher than the national average.

Eleven percent of Boulder County's population commutes to the outlying suburban areas and to downtown Denver, with most of these commuters relying on private automobiles for transportation. In fact, the DMA has one of the highest rates of automobile ownership in the United States. Only 6 percent of all households outside the central city do not own automobiles.

5.2.2 System History

In the early 1960's, Boulder developed a three route radial pulse public transit system. Timed meets occurred downtown every 30 minutes. As Boulder grew, this system expanded to five radial routes. All routes were scheduled to meet at three transfer points: (1) 14th and Walnut (downtown); (2) Table Mesa and Broadway; and (3) Mohawk and Baseline. Seventeen buses provided peak period service and 10 buses provided off-peak service. In this small system, the drivers typically knew their passengers' travel patterns and most timed transfers were completed.

In 1976, the Denver Regional Transportation District (RTD) began operating the Boulder system. Ridership continued to increase and in 1978 the system expanded to nine local routes, with 28 buses operating during the peak periods and 10 buses during the off-peak. RTD added a fourth timed transfer point at 28th and Glenwood and all routes, except one, operated on 30-minute headways during the off-peak. Drivers were notified of their scheduled "meet" buses at each transfer point, and most drivers tried to coordinate passenger transfers.

RTD also provided regional transit service to Boulder. Six routes connected Boulder with Denver, Longmont and Louisville. Boulder's transit center for intercity bus routes was located at 9th and Canyon, about 5 blocks from the downtown local route transit center at 14th and Walnut, making transfers between regional and local routes inconvenient physically.

Since 1978, Boulder's local transit system has evolved into a more conventionally scheduled and routed grid system. Ten local routes now follow a "modified grid" pattern. At outlying transfer points, some transfer connections are still coordinated between routes, although most connections encourage transfers in only one direction.

The change was due primarily to a shifting of scheduling objectives and responsibility from Boulder to Denver. The Denver RTD scheduling department now develops Boulder routes and schedules and scheduling decisions are based on individual route criteria and efficiencies. RTD-Denver is seeking improved service without introducing the time loss that is usually a part of timed transfers.

5.2.3 Timed Transfer System

5.2.3.1 Route Structure

Boulder's timed transfer system concentrated on the developed central and southern sections of Boulder with some routes extending into the northeastern and eastern sections, in response to residential and industrial growth (see Exhibit 5.11). The characteristics of the nine bus routes that provided timed transfer service in Boulder are listed in Exhibit 5.12. In this system, none of the routes were paired.

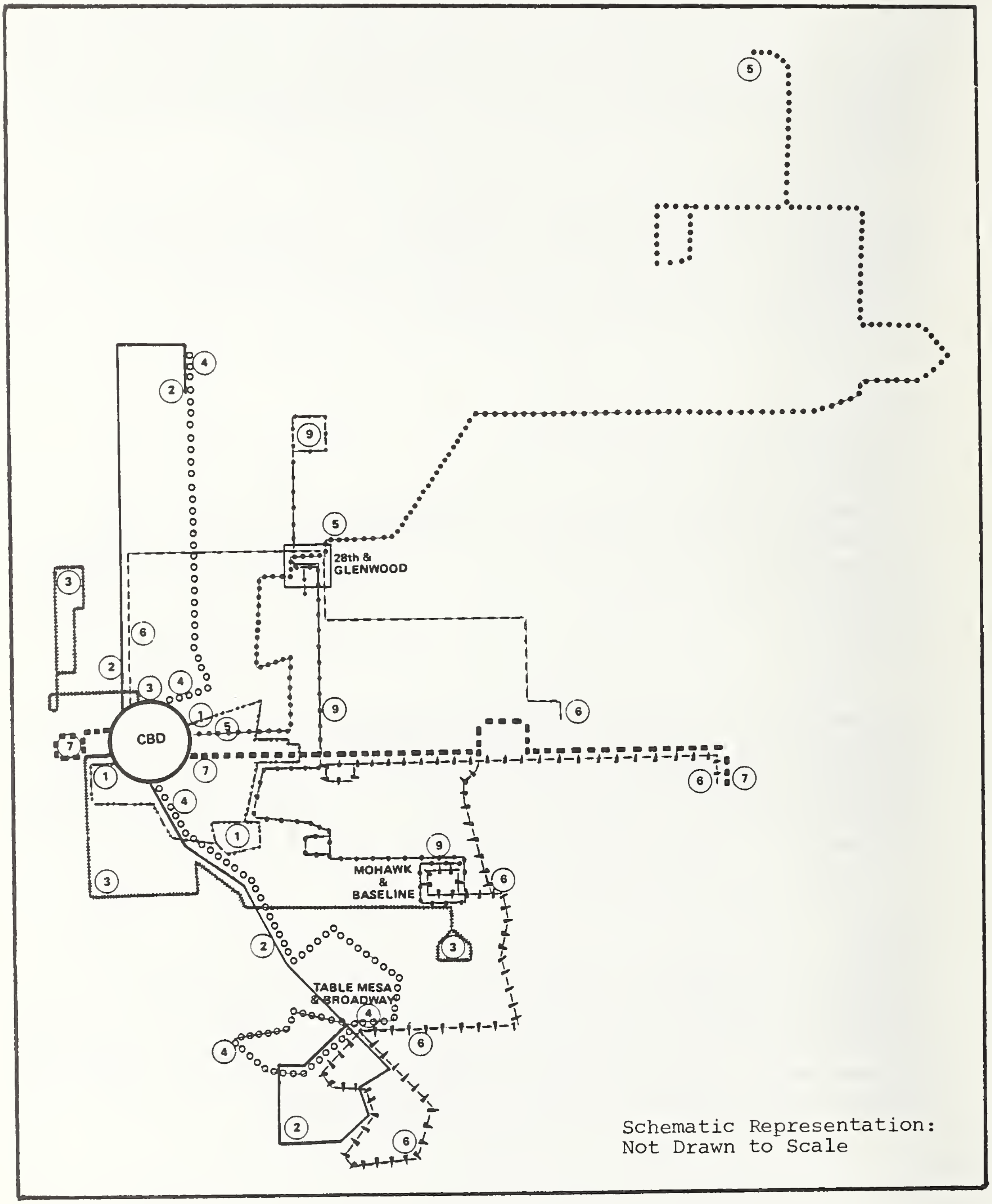
Seven routes served downtown Boulder and the other two routes provided crosstown service. Route 6, the Manhattan Crosstown, connected major outlying educational, industrial and commercial centers through the Mohawk and Baseline and Table Mesa and Broadway transfer points. Route 9, the 30th Crosstown, ran north-south linking residential areas with the University, a variety of commercial and shopping centers and the 28th and Glenwood and the Mohawk and Baseline transfer points.

Seven routes each served two timed transfer points. Two routes (Route 6 and Route 9) provided service between two outlying transfer points. The remaining five routes each served one outlying transfer point and the downtown transfer point. The most common pattern for these routes was to provide local circulation services before meeting to exchange passengers at the first transfer point. Direct service was then provided to downtown or to the other transfer points. Some routes terminated at their second transfer point while other routes continued through to provide more local circulation services.

Exhibit 5.11

BOULDER BUS ROUTE MAP

1978



Schematic Representation:
Not Drawn to Scale

Exhibit 5.12

BOULDER BUS ROUTE CHARACTERISTICS

(Timed Transfer — 1978)

Route No.	Name	Headway		Round Trip			Patronage		
		Peak (min)	Off Peak (min)	Distance (miles)	Time (min)	Avg Speed (mph)	Daily	Per Trip	Per Hour
1	Free B	No Service	20	5.39	40	8.1	546	14.4	21.6
2	Yarmouth-Table Mesa	15	30	16.24	75	13.0	3,038	64.6	51.7
3	Baseline-4th	15	30	15.98	75	12.8	1,396	29.1	23.3
4	Yarmouth-Table Mesa	15	30	17.38	75	13.9	2,551	55.5	44.4
5	Canyon-Gunbarrel	30	30	30.25	90	20.2	770	27.5	18.3
6	Manhattan Crosstown	30	30	13.75	60	13.8	798	26.6	26.6
7	Vo-Tech-Justice Center	15	30	12.01	60	12.0	923	20.5	20.5
8	Iris-Valmont	30	30	12.26	60	12.3	701	28.0	28.0
9	30th Crosstown	30	30	13.58	60	13.6	920	27.9	27.9

5.2.3.2 Points, Routes and Schedules

Boulder developed schedules for local route timed transfers at four locations in 1978. Exhibit 5.13 shows the scheduled arrival and departure times for the routes serving the major timed transfer locations between 7 AM and 8 AM. At 14th and Walnut, due to the number of routes, the complexity of the route structure and the demand for service there were no uniform transfer times and different routes departed every few minutes. At 28th and Glenwood as well as other locations, usually at least three buses were scheduled to meet at the transfer points within zero to 5 minutes of each other. A closer examination of the schedules at these sites reveals meet patterns at:

- 28th and Glenwood: at :05,[4] :15, :30, :45 and :60 minutes past the hour (15-minute pulses);
- Table Mesa and Broadway: at :10, :20, :30, :40, :50 and :60 minutes past the hour (10-minute pulses);
- Mohawk and Baseline: at :10, :25, :40 and :55 minutes past the hour (15-minute pulses).

Scheduled meet times overlap from two to six minutes, with most meets having a four minute scheduled layover to exchange passengers. Detailed analysis of one transfer point can provide a better understanding of the overall system. The 28th and Glenwood transfer point offers a good example of the different routes' functions and the complexities of the Boulder system.

5.2.3.3 System Example

The map in Exhibit 5.11 shows all the timed transfer points and the route interactions discussed in this section. Routes 5, 8 and 9 stop at the 28th and Glenwood transfer point and had 30-minute headways during both the peak and off-peak periods. Route 5 provided local service every 30 minutes to the Glenwood (and 28th) Shopping Center and the northeastern Heatherwood residential area with a scheduled running time of 18-22 minutes. Running times varied by time of day, in response to traffic conditions and by the number of stops and passenger loads. At 28th and Glenwood, a Route 5 bus heading toward downtown could exchange passengers with a Route 9 Northbound bus at about 5 minutes after the hour during the peak periods or with Routes 8 and 9 on the half hour or hour, during the balance of the day. A Route 5 heading outbound could exchange passengers with Routes 8 and 9 in each direction at :15 and :45 after the hour.

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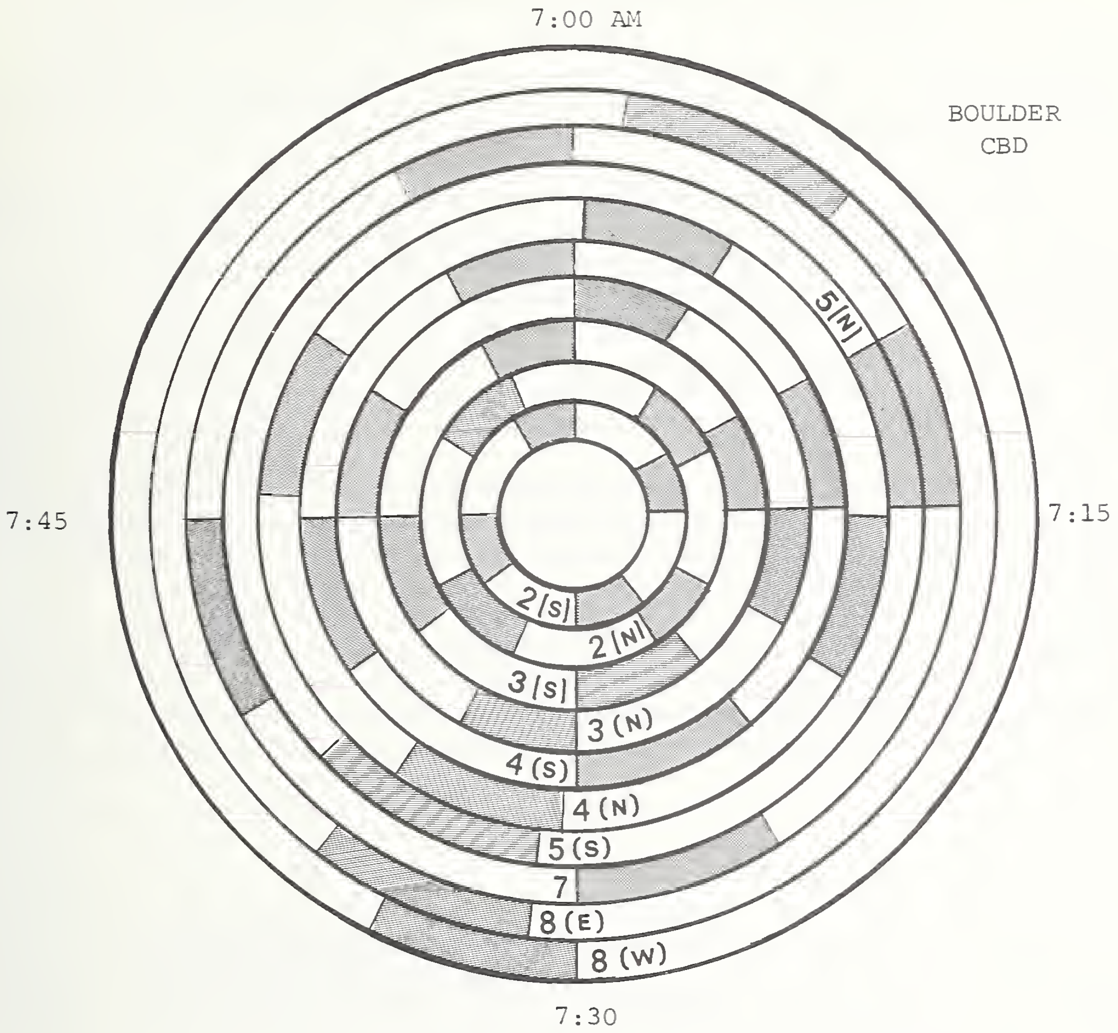
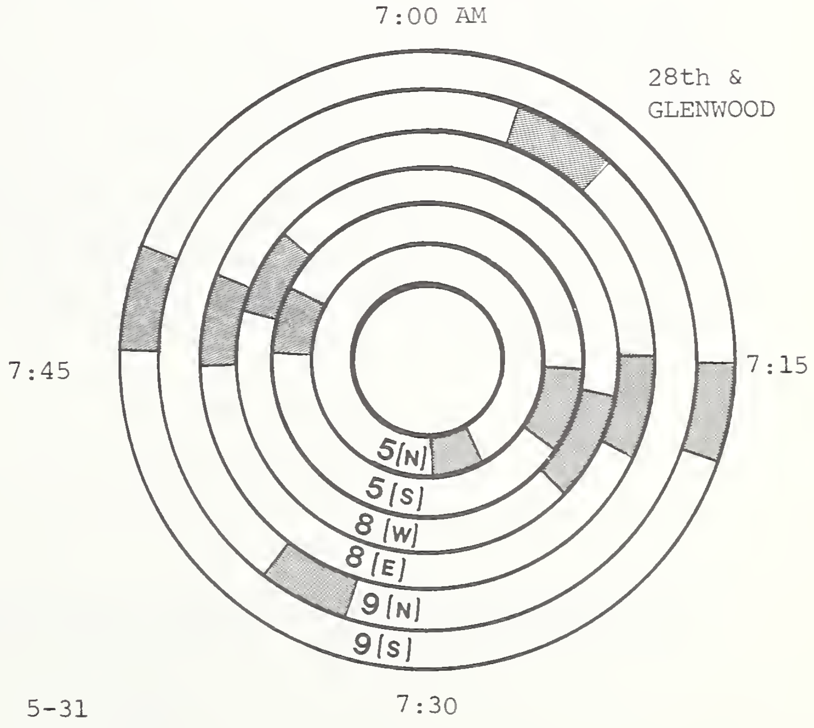
[4] One 10-minute pulse occurs at :05 during peak periods.

Exhibit 5.13

BOULDER TIMED TRANSFER SCHEDULES





LEGEND:

▨	Scheduled Timed Transfer Layover Time
4	Route Number
(N)	Northbound
(S)	Southbound
(E)	Eastbound
(W)	Westbound

Route 8 heading inbound originated in the east at 57th Street and Flatiron, at :19 and :49 after the hour. Travelling north, it reached the Scaggs Parking Lot[5] 9-12 minutes later. Route 9 heading south, originated at Palo Prado Park every 30 minutes, and travelled down 28th Street reaching "Scaggs" 9-10 minutes later.

From 28th and Glenwood, Routes 5 and 8 offered alternative services to downtown. Route 5 travelled south to 14th and Walnut in 14-18 minutes. Route 8 travelled west arriving downtown in only 11-12 minutes. Both Route 5 and Route 8 terminated downtown and their schedules were timed with Routes 3, 4 and 7 to facilitate commute travel from the northeastern sections of Boulder to central and southern destinations. Passengers traveling in the opposite direction could also transfer to Routes 5 or 8 at 14th and Walnut.

From 28th and Glenwood, Route 9 travelled south past Crossroads Shopping Center and the University before terminating at the Mohawk and Baseline transfer point, 19-21 minutes later. At Mohawk and Baseline passengers could transfer to either a Route 3 or 6 northbound or southbound at about :10 or :40 minutes after the hour during peak periods, or to Route 3 northbound or southbound at :25 or :55 after the hour during off peak periods. Although Route 9 maintained 30-minute service, its schedule shifted during the peak and off peak periods so that it could meet Route 5 at 28th and Glenwood in both directions.

5.2.3.4 Driver's Responsibility

In 1978 and 1979, when Boulder emphasized its timed transfer system, the local schedulers, supervisors and dispatchers understood the importance of maintaining reliable services. Drivers were given connecting route schedules and instructed to wait up to two minutes at each specified transfer location for their "meet" buses to arrive. Buses were equipped with two-way radios and drivers could wait up to 5 minutes beyond their scheduled departure times, if requested by another driver, dispatcher or supervisor, or if the bus was in sight. Departures more than 5 minutes late or 30 seconds early were considered unacceptable. However, the dispatcher could direct the driver to wait for transferring passengers, if a bus broke down, if it was the last run of the day, or if a severe snowstorm was underway. Exhibit 5.14 summarizes these earlier Boulder bus driver performance instructions. Although these performance rules still exist, drivers receive little instruction on maintaining scheduled meets, because timed transfers are not emphasized.

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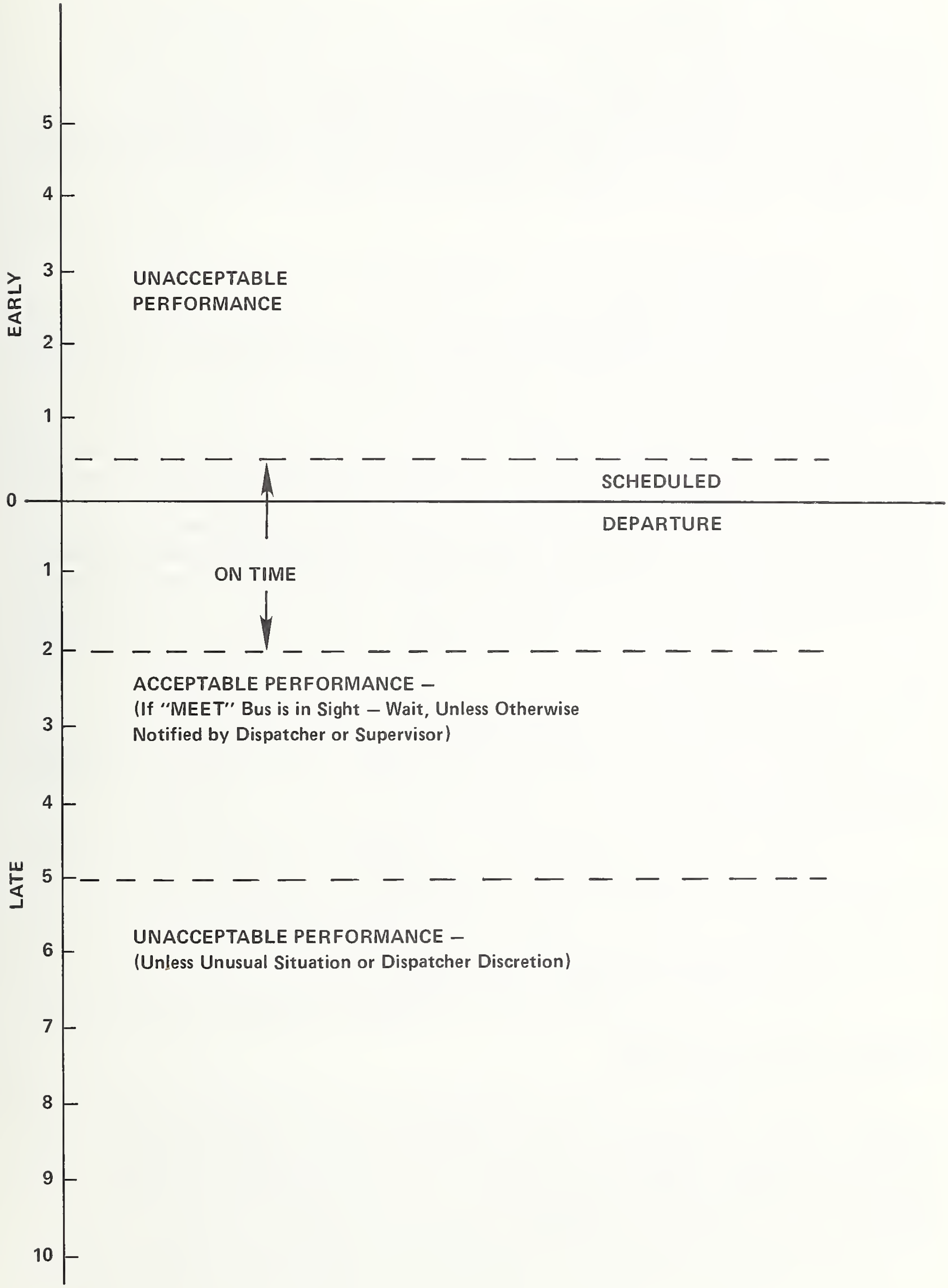
[5] The Scaggs Parking Lot is located on 28th and Glenwood. Later, in 1978, the timed transfers were moved onto Glenwood.

Exhibit 5.14

DRIVER PERFORMANCE INSTRUCTIONS (BOULDER)



5.2.4 Current System

5.2.4.1 Route Changes

Between 1978 and 1980 RTD did not implement any major routing changes in Boulder. In fact, the current route structure is very similar to the earlier timed transfer configuration. The only significant change was the pairing of two routes. Routes 2 and 4 now switch back and forth at their northern terminus, Broadway and Yarmouth. This helps to maintain schedule reliability and reduces the level of passengers transferring between these two routes.

5.2.4.2 Schedule Changes

Between 1978 and 1980 RTD made numerous minor changes to individual schedules with the objective of improving system efficiency. RTD adjusted running times to accommodate increases in ridership and actual travel time requirements. They alloted more running time to some routes (e.g. Route 5), while cutting back on others. They adjusted headways to reflect individual route demands. For example, peak period headways on Route 3 and Route 7 increased from 15 to 20 minutes, because of low ridership. In general, RTD allowed a maximum of 10 minutes of recovery time in each route's schedule. As a result of these changes, by 1980 only limited and primarily one-directional schedule coordination was occurring in Boulder.

5.2.4.3 Coordinated Transfers

Transfers that were favored in the RTD-Boulder 1980 schedule included:

At 28th and Glenwood

From Route 5 south	To	Route 8 west Route 9 south
From Route 5 north	To	Route 9 north Route 8 east

At Table Mesa and Broadway

Most transfers were difficult due to unequal headways on the three routes. Service on Routes 2 and 4 was nominally at 15-minute intervals during the peak periods, while Route 6 was on 30-minute intervals. But, Route 6's schedule shifted throughout the day. As a result, the convenience of transfers between 2 or 4 and 6 depended on the time of day and the particular routes selected.

At Baseline and Mohawk

From Route 3 north To Route 6 north
Route 6 south
Route 9 north

Because Route 3 operated on 20-minute peak period headways and Route 6 and 9 operated on 30-minute headways, the schedules were characterized by a few convenient transfers, combined with a number of inconvenient transfers.

14th and Walnut

The large number of buses that stopped downtown, and the irregularities in local route headway schedules, effectively prevented timed transfers downtown. In 1979, an interim analysis indicated one half of the transfers could be made with scheduled waits of five minutes or less.[6]

5.2.4.4 Impact on Passenger Activity

Data on passenger boardings and alightings were collected at the four transfer points in the Fall of 1980. Exhibit II in Appendix C lists the mean number of passengers boarding and alighting each bus, including a total passenger count on departure for each of the routes serving each transfer point. Separate entries are given for the morning and evening peaks and for the mid-day period.

Passenger activity is heaviest downtown with the other sites having considerably less activity. An examination of the activity at individual Boulder sites suggests some passenger directional flows.

For example, during the morning peak on Route 9, over one-half the passenger boardings occur at 28th and Glenwood with most passengers alighting at Baseline and Mohawk. At Baseline and Mohawk, Route 3 boardings are heaviest in the AM peak and alightings are heaviest in the PM peak. Throughout the day, a large number of passengers departed on buses from Table Mesa and Broadway, although relatively few boardings and alightings occurred at this point, suggesting a lower level of transfer activity. This may occur because Routes 2 and 4 are paired and most passenger boarding, alighting and transfer activity occurs downtown.

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[6] SYSTAN, Inc., "Proposed Evaluation of Timed Transfer, Focal Point Transfer Systems", April, 1979.

5.2.4.5 Impact on Transfers

RTD drivers collected all transfer slips on April 1, and November 5 and 6, 1980. The total number of transfer slips collected does not reflect the actual number of transfers that were made, because between one-third to one-half of Boulder's passengers use monthly transit passes, and do not require transfer slips. However, since local transfers are free and RTD Boulder Supervisors estimate similar transfer patterns for transit pass users and individual fare paying users, the collected data can provide the relative weekday volume of transfers and weekday transfer route directional flows.

Exhibit 5.15 summarizes the level of transfer activity occurring at each transfer point and throughout the system. Over 60 percent of all transfers occurred downtown. Table Mesa and Broadway was the next most popular transfer location, with 15 percent of all local route transfers. Even though schedules were not coordinated for timed transfers, more than 90 percent of all transfers took place at the four focal transfer points.

Relationships between routes, paired by the number of transfer slips issued and received at two of the focal transfer sites -- 14th and Walnut (downtown) and 28th and Glenwood -- are also provided in Exhibit 5.15. In downtown Boulder, almost one-third of all transfers were between a Route 2 or 4 and a Route 7, providing connecting services between the major north-south and east-west corridors. These route schedules are favored for coordinating timed transfers. Twelve percent of all riders transferred between the paired Routes 2 and 4 and 45 percent transferred from or to a Route 2 or 4. Very little transfer activity involved Route 8.

At 28th and Glenwood, over one half of all transfers were between Route 5 and Route 9. The schedules also favored this transfer connection. Again, the smallest number of transfers involved Route 8, despite the fact that the schedules favored transfers between Routes 5 and 8.

5.2.4.6 Route Performance - Downtown

Using data collected on October 28 and 29, 1980, Exhibit 5.16 shows the schedule performance for all of the bus routes that served downtown Boulder. The vertical bars represent the frequency of arrival at different times before and after the schedule time. The light shaded bars are arrivals and the dark shaded bars are departures. The solid and dashed vertical lines mark mean arrival and mean departure times, respectively, for each bus route.

Almost all arrivals and departures occurred at or after schedule time. The reliability performance and range of this performance varied by bus route. Route 3 had the narrowest performance range with the earliest arrival 2-1/2 minutes before schedule and the latest departure

Exhibit 5.15

SUMMARY OF BOULDER TRANSFERS

By Location	Transfers Received (%)
14th & Walnut	61.2
Table Mesa & Broadway	14.5
28th & Glenwood	7.8
Baseline & Mohawk	6.7
All Other	9.8
Total	100.0

14th & Walnut

Receiving Route \ Issuing Route	2-4	3	5	7	8	Total 100.0
2-4	26.5 12.0	18.2 8.2	16.6 7.5	25.7 11.6	13.0 5.9	100.0 45.2
3	48.1 4.5	—	15.4 1.4	25.0 2.3	11.5 1.2	100.0 9.3
5	72.9 9.1	15.7 2.0	—	5.7 0.7	5.7 0.7	100.0 12.5
7	75.5 19.3	11.2 2.9	1.4 0.4	—	11.9 3.0	100.0 25.5
8	69.0 5.2	9.5 0.7	4.8 0.4	16.7 1.3	—	100.0 7.5

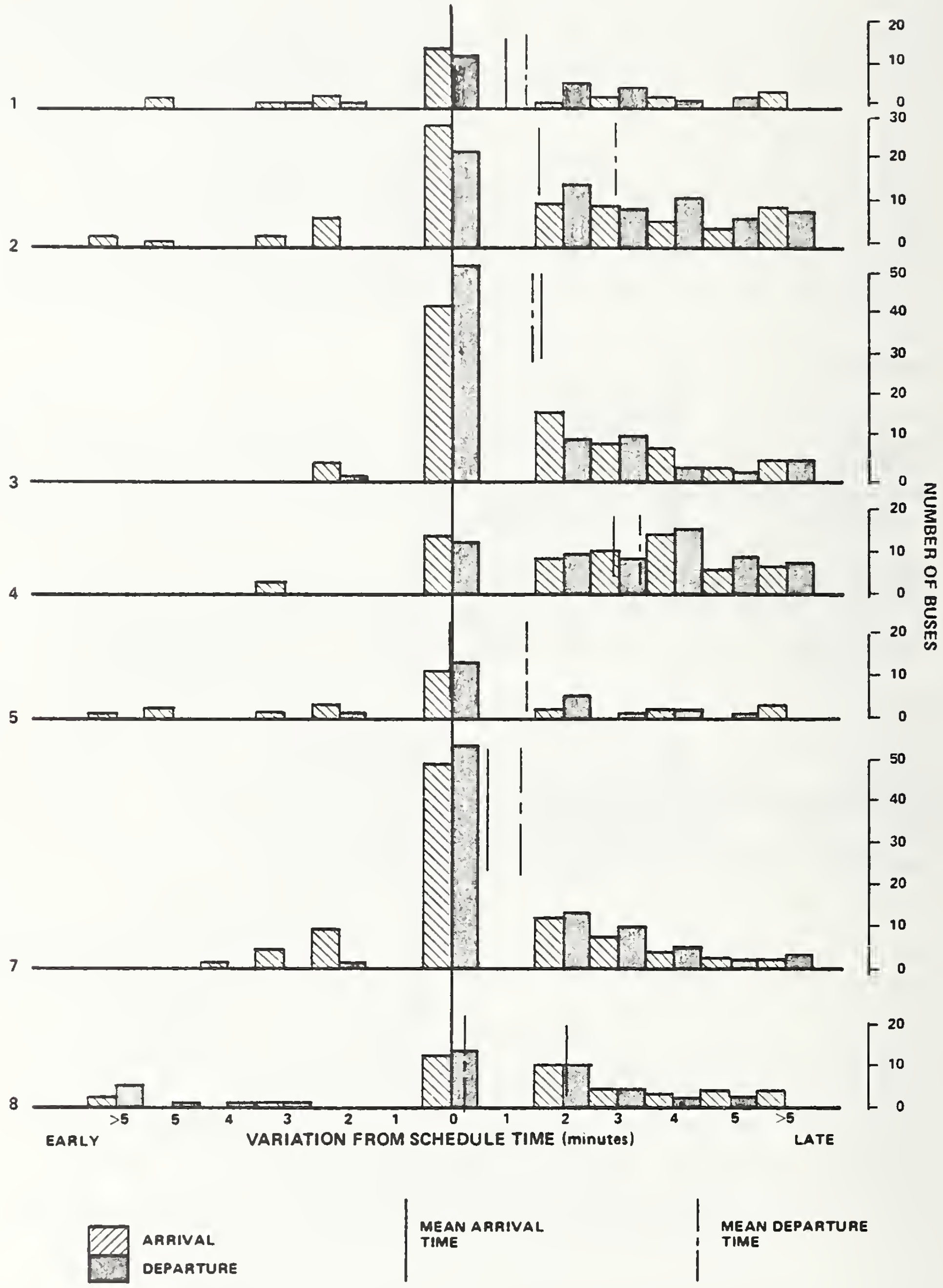
28th & Glenwood

Receiving Route \ Issuing Route	5	8	9	Total 100.0
5	—	27.3 8.8	72.7 23.5	100.0 32.4
8	38.5 7.4	—	61.5 11.8	100.0 19.2
9	63.6 30.9	36.4 17.7	—	100.0 48.5

% of Receiving Route Transfers
% of Transfers by Location

Exhibit 5.16

BUS SCHEDULE PERFORMANCE BY ROUTE (BOULDER CBD)



just over 5 minutes after schedule. Performance on Route 5 was even better -- mean arrivals were on time and mean departures were just over 1 minute late. In 1978, before route running times were adjusted Route 5 experienced many reliability problems. Except for some early departures, Routes 1 and 7 also had good performance.

The reliability performance on Routes 2, 4 and 8 were not as good. In fact, Route 8 had the largest variation and number of early departures and also seemed to rely on its downtown scheduled layover time to maintain its schedule, resulting in earlier mean departure times than mean arrival times. This may explain why although Route 8's printed schedule favors transfer activity, the smallest number of transfers involve Route 8.

5.2.4.7 Route Performance at Other Transfer Points

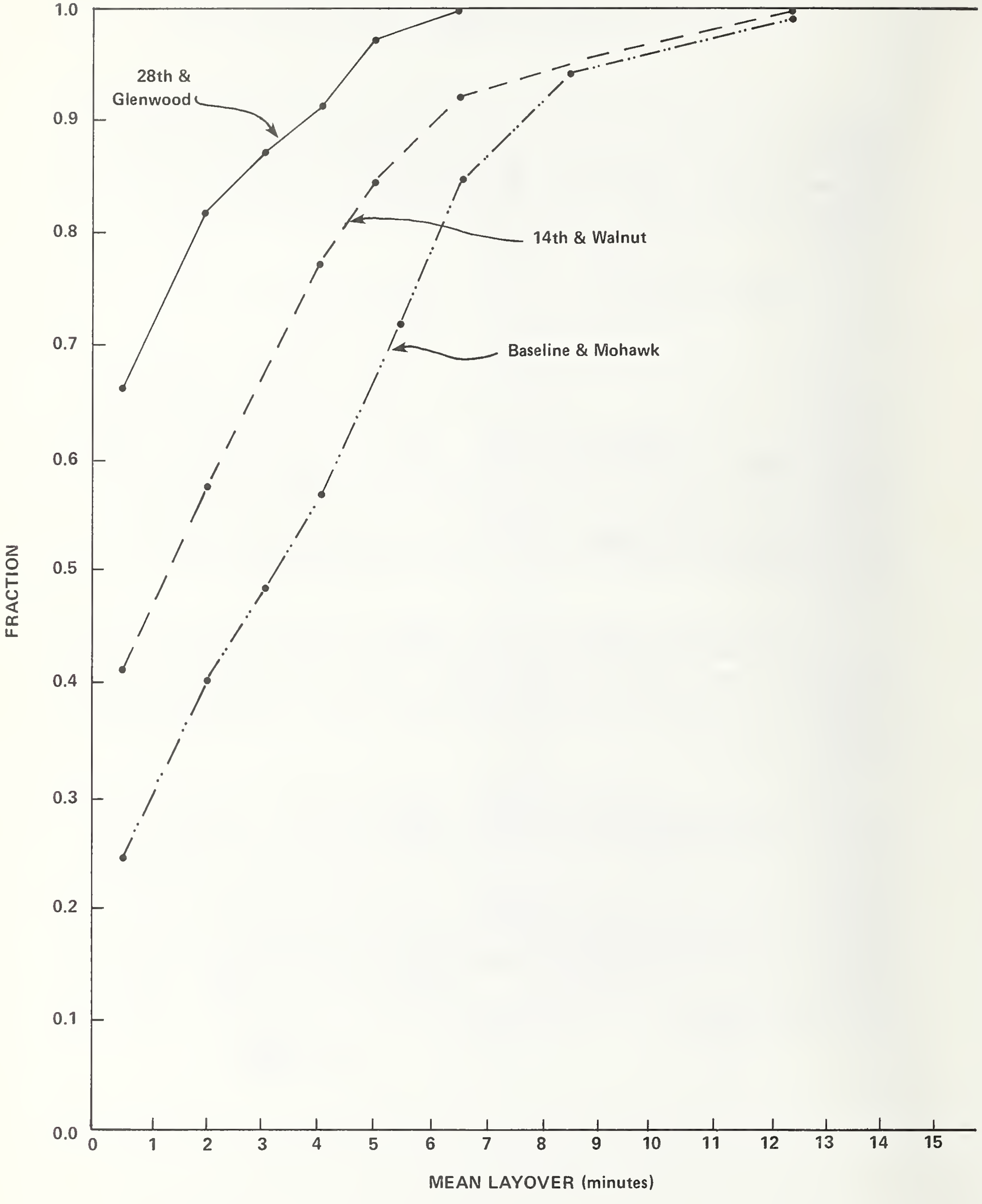
Reliability performance at the other focal transfer points are comparable. Exhibit II in Appendix E lists mean schedule performance for all bus routes at the four transfer sites. Only limited data were available for Table Mesa and Broadway. Mean arrival times were after schedule times for all routes except two -- Route 9, at Baseline and Mohawk, and Route 5, at 14th and Walnut -- which arrived on schedule. All departures were after schedule time, with the latest departures occurring an average of 3 to 3-1/2 minutes after schedule. The two worst cases were Route 6, at Table Mesa and Broadway and Route 4, at 14th and Walnut.

An examination of Routes 6 and 4 at other transfer points indicates these routes made up some of their delays by travelling faster and by shortening transfer point layover times. Those routes which have extra layover time can maintain reliable schedules. But, reducing the amount of time at the transfer point decreases the amount of time allowed for transfer activity.

Exhibit 5.17 shows a cumulative distribution of all layover times, at three of Boulder's focal transfer points in 1980. Practically all layovers were less than 6 minutes. In fact, at 28th and Glenwood over 70 percent of the layovers were less than 1 minute and none exceeded 6 minutes. About one-half of the bus layovers were one minute or less at 14th and Walnut and up to 3.5 minutes at Baseline and Mohawk, and layovers at neither site exceeded 12 minutes. Because a large number of downtown arrival and departure times varied up to 4 minutes, many buses may have missed connecting buses. In timed transfer systems longer layovers, consistent schedules and enforcement of reliability standards are usually necessary.

Exhibit 5.17

CUMULATIVE DISTRIBUTION OF LAYOVER TIMES (BOULDER)



5.2.5 Ridership Impacts

5.2.5.1 Impacts on Transit Users

In March 1979, one year after RTD expanded its timed transfer system, an on-board transit survey was conducted as part of the Evaluation of the Denver RTD Route Restructuring Project.[7] Another on-board survey was conducted in Boulder in October 1980. Although these surveys were independently developed and administered, many of the questions addressed comparable issues, in terms of: (1) user characteristics, (2) trip characteristics, and (3) user perceptions of services.

A comparison of these survey results can provide a better understanding of timed transfer impacts on users. Both surveys were self-administered by passengers on-board RTD Boulder transit vehicles. The samples were approximately 680 in 1979 and 1080 in 1980. The samples were drawn from weekday passenger services from throughout the Boulder RTD route system. The survey questionnaires and summary tabulations of the 1980 survey responses are included in Appendix B.

Effects on User Characteristics. A comparison of the ridership profiles of RTD passengers in the 1979 and 1980 surveys showed little difference between the distribution by age, sex and availability of automobiles. Exhibit 5.18 charts the percentage of respondents in each category from the two on-board surveys. The University's dominant position in Boulder is reflected by the large proportion of riders in the 16 or 17 to 44 age categories. Although one might expect a decrease in elderly ridership as transferring becomes more difficult, there were comparable levels of elderly riders during both surveys.

Effects on Trip Characteristics. A comparison of trip characteristics shows RTD passengers walking further, waiting slightly longer and transferring more frequently in 1980 than they were in 1979, an indication that passengers were receiving a lower level of service in later years. Exhibit 5.18 summarizes these findings. Assuming it takes an average of two minutes to walk one block, 43 percent of the respondents reported walking one block or less in 1979, while about one-third reported this short a walk in 1980.

Two-thirds of all passengers reported waiting 5 minutes or less for their bus to arrive in both 1979 and 1980. No passengers waited one half hour or longer in 1979, although a few passengers reported these long waits in 1980. The average overall wait for the initial bus was 6 minutes, increasing only slightly between 1979 and 1980.

Changing the Boulder transit system from a timed transfer system to a more conventionally scheduled system also affected passenger transfer rates. In 1979, 80 percent of the riders reported making bus trips

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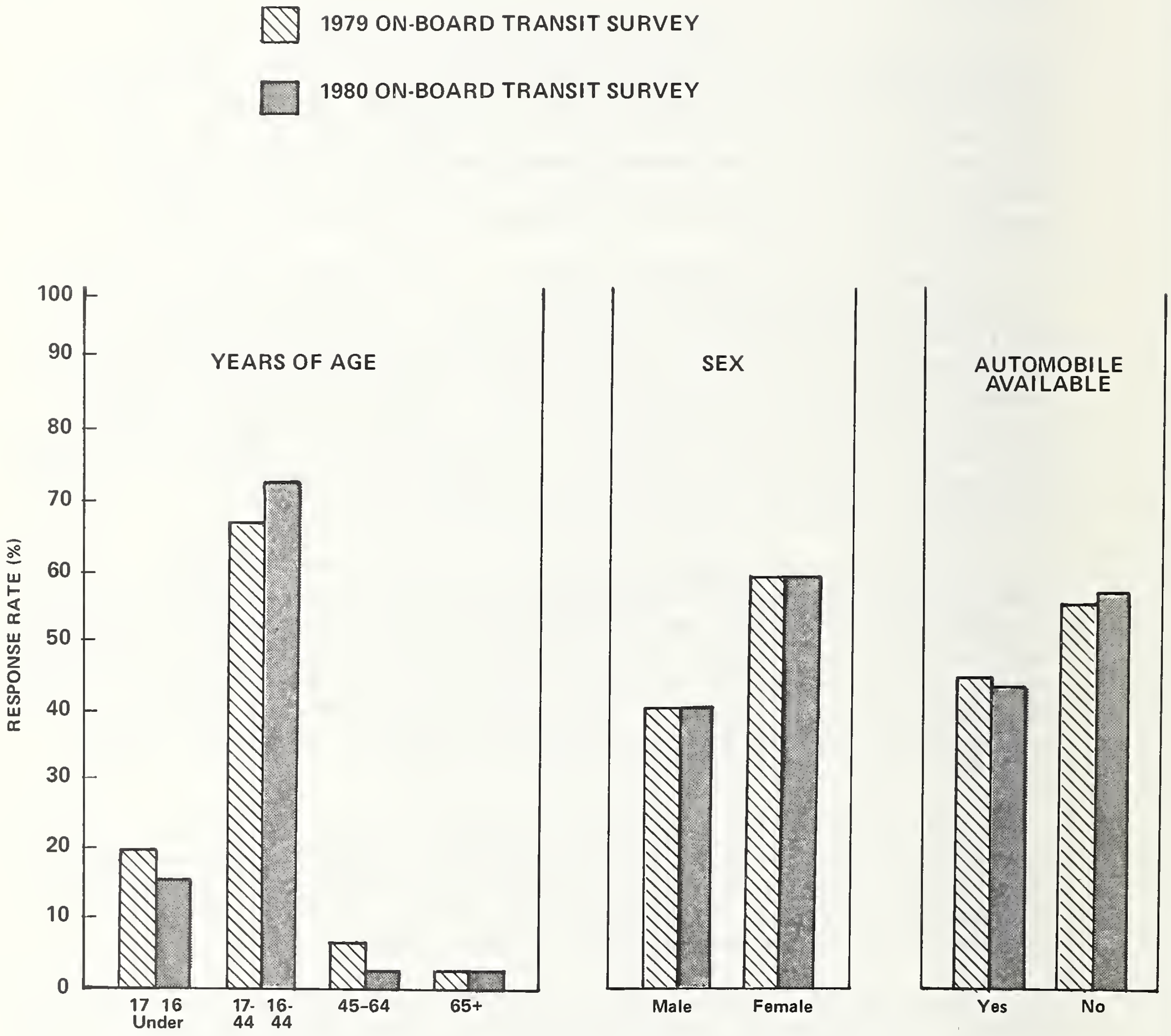
[7] Donnelly, R.M. Evaluation of Denver RTD Route Restructuring Project, July, 1981.

Exhibit 5.18

USER CHARACTERISTICS



without transferring, while in 1980, 68 percent reported using only one bus to complete their trip. Since the route configuration did not change, it is not surprising that many passengers still needed to transfer, but it is surprising that more riders were transferring in the later period when it was less convenient. The average number of buses per trip increased 11 percent from 1.2 in 1979 to 1.4 in 1980.

Passenger Perceptions and Attitudes. Passengers responding to the 1980 survey who indicated that they had been using RTD Boulder services in 1978 were asked to compare the services of the two periods. As indicated in Exhibit 5.20, passengers felt that improvements had been made in the convenience of the schedules and the overall convenience of the system. Many also perceived improvements in the frequency and directness of services, the convenience of routes and the comprehensibility of the system. Twelve to thirteen percent of the passengers noted worsening of on-time reliability and total trip time.

5.2.5.2 Impacts on Transfer Wait Times

On the 1980 survey, passengers were also asked how long they had waited or how long they expected to wait at each transfer point. The results were disaggregated according to whether it was the passenger's first or second transfer. About 14 percent noted increases in transfer time between 1978 and 1980 -- the largest negative difference noted between the two time periods.

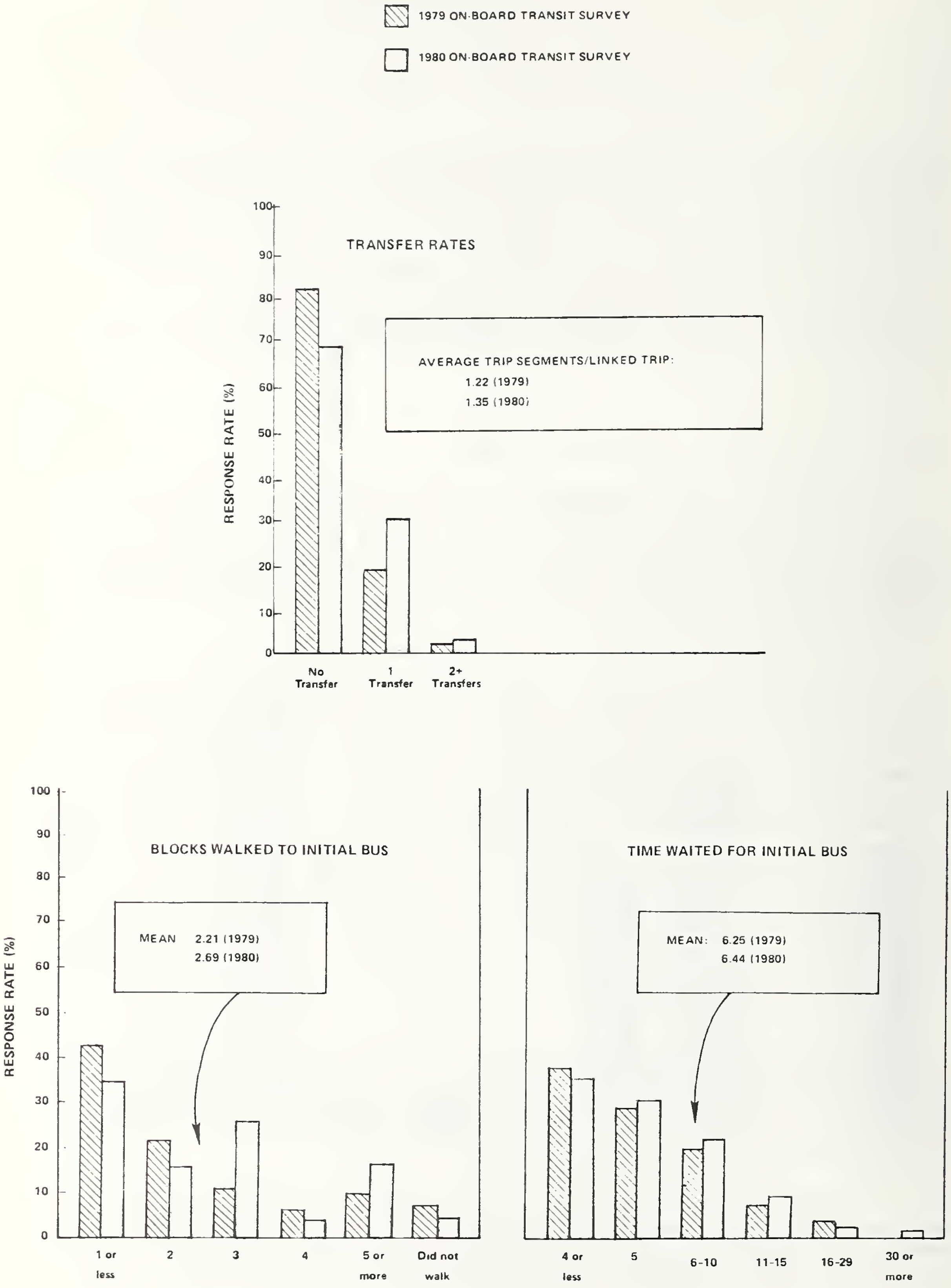
Timed Transfer Location. Although the sample size at each transfer point except downtown Boulder is small (n<30), waiting times seemed to vary by location. While over half of the passengers who transferred at downtown and at Table Mesa/Broadway and close to three quarters of the passengers at 28th/Glenwood waited 5 minutes or less, only a third of the passengers at Mohawk/Baseline reported similar waits for their transfers. The tabulated results, shown in Exhibit 5.21, indicate that the shortest transfer delays were at 28th/Glenwood (average wait = 5.3 minutes) and the longest delays were at Mohawk/Baseline (average wait = 12.2 minutes). This is likely due to longer scheduled layovers at Mohawk/Baseline. The average transfer wait time at downtown and Table Mesa/Broadway is about 7.5 minutes. The amount of time passengers said they actually waited and the amount of time they expected to wait is comparable at downtown Boulder.

First vs. Second Transfer. Passengers reported waiting longer during their second transfer than their first transfer. While over one half of the passengers (54.3 percent) said they waited for 5 minutes or less at the first transfer point, less than one third (30.4 percent) responded that way at the second transfer point.

It seems that passengers are fairly accurate in their estimates of waiting time during their first tranfer. When the time waited is compared to the time the passengers expected to wait, discrepancies are relatively small (less than 7 percent) for all time intervals. Much

Exhibit 5.19

TRIP CHARACTERISTICS (BOULDER)



TRANSFER RATES

AVERAGE TRIP SEGMENTS/LINKED TRIP:
1.22 (1979)
1.35 (1980)

BLOCKS WALKED TO INITIAL BUS

MEAN 2.21 (1979)
2.69 (1980)

TIME WAITED FOR INITIAL BUS

MEAN: 6.25 (1979)
6.44 (1980)

Exhibit 5.20

PERCEPTIONS OF SERVICE CHANGES

Percent of all Respondents who Compared 1978 to 1980 RTD Services	Convenience of Schedule (n = 415)	Frequency of Service (n = 409)	Convenience of Routes (n = 401)	Directness of Service (n = 392)	On-Time Reliability (n = 396)	Comprehensibility (n = 355)	Total Trip Time (n = 385)	Overall Convenience (n = 397)
Better	54.2	47.6	46.6	39.5	40.1	35.2	35.6	51.9
About the same	37.9	47.0	45.7	52.3	46.5	53.8	52.2	40.0
Worse	7.9	5.4	7.7	8.2	13.4	11.0	12.2	8.1

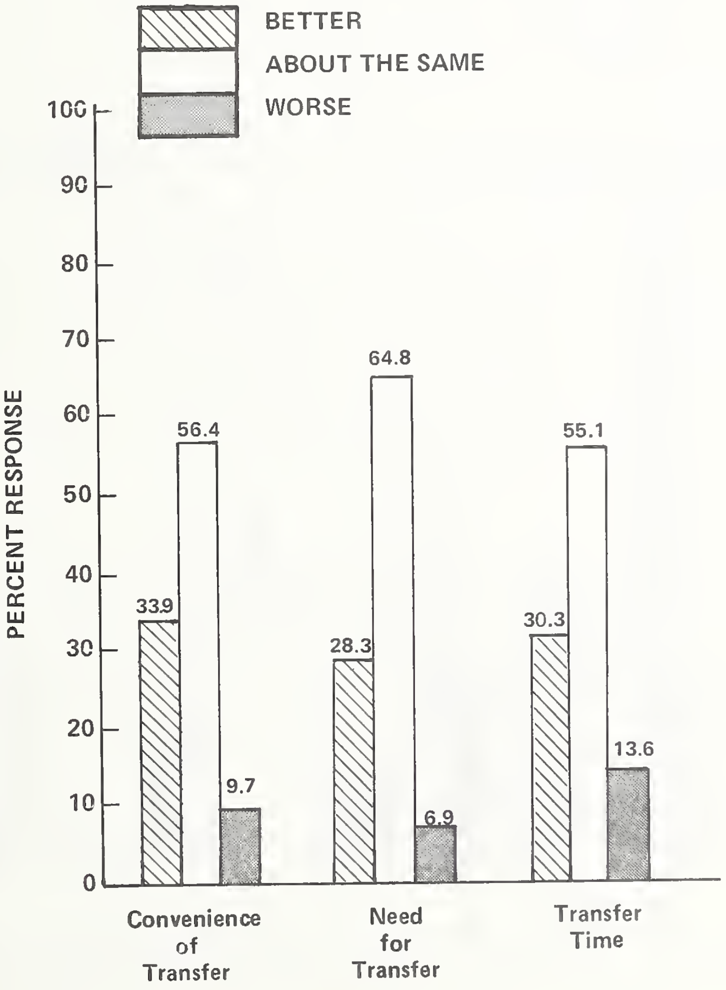
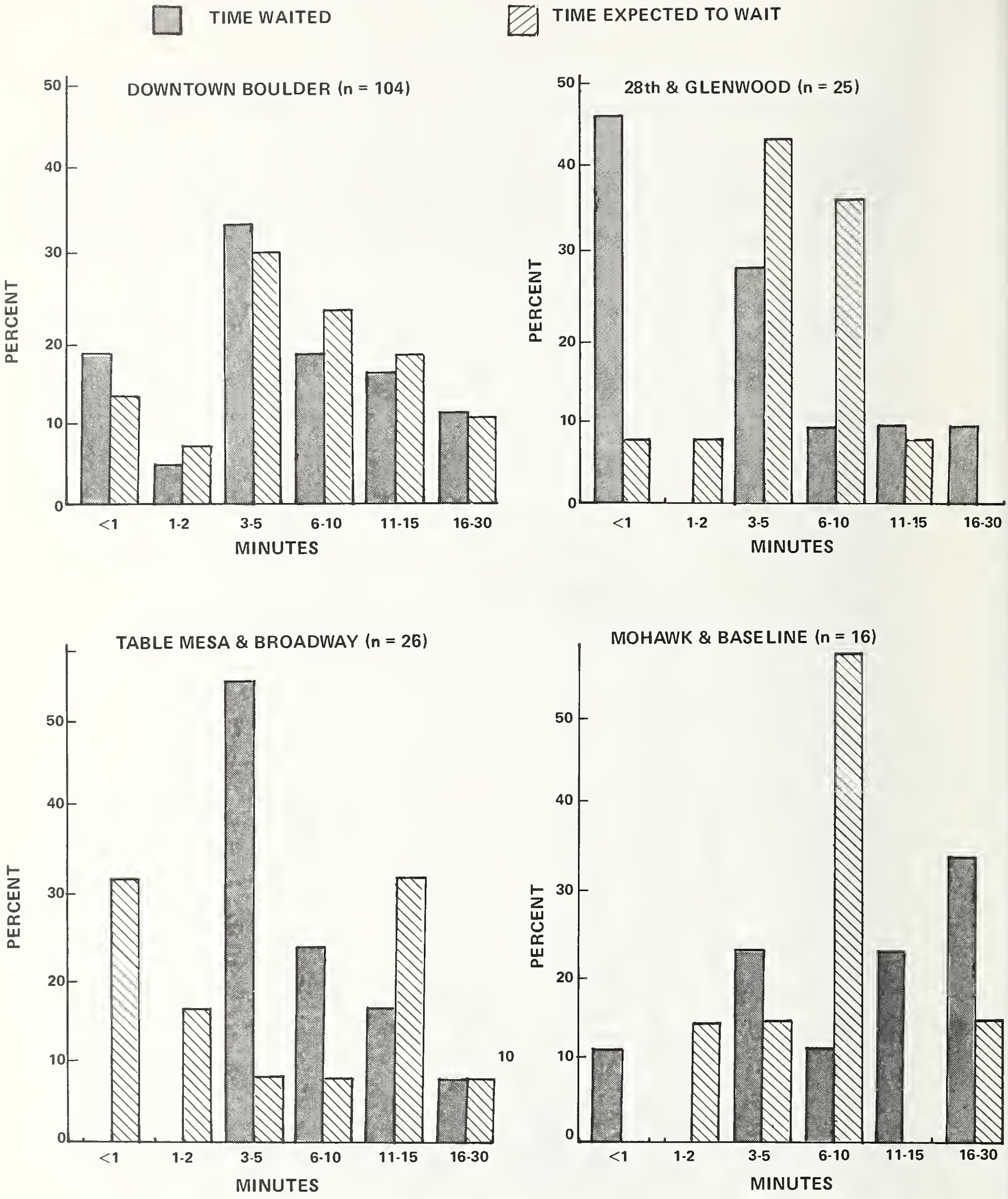


Exhibit 5.21

WAITING TIME BY LOCATION



larger discrepancies (up to 21 percent) were found between the time waited and the time expected to wait at the second transfer point. Although no passenger actually reported waiting over 30 minutes, several passengers stated they expected to wait over 30 minutes.

When the waiting time at the first and second transfer points are combined, half of the passengers said they waited 5 minutes or less and 38 percent said they waited between 5 and 15 minutes. The remaining 12 percent waited between 16 and 30 minutes. These results are summarized in Exhibit 5.22.

This may be a good indicator of passengers' resistance to transferring. Transit passengers may be willing to wait and transfer once, but multiple transfers magnify wait times making them excessively onerous and not unpopular with most transit riders. In 1980, almost one-third of the riders reported one transfer per trip, while less than 3 percent reported two or more transfers per trip.

5.2.5.3 Impact on Boulder Patronage

Although timed transfer can have major impacts on patronage, transit patronage in Boulder was influenced by several major events between 1978 and 1980, confounding the timed transfer impacts. Energy shortages and gasoline price increases during this period encouraged some drivers to try transit. And between February 1978 and January 1979, RTD implemented an off-peak free fare demonstration project. This experiment had an enormous impact on patronage. Exhibit 5.23 shows unlinked monthly patronage for RTD local services in Boulder, in comparison with all other RTD services between 1977 and 1980. Local Boulder ridership is about 8 percent of total RTD ridership. The dates for the free fare project, timed transfer implementation in Boulder, major route restructuring in Denver and subsequent route and schedule changes are marked. Patronage data are based on boarding passenger counts (unlinked trips) and revenue data collected by RTD. These figures have been adjusted to reflect biases associated with RTD's methods of reporting passenger data during different periods (see Appendix A).

Ridership increases resulting from free fares are well documented in the ridership graphs. Increases occurred primarily during the first few months of the free fare program, with 85 percent of the total gains occurring in the first month. Longterm RTD ridership gains resulting from free fares are estimated at about 4 percent of the total post-free fare ridership.[8]

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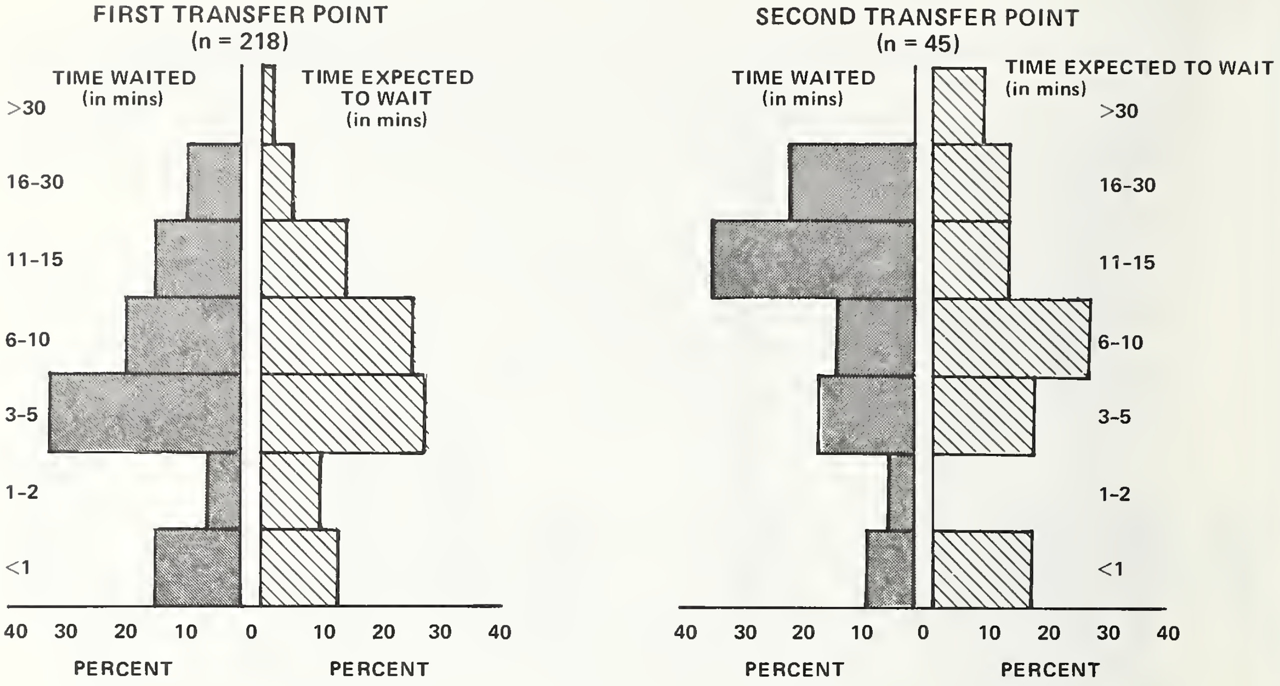
[8] Donnelly, R.M. et al. The Denver RTD Off-Peak Free Fare Transit Demonstration, March, 1980.

Exhibit 5.22

WAITING TIME BY ORDER OF TRANSFER (BOULDER)



FIRST & SECOND TRANSFER POINTS COMBINED (n = 263)

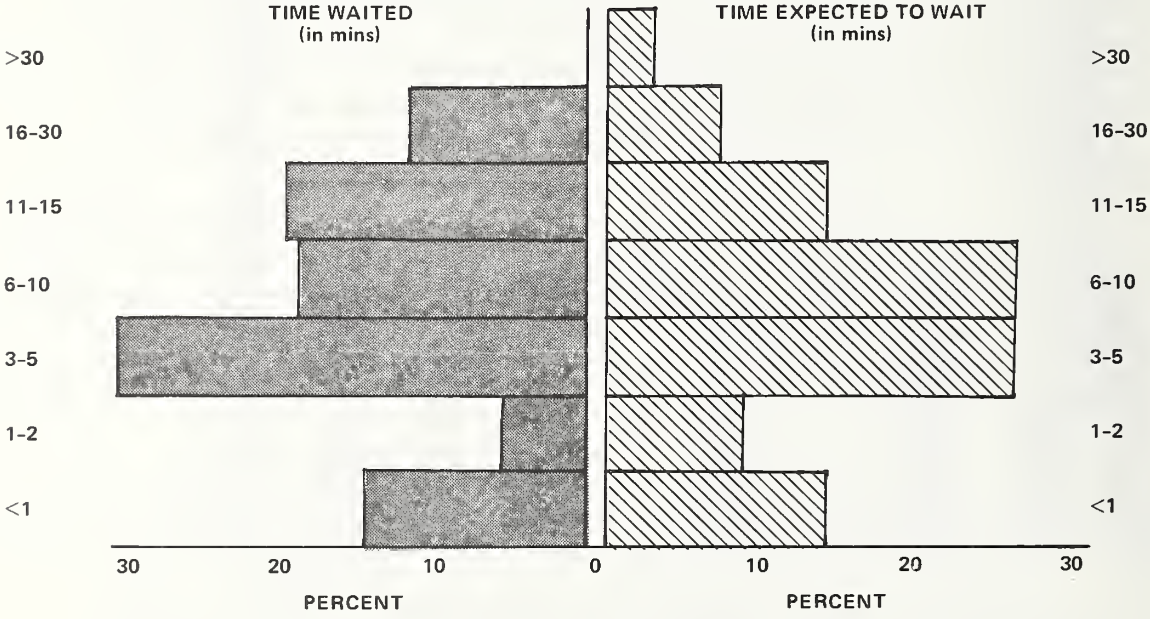
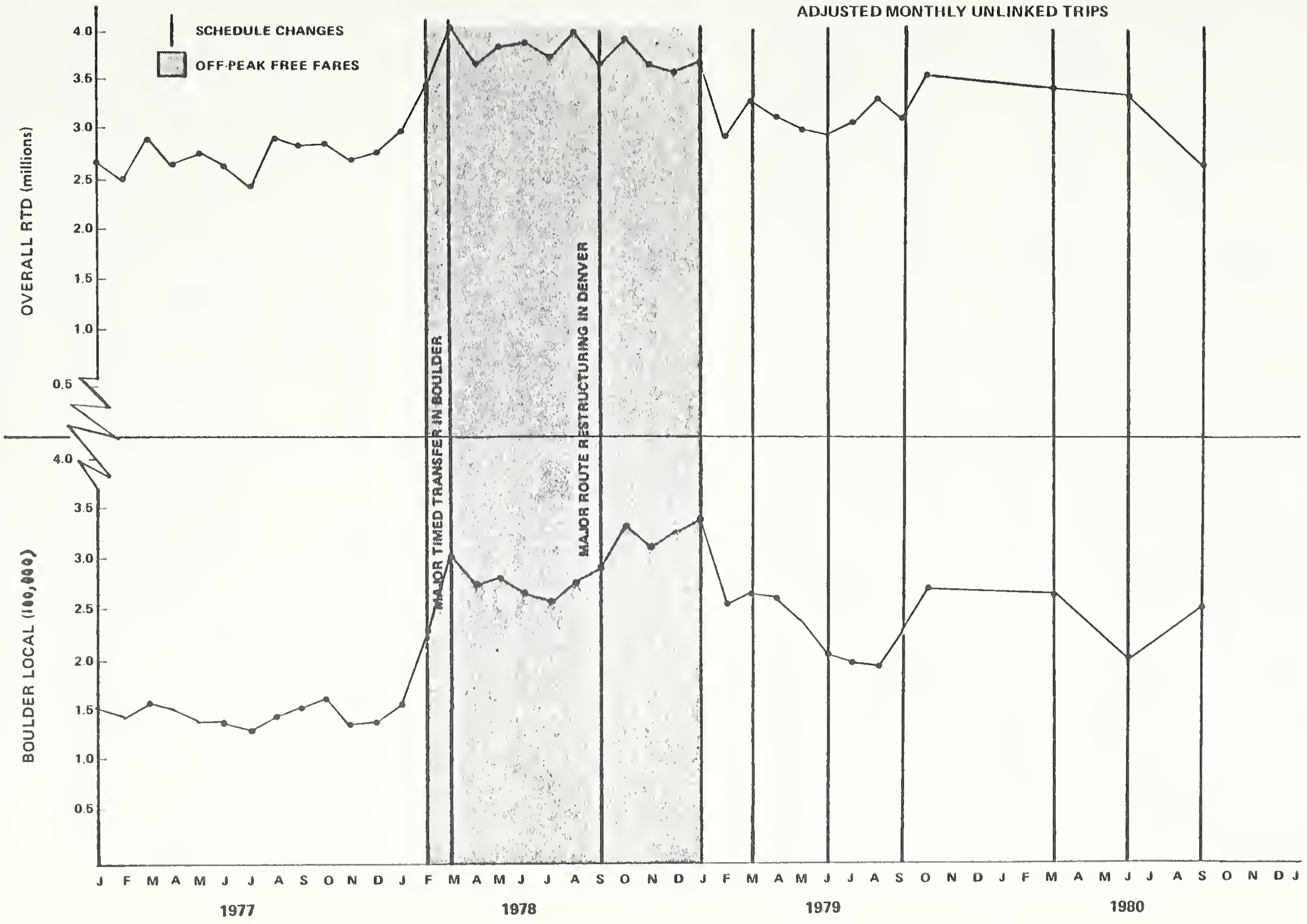


Exhibit 5.23

RELATIVE PATRONAGE GROWTH



However, if Boulder and Denver patronage are examined separately, Boulder seems to have maintained greater long-term ridership gains after the free fare demonstration ended. In analyzing these ridership trends, Boulder's ridership also declines much more significantly than Denver's during the summer months, due to the large seasonal student population. The timed transfer system introduced in Boulder in March 1978 added about one-third more services. This expansion, coupled with the off-peak free fares in Boulder and Denver, induced a far sharper increase in Boulder's ridership between January and March 1978 than occurred in Denver. Ridership in Boulder increased 30 percent between January and February and another 25 percent between February and March. In Denver, ridership increased 12 percent and 15 percent during the same two time periods. And the route restructuring implemented in Denver in September 1978 resulted in about a three percent decrease in ridership, although Boulder's ridership was still increasing.

It is interesting that Boulder's ridership continued to increase to its highest level in the Fall of 1978 -- when both free fares and improved timed transfer services were operating. Denver's free fare service patronage was beginning to level off. It is likely that Boulder's student population was more interested and able to take advantage of free fares during the mid-day period and that timed transfer was better suited to the needs of these mid-day users.

5.2.6 Relative Speed and Quality of Service

5.2.6.1 Impact on Bus Speeds

In order for timed transfer to be successful, buses must consistently meet at the same time. Vehicle run times cannot vary very much from the schedule. An examination of the bus speeds on one of the three route segments at the 28th and Glenwood transfer point may reveal why timed transfer connections were not always successfully completed in 1978.

	Scheduled Running Time* (minutes)		Distance (miles)		Mean Speed (mph)	
	Out	In	Out	In	Out	In
Route 5						
Peak	39	39	15.05	15.20	23.2	23.4
Off-Peak	35	37			25.8	24.6
Route 8						
Peak	19	22	6.12	6.14	19.3	16.8
Off-Peak	21	23			17.4	16.0
Route 9						
Peak	29	27	7.34	6.24	15.2	13.9
Off-Peak	31	27			14.2	13.9

*Does not include layover time, scheduled at end points.

The scheduled running times varied as much as 17 percent among the peak and off-peak periods and the inbound and outbound trip segments. Route 5's scheduled roundtrip time, including layover time, was 90 minutes, but its actual roundtrip time was 95 minutes. As indicated above, Route 5's mean travel speed was expected to be 23 mph during the peak and 25 mph during the off-peak. If bad weather, an accident, congestion or traffic resulted, which frequently occurred during the outbound PM peak, Route 5 could not make its meet. These travel time problems were later exacerbated by the growth in ridership, which increased the number of stops and the boarding and alighting time required per trip.

5.2.6.2 Alternative Travel Speeds

A sample of eleven representative trips were selected to compare the quality of alternative travel modes in Boulder. Three travel alternatives are examined for each trip: (1) automobile; (2) present RTD bus service; and (3) 1978 RTD timed transfer bus service. The approach and methodology used in the calculation of trip times are explained in Section 1.2.4. Exhibit II in Appendix D lists the tabulated results of the eleven sample Boulder trips.

As expected, the automobile was consistently the fastest mode of travel. There is virtually no waiting and little walking time involved in boarding and disembarking from an automobile, parking is readily available at most destinations and traffic is uncongested except near downtown. Among the eleven sample automobile trips, all but one were less than 5 miles.

Of the 11 sample bus trips, five required transfers, both before and after timed transfer services operated. Three of the transfers occurred at timed transfer points and two transfers occurred at the first intersection of the two routes. Passengers making other bus trips could have transferred, but transferring would take longer than walking a slightly longer distance.

5.2.6.3 Convenience of Service

The elapsed time ratio displayed in Exhibit 5.24 provides insights into the performance and convenience of the 1978 timed transfer as compared to the 1980 bus services. The elapsed time ratio uses total travel time for automobile trips as the base factor for comparing the total travel time for the two transit options. The 1980 bus/automobile elapsed time ratio ranges from 1.9 to 5.4, and the 1978 bus service ratio ranges from 2.1 to 5.7. The slight superiority of the 1980 service is also reflected in a slightly lower mean elapsed time ratio (3.22 versus 3.35). The majority of riders in the 1980 passenger surveys felt trip times had improved or were about the same. These findings likely reflect the schedule efficiency changes implemented by RTD.

5.2.7 Impact of Service Changes on Costs

5.2.7.1 Site-Specific Factors

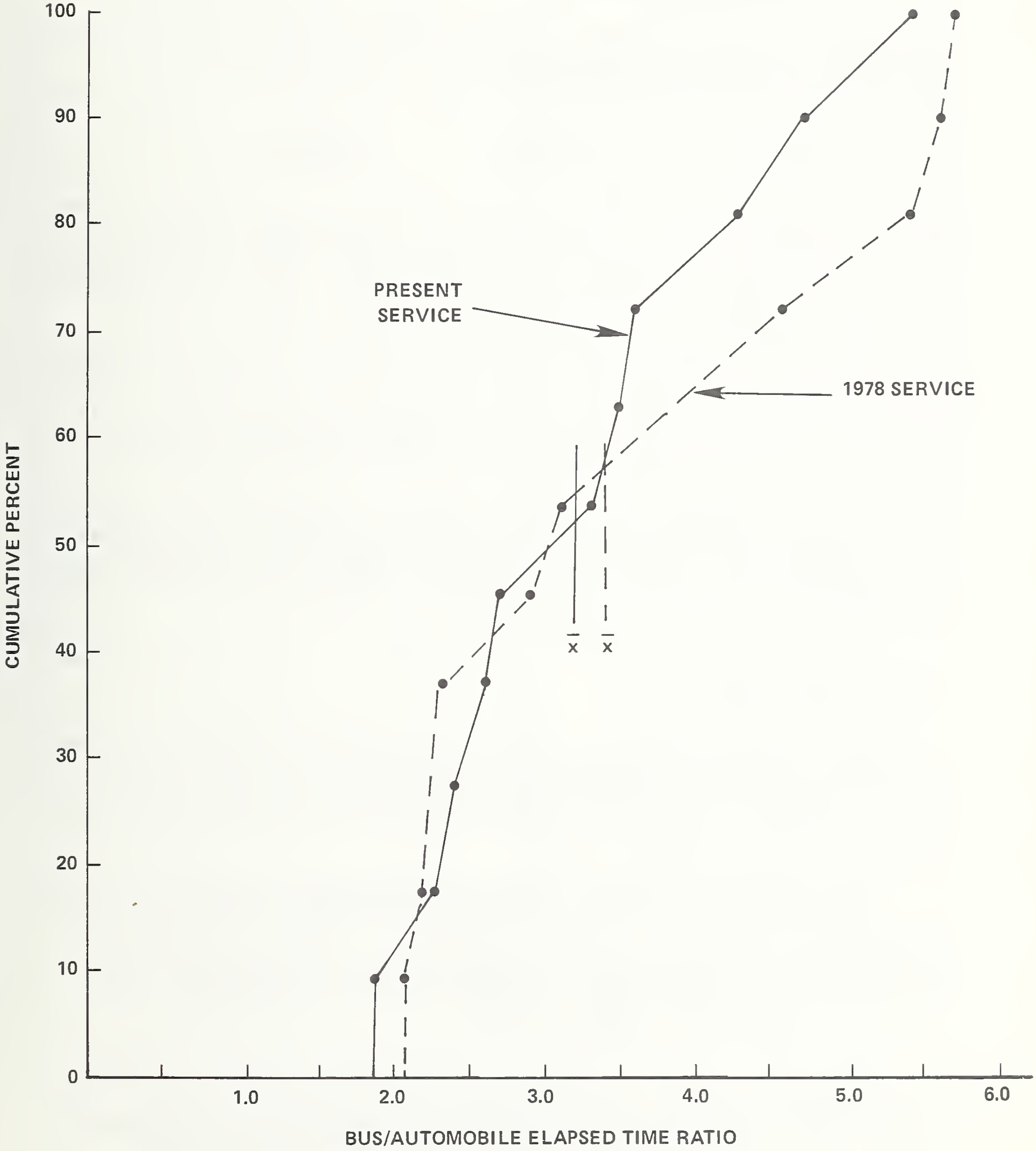
Cost reduction was a major incentive for RTD to change the timed transfer system to a more conventionally scheduled system. RTD felt equipment and resources were being wasted because they were running extra buses to meet the schedule demands of timed transfer services. The analysis of the economic success of this decision is obscured by RTD's off-peak free fare demonstration in 1978, and by the difficulty of separating operating statistics for Boulder from Denver's overall system data.

5.2.7.2 Capital Costs

When Boulder introduced timed transfer services, the system did not incur major capital and start-up costs. In 1975, $3,500 had been spent for shelters at waiting areas; and other shelters at transfer points dated back to 1973. The vehicle fleet was expanded from 17 to 28 vehicles, which was directly related to a 41.1% increase in vehicle hours per day. Vehicle miles per day increased by 38.3 percent. Boulder conducted initial training sessions for bus drivers and

Exhibit 5.24

CUMULATIVE DISTRIBUTION BUS/AUTOMOBILE ELAPSED TIME (BOULDER)



increased supervisory efforts during that period, but cost information for these measures was not available.

5.2.7.3 Operating Statistics

Boulder's annual system costs developed as follows in the transition from "before-timed-transfer" to "timed transfer" to "after-timed-transfer" operations:

1977	1978	1980
$1,562,000	$2,436,000	$3,724,000

The 46% increase between 1977 and 1980 reflects the 40% increase in the level of service. During the next two years costs rose by another 35 percent. Assuming a 13% annual rate of inflation, most of this increase can be attributed to higher fuel and labor costs. Thus, the overall cost comparison shows no apparent impact of timed transfer services.

Exhibit 5.25 lists some operating statistics for Boulder, comparing monthly data of 1978 and 1980. Apart from the cost increases, the table shows an improved ratio of bus miles to bus hours. This shift may be due to the termination of timed transfer meet layovers, and the elimination of other timed transfer scheduling requirements.

Thus, on balance no substantial extra costs appear to be related to the introduction of timed transfer services, and only some cost savings -- represented by a higher mean bus speed -- seem to be associated with the change to more conventionally scheduled services.

5.2.8 Conclusion

Timed transfer service had both minor and major impacts in Boulder. Since the route structure remained fairly constant between 1978 and 1980, the majority of transfers and passenger activity still occurred in downtown Boulder. And practically all local transfers occurred at one of the four focal transfer points.

The increase in the level of bus services and an off-peak free fare policy that accompanied the implementation of timed transfer resulted in substantial increases in transit patronage. To provide such services also resulted in considerable increases in cost. The relative cost, in terms of increased patronage may be justified, but cannot be solely related to impacts from timed transfer.

RTD passenger surveys indicate that the type of user riding Boulder transit has not changed. Although later riders received slightly lower levels of service, the later riders perceived significant improvements in the quality of Boulder's transit service when compared to the previous timed transfer services. The sample trip analysis also

Exhibit 5.25

TRANSIT COST AND PERFORMANCE

(BOULDER)

Statistics by Month*	1978	1980	Change
System Costs	$203,000	$285,322	40.5%
Passenger Trips	275,955	NA	NA
Bus Hours	11,043	11,078	0.3%
Bus Miles	127,120	134,586	5.9%
Passengers per Bus Hour	25	NA	NA
Passengers per Bus Mile	2.2	NA	NA
Costs per Bus Hour	$18.38	$25.76	40.1%
Costs per Bus Mile	$1.60	$2.16	35.0%
Bus Miles per Bus Hour	11.5	12.1	5.2%

* May 1978 compared to monthly average for the second quarter of 1980.

NA = Not available.

indicated the 1980 service was slightly better, in terms of travel time, than the 1978 service. Observed bus performance is also better than previously reported, although particular routes may still need improvement. Overall, RTD Boulder achieved growth in service and ridership with timed transfer and later achieved some cost savings without adversely impacting service to riders by developing a more conventionally scheduled transit system.

5.3 PORTLAND, OREGON

5.3.1 Site Description

Portland is the center of an urban metropolitan area that houses more than one million persons, covers parts of the states of Oregon and Washington and covers over 1,000 square miles. The urbanized area is divided by two major rivers --- the Columbia and the Willamette. Both rivers are navigable and support major domestic and international commerce. Although lumber and lumber products dominate the economy, recent diversification into high technology industry has been successful. The Portland Central Business District (CBD) is the focus of commercial activity for the metropolitan area, though there is extensive activity elsewhere.

The timed transfer points that were examined are located in suburban Beaverton, west of the Portland CBD. Buses engaged in timed transfers serve portions of west Portland, Beaverton and other Westside communities. The Portland CBD is separated from Beaverton by the Portland hills, which form a natural barrier between downtown and the western suburbs.

The Westside has a population of 173,000, of which 74,000 are employed. Overall, the Westside employs 49,000 persons. Life in the Westside is not focused on any one particular residential or employment center. Rather, activity is wide-spread. The mean population density is about 6,000 persons per square mile. Housing is primarily single family homes and one or two story apartments and condominiums. Commerce is distributed among a number of shopping centers; the largest is the Beaverton Mall. Industry is also scattered, with most businesses housed in industrial parks. Tektronix, the largest employer in the Portland area, is located in the Westside.

5.3.2 System History

Public transportation is provided by the Tri-County Metropolitan Transportation District (Tri-Met),[9] which was formed in 1969. Tri-Met is one of the most creative transit properties in the United States. During the 1970's, Tri-Met created a Transit Mall in the Portland CBD and established a fare free zone focused on the Mall to facilitate downtown circulation.

Prior to the implementation of the timed transfer service, the Westside was served by ten bus routes. Nine routes radiated out from the Portland CBD. Headways varied during peak periods from 10 to 40 minutes and during off-peak periods from 20 to 45 minutes. During the

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[9] Tri-Met serves Clackamas, Multnomah and Washington Counties and has one bus route that crosses the Columbia River to Vancouver, Washington.

peak period, 26 buses left the CBD each hour and headed west. One crosstown route intersected all of the radial routes, providing service to south Portland. The 59 buses assigned to the Westside routes had an average speed of 16.6 miles per hour and averaged 10,583 miles each day.

In this system, although local Westside travel was possible, the service clearly favored the person who traveled between the Westside and the CBD. But, even CBD bound passengers had some difficulties. Inbound buses traversed residential areas to collect bus loads, making travel for outlying passengers quite slow. And outbound Westside passengers often had difficulty boarding buses in the CBD because they were filled with persons traveling shorter distances, some of whom could choose among several bus routes.

5.3.3 Timed Transfer System

The principal motivation for initiating the timed transfer service was to offer Westside residents more travel options and to serve some developing industrial areas. Tri-Met paid particular attention to the needs of non-CBD oriented trips. They established two timed transfer points on the Westside, added new services, reduced headways and redesigned the entire Westside route structure to focus on the transfer points.

5.3.3.1 Route Structure

Tri-Met reconfigured the ten existing routes into a 17-route system. Exhibit 5.26 shows the 17-route system map. Ten of the routes originate at the Portland CBD. Three of the ten provide service to the two Westside timed transfer transit centers. The other seven provide radial service to different parts of the Westside. Three routes provide service between the two transit centers; three routes originate at a transit center and provide local service to parts of the Westside; and one route connects both transit centers and provides crosstown service to the western portion of the service area. Exhibit 5.27 lists the principal characteristics of the nine Westside routes that participate in the timed transfer operation, and shows a schematic illustration of the relationships among these routes.

Tri-Met implemented 20-minute peak hour headways for most routes and 30-minute off-peak headways. One trunk route -- No. 57, Forest Grove -- has six minute headways during morning and evening peaks. This increased peak hour service to the CBD only fifteen percent from 26 to 30 buses per hour, although service to the suburban areas more than doubled.

With two exceptions, round trip route distances are about 20 miles; however, the two exceptions are important. Route 57 is the frequent and heavily used peak-period trunk route between the Portland CBD and the

Exhibit 5.26

PORTLAND BUS ROUTE MAP

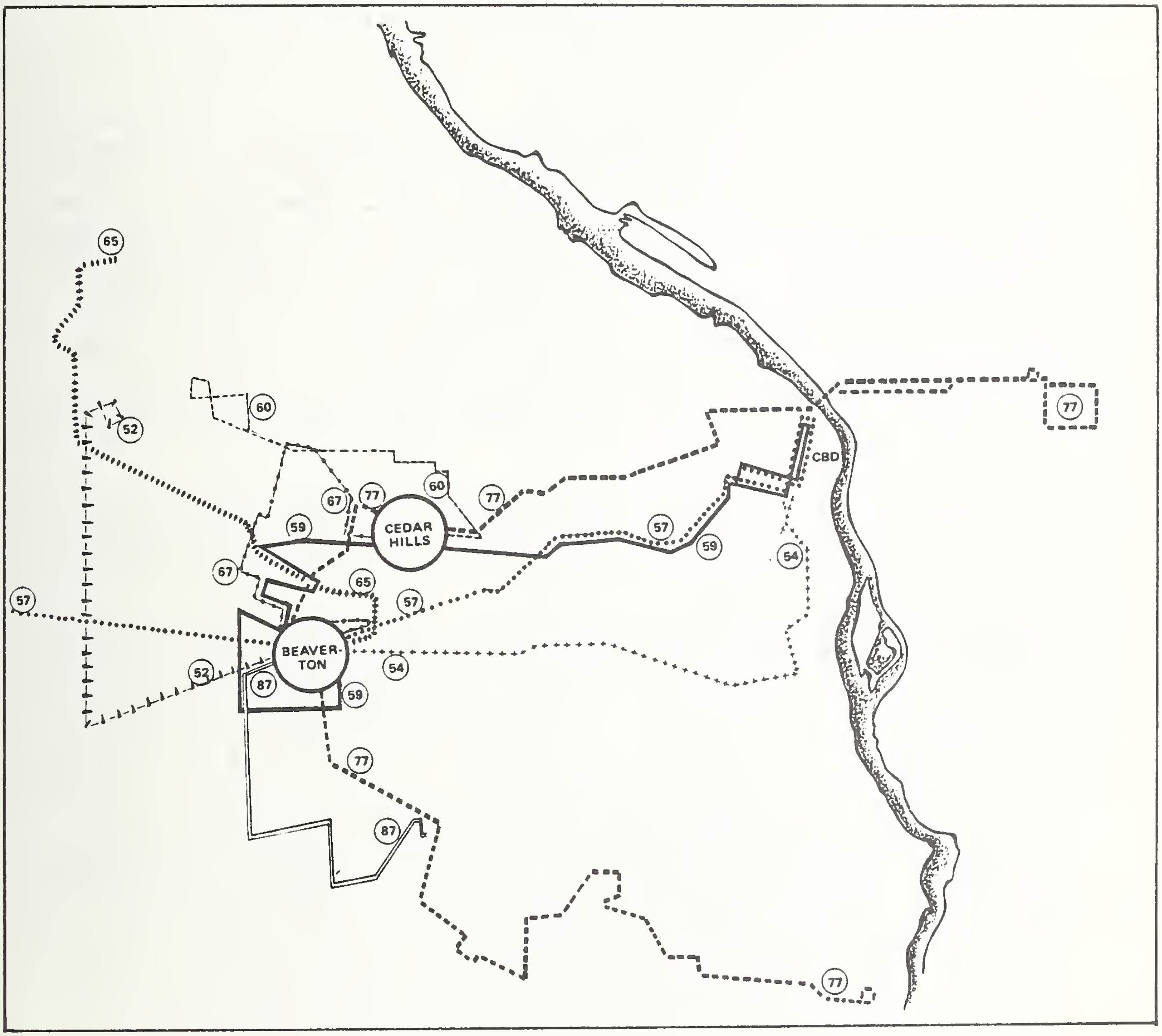


Exhibit 5.27

PORTLAND BUS ROUTE CHARACTERISTICS

Route No.	Name	Headway		Round Trip			Patronage		
		Peak (min)	Off Peak (min)	Distance (miles)	Time (min)	Avg Speed (mph)	Daily	Per Trip	Per Hour
52	Beaverton-Tanasbourne	20	30	17.8	60	17.48	939	12.0	20.9
54	Beaverton Hillsdale Highway	20	30	22.1	90	14.7	841	11.8	14.9
57	Forest Grove	6	30	51.8	150	20.7	7,714	53.6	30.2
59	Cedar Hills	20	30	34.1	120	17.1	2,755	30.6	27.1
60	Oak Hills-Cedar Hills	20	30	15.0	60	15.0	504	6.7	11.2
65	PCC (Rock Creek)-Beaverton	20	30	20.2	60	20.2	656	8.7	15.1
67	Beaverton-Cedar Hills	20	30	18.1	60	18.1	806	9.5	16.5
77	Beltline	20	30	59.6	240	14.9	3,670	39.9	19.4
87	Washington Sq.-Beaverton	20	—	16.9	54	18.8	132	12.0	23.0

Beaverton Transit Center. Some peak period buses turn around at the Beaverton Transit Center, but most continue out to Forest Grove -- a distance of about 14 miles. The other long route is crosstown Route 77. This route extends from Lake Oswego on the south, through both transfer points and across the Willamette River to Providence Hospital which is about four miles east of the Portland CBD. These two long routes carry more passengers than any other routes serving the transit centers.

5.3.3.2 Points, Routes and Schedules

The two timed transfer points are located at Beaverton and Cedar Hills, about six miles west of the Portland CBD. The Beaverton Transit Center is in downtown Beaverton on the Beaverton-Hillsdale Highway, a little less than a mile from the Beaverton Mall. The Cedar Hills Transit Center is just behind the Cedar Hills Shopping Center. Each center contains a sawtoothed curb (Exhibit 5.28) to facilitate bus pull in and pull out, bus shelters and schedule displays. Bus operations are coordinated at each timed transfer point so that while buses are at the transfer point, passengers can transfer between any pair of buses.

Exhibit 5.29 illustrates scheduled operations at the Cedar Hills and Beaverton Transit Centers between 7:00 and 8:00 AM on a weekday. Each bus route is assigned a concentric ring. The shaded areas designate the periods when a bus is at the transit center.

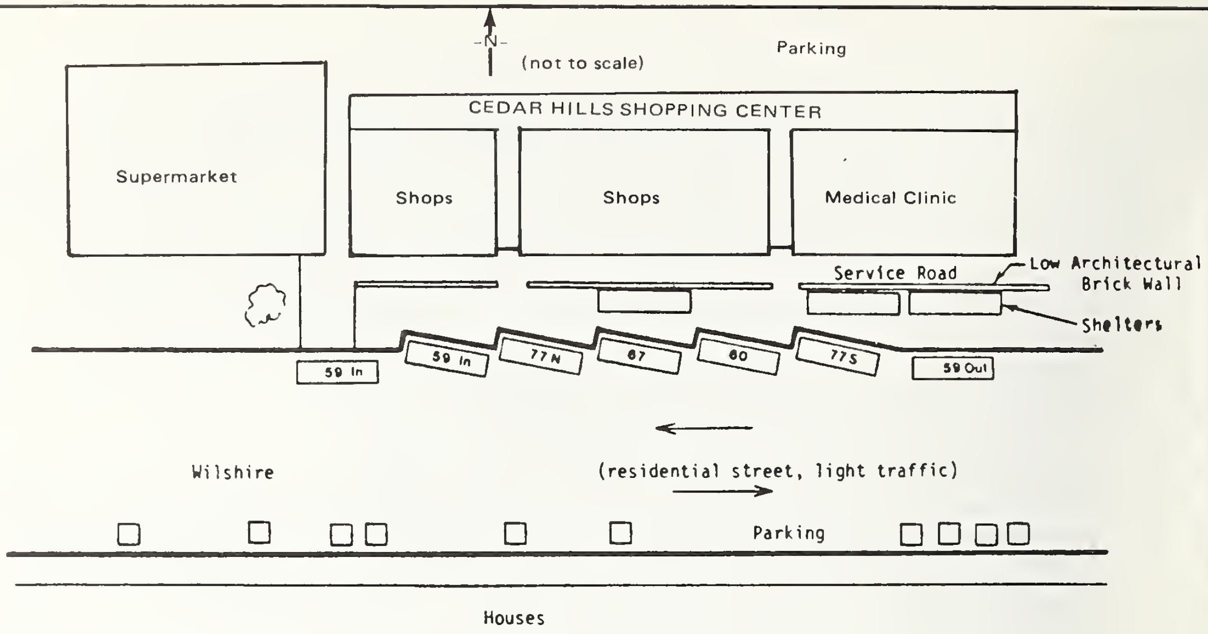
At Cedar Hills, there are three timed transfers between 7AM and 8 AM: one at 7:14, one at 7:34 and one at 7:54. Buses serving route 67 have the longest dwell times -- typically 9 minutes. Scheduled dwell times for Route 60 buses are only two minutes. During off peak periods, there are only two meets per hour.

The timed transfer operation at the Beaverton Transit Center is considerably more complex than the one at Cedar Hills. As shown in Exhibit 5.29, ten different buses participate in each timed transfer at Beaverton between 7 AM and 8 AM. Buses for the first meet depart at 7:16, those for the second meet at 7:36, and those for the third meet at 7:56. Individual buses are scheduled for slight variations. Scheduled dwell times vary between three and 15 minutes, with most about nine minutes. Route 57 buses depart so frequently during the peak period that they do not wait for individual timed transfers to occur. Instead, they proceed along their routes as quickly as possible.

5.3.3.3 Summary

On the strength of the Westside system, Tri-Met established four more transfer points on the eastside of Portland in June 1981. If these, too, are successful, Tri-Met will continue to develop a comprehensive timed transfer service throughout the Portland Metropolitan area.

Exhibit 5.28



CEDAR HILLS TRANSIT CENTER

BEAVERTON TRANSIT CENTER

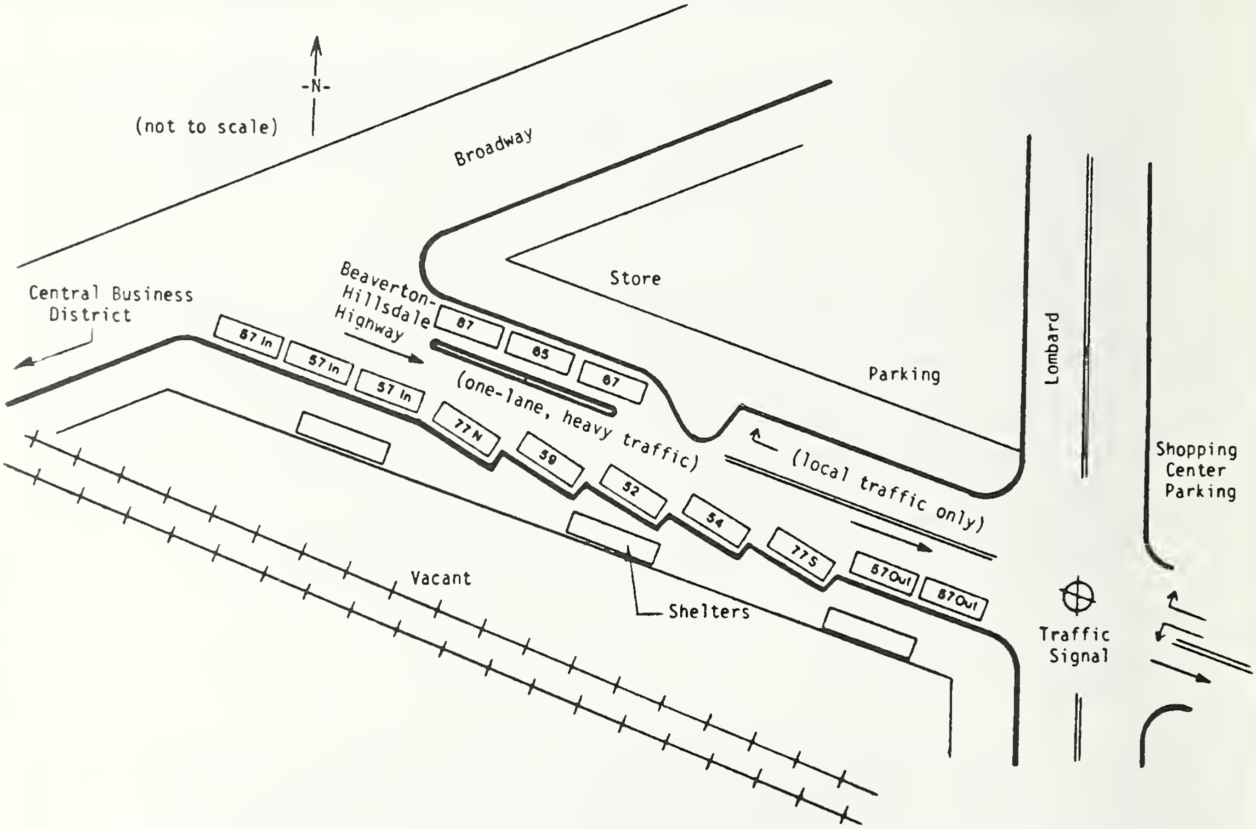
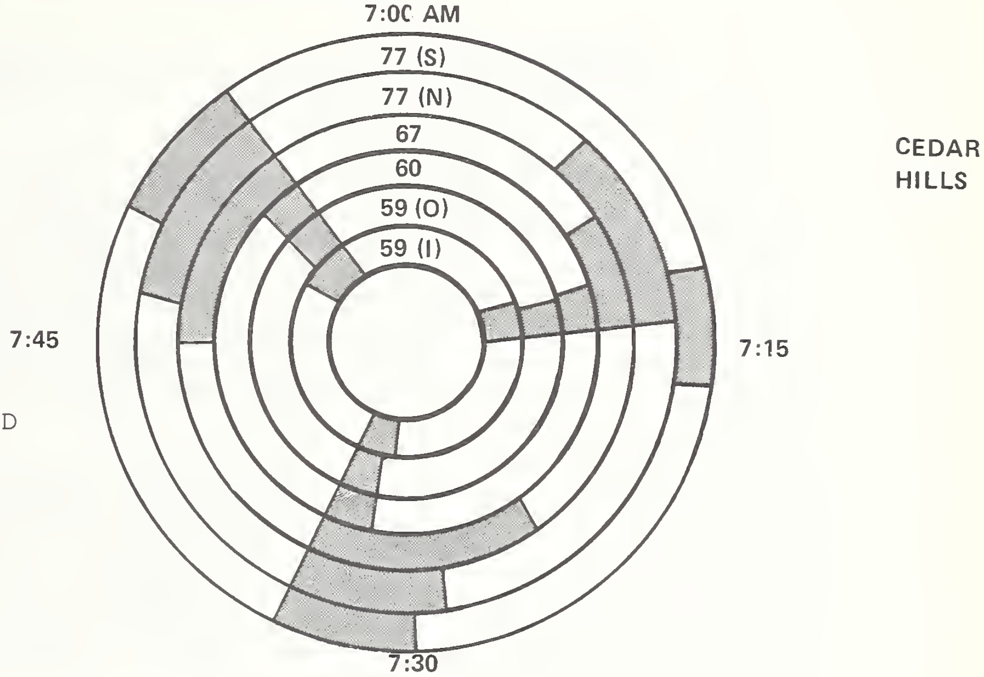


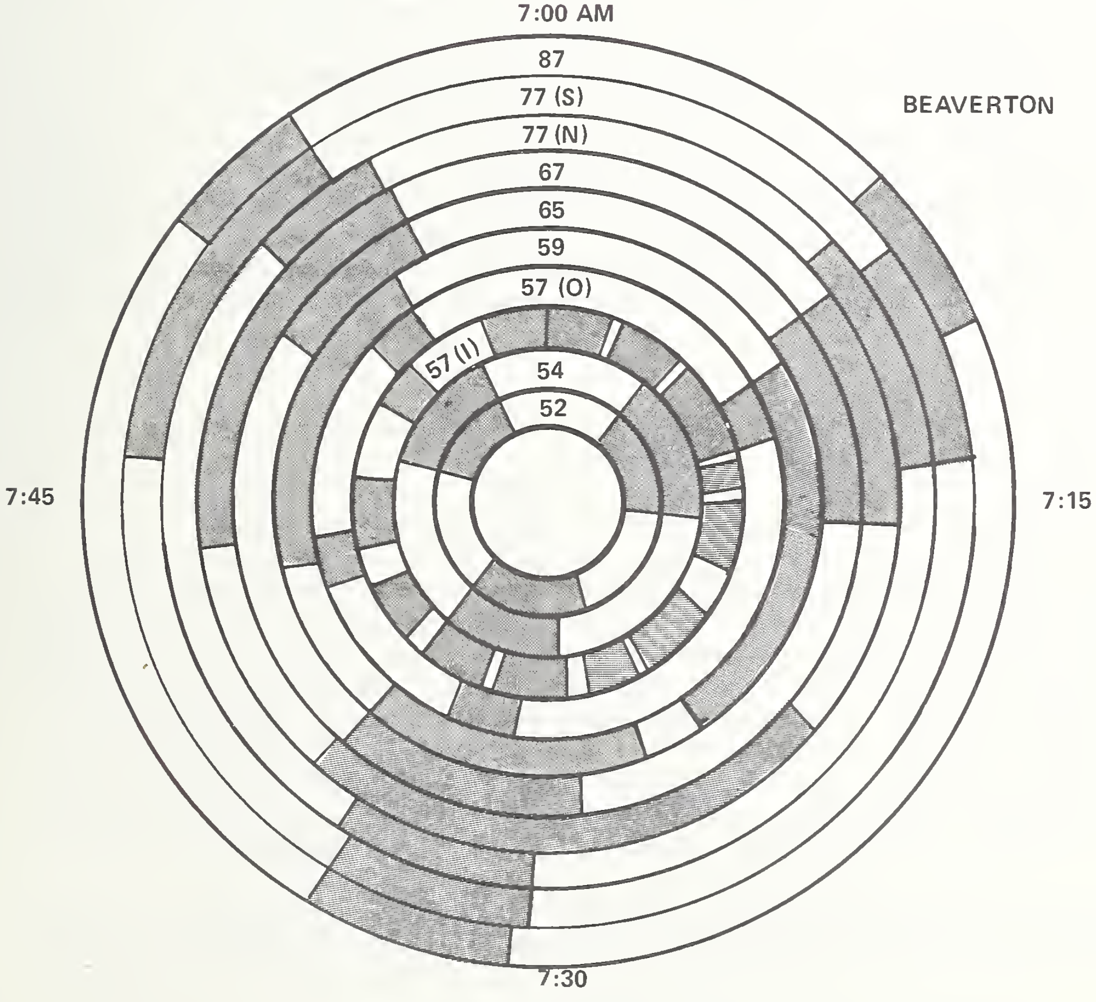
Exhibit 5.29

PORTLAND TIMED TRANSFER SCHEDULES
7:00 TO 8:00 AM, WEEKDAY

LEGEND:

▨	Scheduled Timed Transfer Layover Time
52	Route Number
(I)	Inbound to CBD
(O)	Outbound from CBD
(N)	Northbound
(S)	Southbound





5.3.4 Ridership Impacts

5.3.4.1 Impacts on Transit Users

Tri-Met expanded and redesigned their entire Westside system in 1979 to accomodate growing and diverse Westside travel patterns. Most routes are now scheduled to exchange passengers every 20 minutes during the peak and every 30 minutes during the off-peak at Westside Transit Centers. Other Westside routes never go to either the Beaverton or the Cedar Hills transfer points and provide direct passenger service. This combination of services significantly increased the level of transit to the Westside, especially for riders traveling between outlying locations.

To help riders adjust to the changes in the system, Tri-Met launched an aggressive marketing campaign. The marketing division coordinated the design of route maps, schedules and signs and sponsored meetings to explain the new system. When the services began, Tri-Met also assigned staff to the Transit Centers to answer questions, distribute information and assist riders in making their transfer connections.

Based on informal passenger interviews conducted at the Beaverton transfer point in 1981, most passengers favor the timed transfer service. As summarized in Exhibit 5.30, 73 percent of the passengers interviewed said that timed transfer works all or most of the time; 71 percent considered timed transfer to be more convenient than conventional transit service; and 82 percent said that the new service met their travel needs. Of the travelers interviewed, only 23 percent were able to make their trips without transferring. Most, 64 percent, made one transfer. Only a handful, 13 percent, were required to make two or more transfers. Fifty-five percent of the transfers were between a local route and a trunk line and 45 percent were between two trunk lines. There were no transfers between two local routes.

5.3.4.2 Impact on Portland Patronage

In the Spring of 1979, before Tri-Met implemented timed transfer in the Westside of Portland, the Westside service carried about 14,000 passengers per weekday. These riders accounted for about 10.6 percent of the entire Tri-Met ridership, which averaged 132,000 passengers each weekday. These counts are based on the number of originating or linked trip passengers. At this time, Tri-Met was not coordinating passenger transfers in terms of their routes or schedules in the Westside or in the overall system. In the overall system, about 17,700 originating passengers transferred each weekday, a rate of about 13.4 percent. On the Westside, approximately 1,500 passengers transferred each weekday, for an originating passenger transfer rate of 10.65 percent.

During the Summer of 1979, Tri-Met expanded services and implemented a timed transfer system on the Westside of Portland. Before

Exhibit 5.30

PASSENGER ATTITUDES (WESTSIDE PORTLAND)

- Does timed transfer work?

All of the time	29%
Most of the time	44%
Sometimes	11%
No opinion	16%

- Is the timed transfer service more convenient than conventional service?

Yes	71%
No	12%
No opinion	17%

- Does the timed transfer service meet your travel needs?

Yes — 82%; Sometimes — 3%; No — 14%; No opinion — 1%

Why?		Why not?	
Convenient	49%	Weekend service not dependable	21%
Goes where desired	9%	Service times not convenient	21%
Goes when desired	11%	No late night service	21%
Inexpensive	11%	Buses don't wait	17%
Other	20%	Other	20%

- How many transfers will you make on this trip?

None	23%
One	64%
Two	11%
Three or more	2%

- Did you have an automobile available for this trip?

Yes	50%
No	44%
No response	6%

timed transfer, Tri-Met operated an average of 640 hours and about 10,600 miles of service each weekday. After timed transfer Tri-Met operated an average of 960 hours and 14,900 miles of service each weekday. This expansion represents a 34 percent increase in hours and a 29 percent increase in mileage on the Westside.

Ridership on the Westside increased. By the Spring of 1980, Westside patronage was about 19,000 originating riders per weekday. Comparing ridership figures with a year earlier, this represents an increase of 26 percent. The transfer rate also jumped substantially on the Westside. By the Spring of 1980, approximately 2,800 passengers were transferring on the Westside, an increase of 47 percent from the previous year. Transferring passengers thus were representing almost 15 percent of the Westside's originating riders by 1980. Tri-Met also found that local trips and non-work trips, two key timed transfer ridership markets, increased with the new services. In fact, estimates show up to 49 percent increases occurred during the mid-day period. Commuter trunk route trips to and from downtown Portland also increased.

By comparison, the overall Tri-Met system increased service by about three percent and overall ridership grew almost ten percent between 1979 and 1980. The Tri-Met transfer rate, however, increased less than two percent. Tri-Met's overall system figures include the Westside; and Tri-Met estimates half of the system's increase results from the Westside. The system's growth is also attributed to increased local gasoline costs and local marketing efforts.

To understand the relative productivity of ridership on these services, the number of passengers per vehicle hour was calculated as follows:

(Before: Spring 1979)

14,024 Westside Passenger Trips : 637 Vehicle Hours = 22.0 Trips/Hour

132,234 System Passenger Trips : 5,022 Vehicle Hours = 26.3 Trips/Hour

14,024 Westside Passenger Trips : 10,583 Vehicle Miles = 1.33 Trips/Mile

(After: Spring 1980)

18,900 Westside Passenger Trips : 959 Vehicle Hours = 19.7 Trips/Hour

146,108 System Passenger Trips : 5,164 Vehicle Hours = 28.3 Trips/Hour

18,900 Westside Passenger Trips : 14,887 Vehicle Miles = 1.27 Trips/Mile

Before the timed transfer expansion, productivity on the Westside averaged 22 passenger trips per hour. In 1980, although ridership on the Westside had increased 26 percent, productivity dropped to 20 passenger trips per hour, a ten percent decline from the earlier period. This was due to the tremendous increase in the level of Westside service hours.

By comparison, in 1980, the overall system productivity averaged 28 trips per hour, an increase of seven percent over the previous year. An analysis of the Westside and the Tri-Met services indicates that while in 1979 the Westside ridership was less than 11 percent of the overall system, it accounted for almost 13 percent of the service and resulted in 16 percent lower productivities. By 1980, the Westside grew to 19 percent of Tri-Met's vehicle hours of service and 13 percent of all riders, resulting in a 30 percent difference in productivity.

However, if another measure, vehicle-miles, are analyzed, the expanded services fare much better. Before timed transfer the Westside carried 1.33 trips per mile versus after timed transfer it carried 1.27 trips per mile, a difference of less than five percent. The difference in the vehicle-hour and vehicle-mile productivity measures can be explained by the additional time required for the buses' layover times at the transfer point.

Exhibit 5.31 illustrates some patronage trends on different Tri-Met services since the implementation of timed transfer. An analysis of the long-term impacts indicates that by the Winter of 1981, the Westside service had not experienced any more growth than other Tri-Met services. This is due primarily to a levelling off of the Westside ridership and a continuing increase in all other Tri-Met services' ridership.

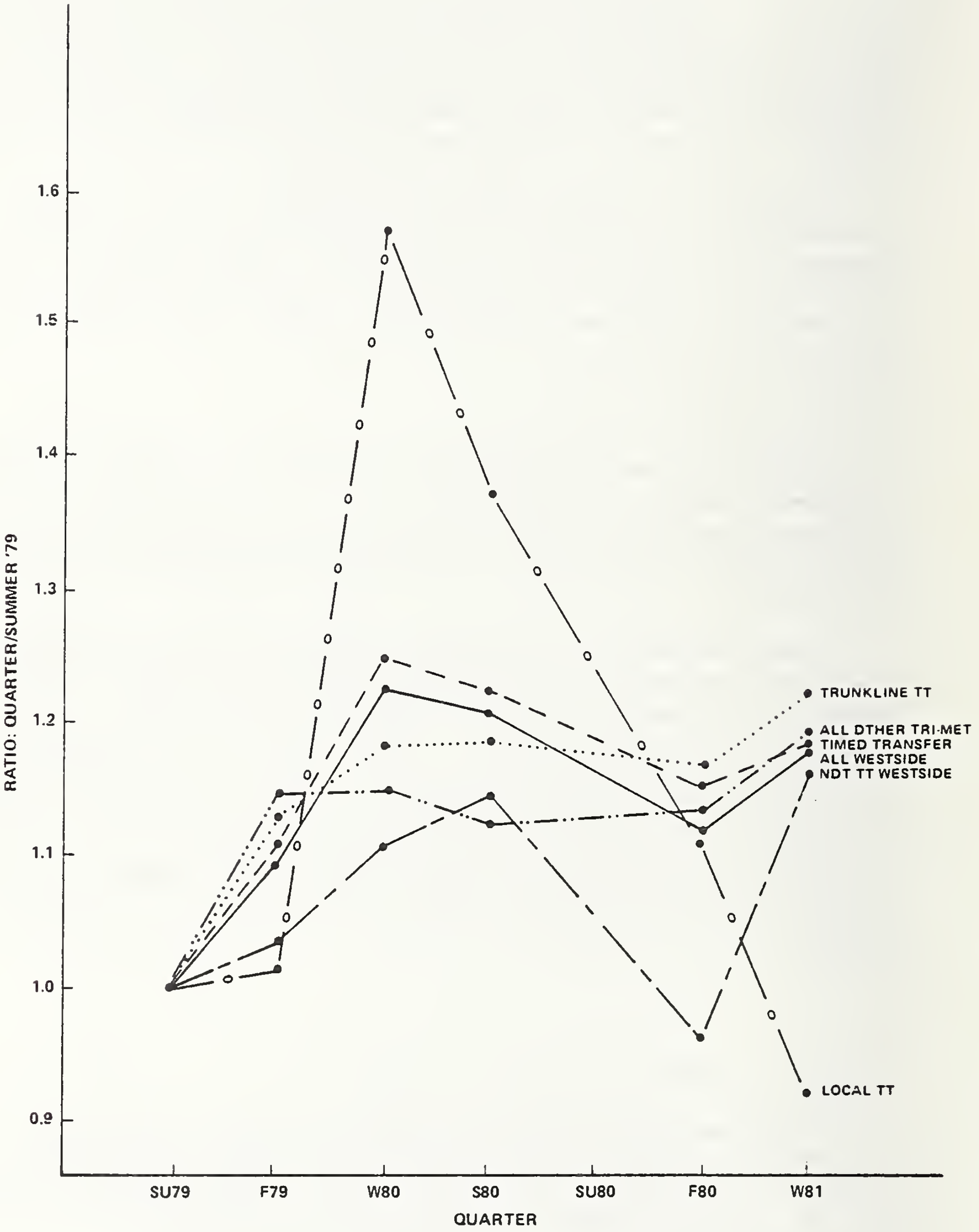
Some interesting differences, however, can be observed within the Westside. Patronage on routes that serve the timed transfer points has grown faster than all Westside patronage. Non-timed transfer patronage lagged particularly during the winter and fall of 1980 while patronage on trunk lines that serve the timed transfer points generally outstripped timed transfer growth as a whole. Patronage growth on local lines that serve timed transfer points was very erratic. There was little growth through the fall of 1979 and then ridership spurted to a level 57 percent above the summer of 1979. It then declined almost as quickly reaching a level in the winter of 1981 that was below the summer of 1979.

5.3.4.3 Impact on Passenger Activity

Passenger boardings and disembarkings were recorded on June 2 and 3, 1981. The Beaverton and Cedar Hills Transit Center both support substantial volumes of passenger traffic. Mean activity by bus route is listed in Exhibit III in Appendix C for the morning peak, off-peak and afternoon peak periods. Mean daily volumes were:

Exhibit 5.31

PATRONAGE TRENDS AFTER TIMED TRANSFER IMPLEMENTATION (PORTLAND)



	Beaverton	Cedar Hills
Passengers arriving on buses	4,302	1,820
Passengers disembarking	2,296	826
Passengers boarding	2,570	834
Passengers leaving on buses	4,576	1,828

Overall, Beaverton had about 2.8 times more activity than Cedar Hills. Eight bus routes serve Beaverton, including the very active Forest Grove, Route 57, while only four serve Cedar Hills. At both timed transfer points, almost half of the passengers disembarked and boarded departing buses. Many passengers originated or terminated their trips at a timed transfer point, but the vast majority of passengers transferred. Some disembarking passengers at Cedar Hills entered the shopping mall and returned later to board an outbound bus.

Local service routes discharged all passengers and took on new loads at the transit centers. For example, during the morning peak Route 52 picks up mostly Westside residents along the route who transfer at Beaverton to trunk lines. The traffic reverses during the afternoon peak with substantial numbers of passengers boarding at Beaverton for residential destinations. There was a considerable amount of off-peak activity on all of the local routes.

The trunk Routes carried the largest loads during the morning and evening peaks. Routes 54 and 57 carried heavy inbound loads in the morning and heavy outbound loads in the afternoon. Almost 40 percent of the busloads departing in the morning boarded at Beaverton and over 60 percent of loads arriving in the afternoon disembarked there. Route 59, which serves both Beaverton and Cedar Hills, picked up most of its passengers between the two timed transfer points and traffic on crosstown Route 77 was reasonably constant throughout the day. Off peak service for trunk routes was also good.

5.3.5 Relative Speed and Quality of Service

5.3.5.1 Alternative Travel Speeds

A sample of trips was analyzed to estimate how passenger travel in the Westside area was affected by the introduction of the timed transfer system. Trip ends and locations were based on the population distributions estimated by the Columbia Region Association of Governments (CRAG) in 1978.[10] The methodology for matching and

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[10] Population and employment densities are identified in Columbia Region Association of Governments (CRAG), The Inner Southwest Subarea: Reference Guide to Travel Factors, Portland, OR: June, 1978; CRAG, The Inner West Subarea, Portland, OR: June, 1978; and CRAG, The Outer West Subarea, Portland, OR: June, 1978.

calculating Portland's trip ends and sample trips is explained in Section 1.2.4.

The results of the sample trips are listed in Exhibit III in Appendix D. The three travel alternatives are: (1) automobile; (2) Tri-Met timed transfer service in June 1979; and (3) Tri-Met service prior to June 1979. Sample trip lengths vary from 1.5 to 13.8 miles. Reflecting the suburban nature of the Westside, the mean trip length of 6.7 miles was longer than the average trip length of five to six miles for all Portland area trips.

The automobile was the fastest transportation mode for all trips. Average automobile speeds were high, reflecting the good highway network on the Westside, although work trips to the Portland CBD were somewhat slower due to peak hour congestion. Bus travel was reasonably competitive with automobile travel for short trips and for routes which followed highways or major roads. Bus travel was comparatively slow for crosstown trips.

Nine of the sample trips could be served by direct bus service on both transit systems. Direct trip times were only slightly shorter than the direct and transfer trips combined. Mean trip length was 5.3 miles for the direct trips versus 6.7 miles for all sample trips. Bus routes and travel times via the new and old systems were identical for four of the direct trips. Of the remaining direct trips, the timed transfer route structure was faster than the old route structure for three trips and slower for two trips. The net difference is slight, but favors the timed transfer system. Mean travel time was 26.3 minutes for the timed transfer trips versus 27.1 minutes for the previous system trips. This suggests that timed transfer may not adversely affect travel times for passengers who previously received direct service.

5.3.5.2 Transfers Required

The eleven remaining trips required transfers. Eight of the timed transfers occurred at the Beaverton Transit Center. None of the sample trips that were direct before June 1979 required a transfer after timed transfer and vice versa.

Bus travel times to the Portland Airport were the same, because this predominantly eastside trip used the same routes and schedules for both bus options. Timed transfer provided substantial improvements in trip time over the previous system structure for four trips (15 to 33 percent reduction in trip time). The previous system had shorter travel times on three trips with the differences in trip times equivalent to the delay time at Beaverton.

The longest timed transfer trips all included transfers to and from Route 77, the crosstown route, which is not perfectly integrated with the other timed transfer routes. Two transfers with Route 77 required 15 minute waits at Beaverton. Overall, trip times improved about 2 percent with the implementation of timed transfer.

5.3.5.3 Convenience of Service

The convenience of timed transfer and previous transit trips can be determined by computing ratios of elapsed times for these bus trips to elapsed times for automobile trips. Elapsed time is the sum of vehicle travel time, walk time and waiting (or early arrival) time. These ratios, displayed in Exhibit 5.32, range from 1.38 to 4.67 for timed transfer service, and from 1.29 to 4.42 for the previous bus service. The mean value for timed transfer trips (3.00) was slightly lower than that for the previous service (3.02), which suggests that the timed transfer service is slightly better overall than the conventional service that it replaced.

5.3.6 Bus Performance

On-time schedule performance is difficult to maintain in Portland. Downtown traffic congestion often delays trunk routes during peak periods. Route 77 is particularly difficult because it is long, meandering and serves both timed transfer points. In addition, central dispatchers do not have full control over timed transfer meets because only 115 of Tri-Met's 550 buses are equipped with radios.

5.3.6.1 Driver's Responsibility

Tri-Met realized the importance of the operator's participation in timed transfer and carefully trained the initial drivers in the timed transfer system. Full-time supervisors (two shifts) were also stationed at both timed transfer points to coordinate the transfers and to deal with driver problems. Unfortunately, drivers selecting timed transfer routes on subsequent bids and extra board drivers could not be equally trained, and on-site supervisors were reduced to roving supervisors, after the first year.

5.3.6.2 Individual Route Performance

Exhibit 5.33 shows the schedule performance for each bus route serving the Beaverton and Cedar Hills Transit Centers. The cross-notched vertical bars mark the frequency of arrivals at different times before and after the scheduled arrival times. The shaded vertical bars give the same information for departures. The vertical solid and dashed lines mark the mean arrival and departure time for each bus route.

Service reliability varied from route to route. A predominant number of buses departed on time; mean departure times were never as much as one minute after scheduled departure times. Most buses arrived either on time or early; mean arrival times were all one minute or more before scheduled arrival time.

Exhibit 5.32

CUMULATIVE DISTRIBUTION BUS/AUTOMOBILE ELAPSED TIME RATIO (PORTLAND)

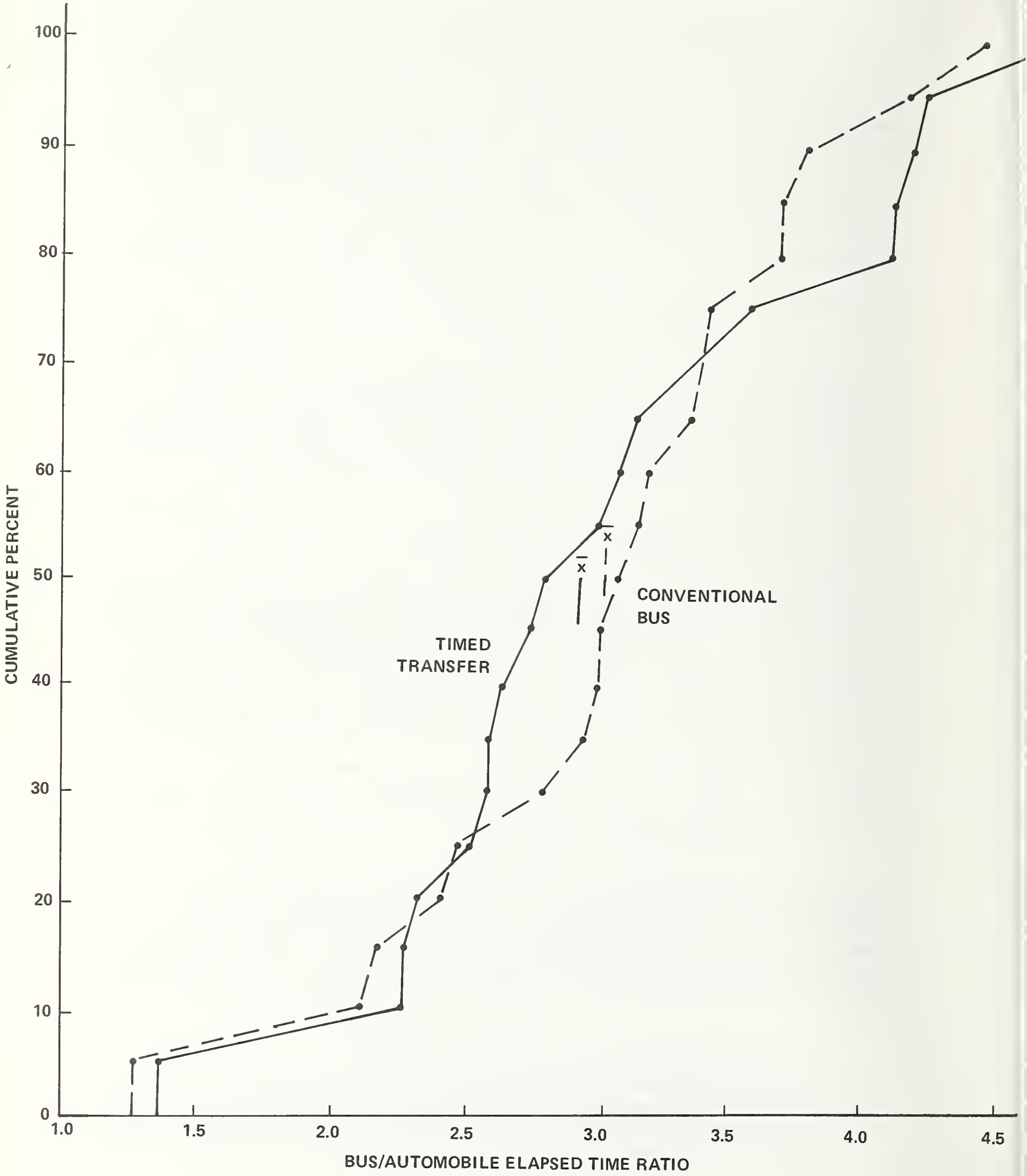
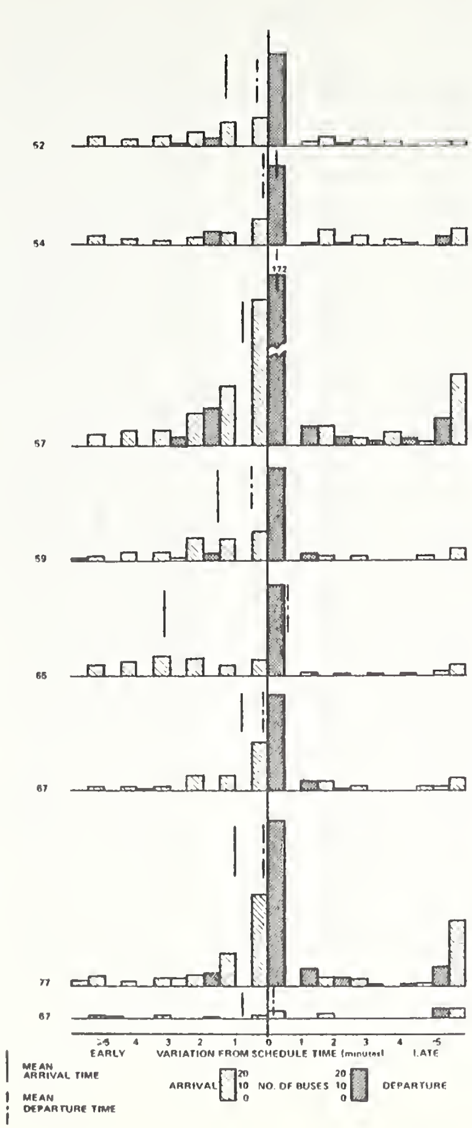
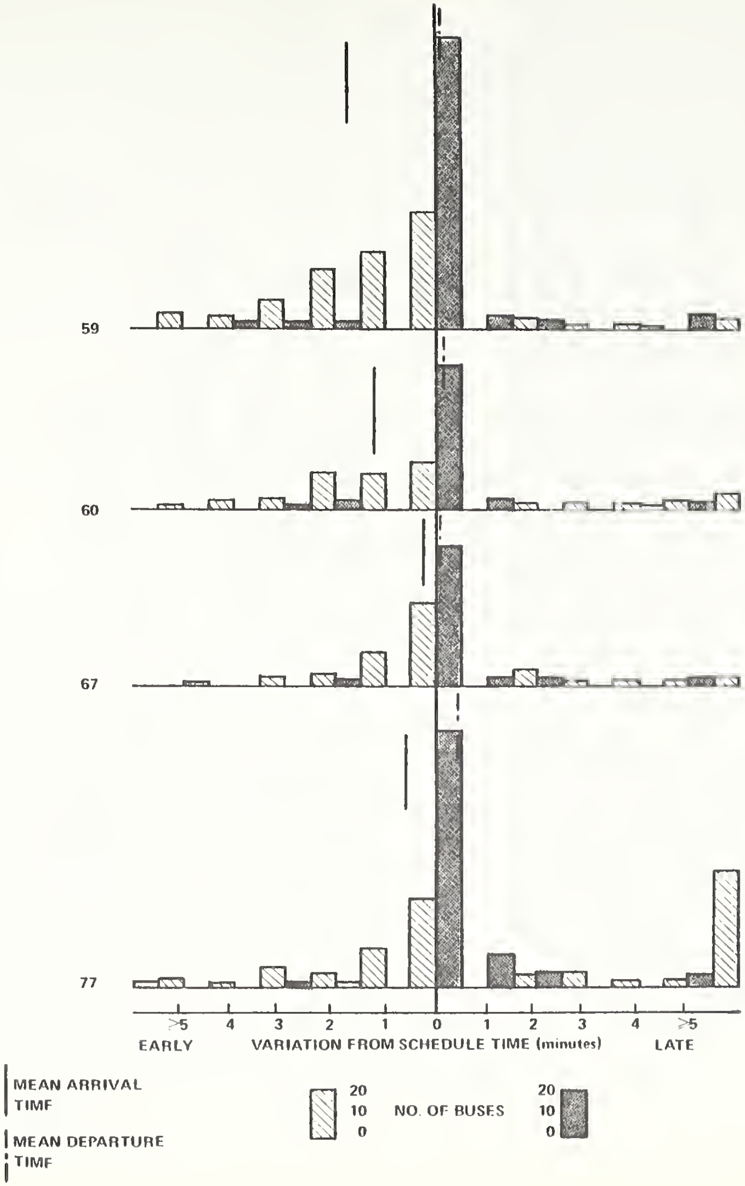


Exhibit 5.33

BUS SCHEDULE PERFORMANCE BY ROUTE (BEAVERTON TRANSIT CENTER)



BUS SCHEDULE PERFORMANCE BY ROUTE (CEDAR HILLS TRANSIT CENTER)



Major deviations from schedule performance occurred on Routes 57 and 77. Both Routes had a number of buses arriving more than 5 minutes late. Route 57 buses were delayed during the evening peak by downtown traffic. However, these delays did not compound from run to run. Checks of downtown departures revealed that most buses left on time throughout the evening peak, with only a few one or two minutes late. Route 77 buses also had difficulties in the afternoon peak because of the length and circuity of their routes. Travel speeds were sensitive to traffic conditions; however, this did not compound because the long round trip spanned the evening peak.

5.3.6.3 Overall Schedule Performance

Tri-Met checked all bus connections over a three day period in the Spring of 1980 with the following results:

Percent of:	Beaverton	Cedar Hills
Successful Connections*		
Weekday	98	98
Saturday	92	100
Sunday	81	100
Successful Meets**		
Weekday	75	93
Saturday	76	100
Sunday	25	100

* A Successful Connection occurred if the later arriving bus opened its doors at least one minute before the earlier departing bus closed its doors.

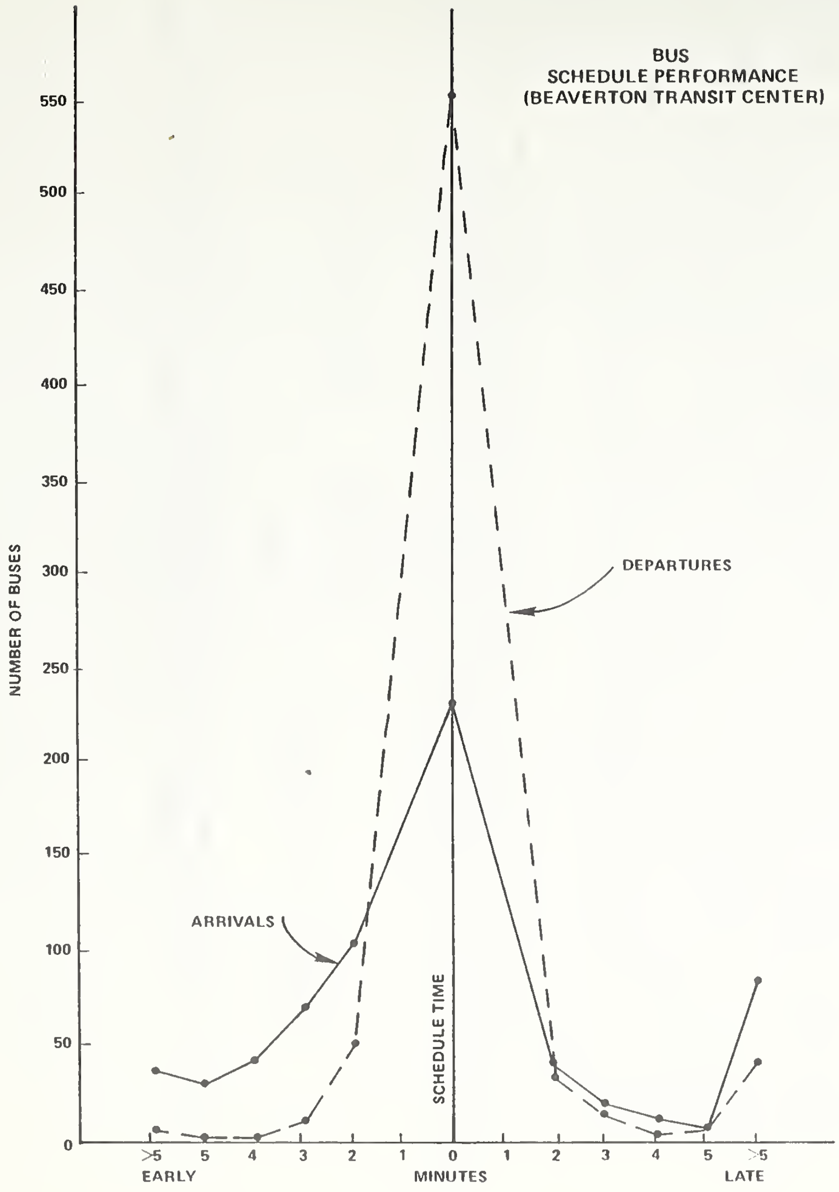
** A Successful Meet occurred if all possible connections between participating buses could be made.

The results indicate the timed transfers were well executed, particularly at Cedar Hills. There were some problems, especially at Beaverton on Sundays. The problems at Beaverton concerned connections between local and trunk routes.

To improve performance, Tri-Met made periodic schedule adjustments. Transfer windows were lengthened about two minutes and trunk line schedules were relaxed during peak periods. Sunday operations were particularly troublesome because of the infrequency of service -- most missed transfers imposed a one hour wait on transferring passengers. Tri-Met attacked this problem through a combination of driver education and motivation. It was uneconomic to increase Sunday supervision.

Bus performance was again measured on two weekends in June 1981. The specific data collected and analyses conducted are described in Section 1.2.4. As shown in the two graphs in Exhibit 5.34, one third of

Exhibit 5.34


BUS
SCHEDULE PERFORMANCE
(BEAVERTON TRANSIT CENTER)


BUS
SCHEDULE PERFORMANCE
(CEDAR HILLS TRANSIT CENTER)

all buses arrived within one minute of their scheduled arrival times. An additional 41 percent arrived early. Thus, the full transfer window was available for passengers on three fourths of the buses. Of the late buses, 40 percent were less than five minutes late. The remaining buses had the potential of causing transfer problems, although no buses were more than 15 minutes late. After all transfers were completed, most buses (77 percent at Beaverton and 83 percent at Cedar Hills) departed on time. A small number of buses (9 percent at Beaverton and 5 percent at Cedar Hill) left prior to the scheduled time. In all observed instances, all timed transfers were complete before departure.

Exhibit 5.35 illustrates the cumulative distribution of layover times (departure time-arrival time) of all buses serving Beaverton and Cedar Hills. The minimum layover time was one minute. About one-half of all layovers were 5 minutes or less. Layovers on trunk routes were significantly shorter than layovers on local routes, averaging 4.2 minutes and 9.3 minutes, respectively. Timed transfer operations often schedule local route endpoints and layovers at timed transfer points to allow shorter layovers for through routes. Layovers at Cedar Hill were shorter (mean time = 5.4 minutes) than those at Beaverton (mean time = 6.4 minutes). Layovers at Cedar Hills were also more uniform than layovers at Beaverton, as indicated by the steeper slope of the line in Exhibit 5.35 for Cedar Hill.

5.3.6.4 Missed Transfers

Very few passengers missed their transfers during the two observation days. Only five out of 1667 passengers boarding at Cedar Hills missed their transfers -- 0.3 percent. The performance at Beaverton was not quite as good. The late arrival of a Route 57 bus stranded twelve passengers for a time. The most frequent problems occurred with Route 77 where four instances of late arrivals caused inconvenience for several passengers. In all, 49 passengers missed timed transfers, representing just under one percent of the 5,139 persons who boarded buses at the Beaverton Transit Center.

Equating each missed transfer as a missed connection, then there were five missed connections out of 399 bus departures at Cedar Hills and 16 missed connections out of 690 bus departures at Beaverton. This produces the following reliability measures:

	Beaverton	Cedar Hills
Successful Connections		
Weekday	98%	99%

These values are comparable to measurements taken by Tri-Met in the spring of 1980.[11] Observations and passenger comments suggest that there

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[11] Tri-Met, op. cit.

Exhibit 5.35

CUMULATIVE DISTRIBUTION OF LAYOVER TIMES (PORTLAND)

may still be bus meet and transfer connection problems on Sundays.

5.3.6.5 Summary

Overall, timed transfer bus performance is reliable in Portland. Exhibit 5.36 illustrates the performance at both timed transfer points between 7:00 and 8:00 AM on the morning of June 3, 1981. A comparison of Exhibit 5.36 with Exhibit 5.29 shows the actual versus the scheduled performance on these routes in the morning. With one exception, on-time performance at Cedar Hills was good. The Route 60 bus scheduled to arrive at 7:12 was four minutes late and missed transfers with all buses except the Route 77 (south). This did no damage because the Route 60 bus arrived empty from the garage. The one passenger seeking to transfer to Route 60 was accommodated. Otherwise, buses arrived at Cedar Hills on time or up to three minutes early and departed on time. Service at Beaverton was also good, with one exception. The Route 87 bus scheduled to arrive at 7:31 and depart at 7:34 never arrived. Otherwise, buses arrived on schedule or a few minutes early and they departed on schedule.

5.3.7 Impact on Costs

5.3.7.1 Site-Specific Factors

Tri-Met added new transit services and achieved a substantial increase in patronage and a high level of passenger acceptance with their new timed transfer system in the Westside. This success was achieved at high costs.

5.3.7.2 Capital Costs

The following capital and start-up costs were incurred with the introduction of timed transfer services in 1979:

Shelters	$10,000
Curb modifications, Signs	$90,000
Marketing	$50,000
Driver Training	$160,000
Extra Supervision	$110,000

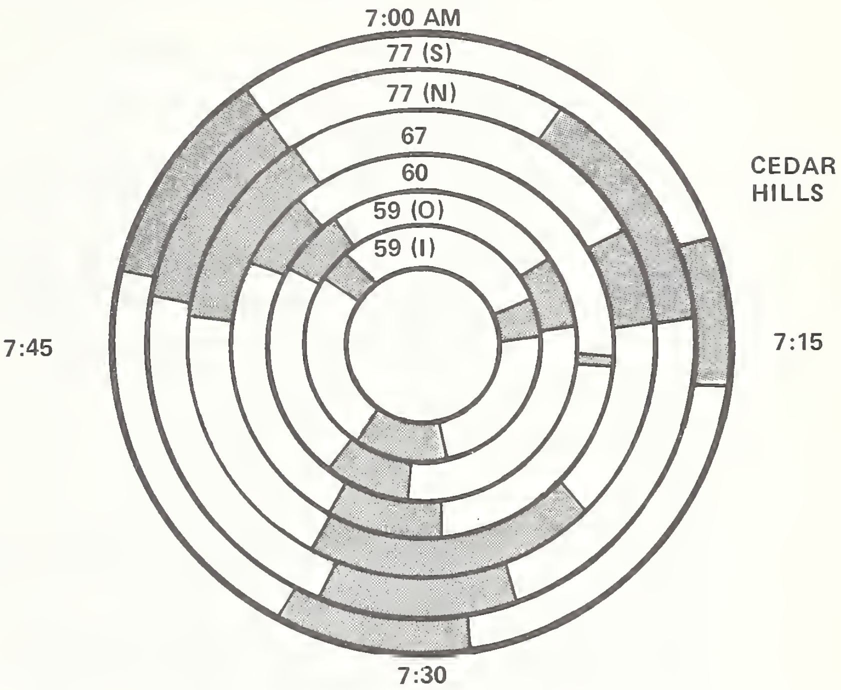
	$420,000

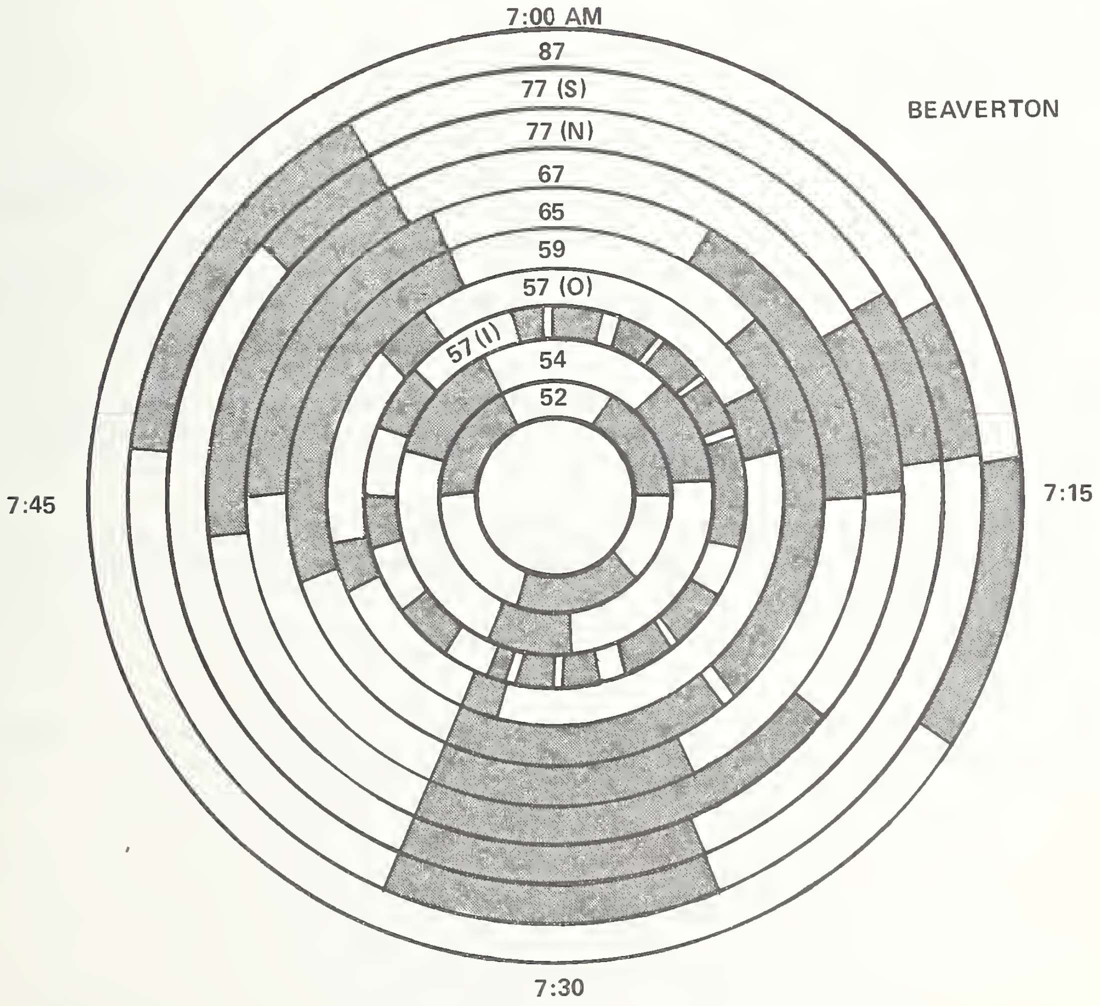
Also, Tri-Met leased 27 surplus buses from Seattle and hired additional drivers to operate them. These costs, however, were directly associated with an increase in the level of service, as shown in the following table:

Exhibit 5.36 – TIMED TRANSFER SCHEDULE PERFORMANCE (PORTLAND)
7:00 TO 8:00 AM, WEDNESDAY, JUNE 3, 1981

LEGEND:

▨	Observed Timed Transfer Layover Time
52	Route Number
(I)	Inbound to CBD
(O)	Outbound from CBD
(N)	Northbound
(S)	Southbound





	Pre-timed Transfer	Timed Transfer	Percent Change
Buses	59	86	+45.8
Vehicle-hours/weekday	637	959	+50.5
Vehicle-miles/weekday	10,583	14,887	+40.7

Average bus speed decreased by about 7%, reflecting the layover times spent at transfer points, and a reduced fraction of running time spent on expressways.

5.3.7.3 Operating Statistics

Some operating statistics for the Westside as well as Tri-Met's systemwide services are listed in Exhibit 5.37, comparing weekday data of 1979 and 1980. On the Westside, the increase in the level of service was accompanied by a similar growth in operating costs. At the same time, weekday ridership increased substantially, which resulted in only marginal changes in overall productivity.

5.3.8 Conclusions

The Portland timed transfer service appears to be successful. Observed bus performance is good. Passenger responses also indicate that buses adhere to schedule. Although some of the increased patronage may be due to better coverage rather than to timed transfer, the Westside service has attracted a substantial number of new riders and the quality of the service has retained these riders for over two years.

The sample trip analysis also indicated timed transfer has had a small positive impact on travel time. Nonetheless, the psychological impact seems strong. Riders perceive timed transfer service as being better than conventional service.

Finally, timed transfer cost appear justifed in terms of the increased number of trips. Thus, timed transfer has helped Tri-Met to better serve one suburban area.

Exhibit 5.37

TRANSIT COST AND PERFORMANCE

(PORTLAND - WESTSIDE)

Statistics (per weekday)	Spring 1979		Spring 1980	
	Westside	Portland	Westside	Portland
Operating Cost Change	$16,800	$130,900	$24,600 (+46%)	$145,000 (+10%)
Originating Passengers Change	14,024	132,234	18,900 (+35%)	146,108 (+10%)
Bus Hours Change	637	5,022	959 (+50%)	5,164 (+ 2%)
Bus Miles Change	10,800	69,600	14,500 (+34%)	76,900 (+10%)
Passengers per Bus Hour	22.0	26.3	19.7	28.3
Passengers per Bus Mile	1.3	1.9	1.3	1.9
Operating Cost per Bus Hour	$26.40	$26.00	$25.65	$28.00
Operating Cost per Bus Mile	$1.55	$1.88	$1.70	$1.88
Operating Cost per Passenger	$1.20	$ .99	$1.30	$ .99

Source: Tri-Met Service Planning Department, "Westside Service Evaluation: An Assessment of Timed-Transfer Service in the Suburban Westside", October, 1980.

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Appendix A

DATA COLLECTION FORMS AND ADJUSTMENTS

Exhibit I:	RELIABILITY DATA: SAMPLE SYSTAN FORM
Exhibit II:	CHECK OF TIME AND PASSENGERS: SAMPLE RTD FORM
Exhibit III:	ADJUSTMENT FACTORS FOR BIASES IN RTD PASSENGER DATA

Exhibit I

TIMED TRANSFER RELIABILITY DATA

CITY________________________

OBSERVER________________________ DATE__________________

LOCATION________________________ WEATHER__________________

CROSS STREETS

BUS	ROUTE IN OUT	TRAIN	Inbound	Outbound	SCHEDULE		ACTUAL		HOW MANY PASSENGERS						Did the BUS make TT MEET		REMARKS
					AM PM ARRIVE	AM PM DEPART	AM PM ARRIVE	AM PM DEPART	Were on BUS on ARRIVAL	GOT OFF	GOT ON Transfer	GOT ON Walk-on	Were on BUS LEAVING	Missed Transfer	YES	NO	

Exhibit II

RTD

CHECK OF TIME AND PASSENGERS

Observer W. M. Harden

Page 2 of 2

Route Name 5, 8, 9 Route No. ______ Date Oct 29, 80 Day of Week Wed

Schedule No. 814B1 #2 Location Glenwood & 28 Weather Clear

N E W S [✓ Inbound]/Outbound

Vehl No.	Blk No.	ROUTE	SEATS	Passengers Arr	On	Off	Lv.	[✓ AM]–PM Sched.	Act.	Early (+) or Late (-)
120	1	9		6	5	0	11	647/651	647/652	0
101	3	8		14	6	0	20	710/712	710/712	0
106	1	8		20	8		28	710/712	713/715	0
123	4	5		22		8	30	712/713	711/713	0
117	2	9		5	20	0	25	717/721	715/722	+2
129	4	9		26	0	6	20		718/719	XL
102	2	8		15	0	5	20	740/742	[illegible]	-4
106	2	5		24		8	16	742/743	[illegible]	+2
121	XL	8		25	9		33		743/[illegible]	XL
120	1	9		8	10	0	18	747/751	747/751	[illegible]
101	1	8		18	2	1	20	810/812	811	-1
109	3	5		5	0	0	5	812/813	815/816	-3
117	2	9		8	12	0	20	817/812	817/81[illegible]	[illegible]
102	2	8		5	1	1	5	840/842	8[illegible]/843	-3
123		5		10	0	0	10	847/848	847/849	[illegible]/-1
120	1	9		0	1	0	1	847/848	846/849	+1/[illegible]
	(Break 9-10)									
101		8		2	1	0	3	1009/1012	1011/1013	-2/-1
117	2	9		4	0	1	5	1016/1016	1018/1020	-2/-2
123	1	5		3	0	1	2	1017/1018	1016/1020	+1/-2

N E W S [✓ Inbound]/Outbound

Vehl No.	Blk No.	ROUTE	SEATS	Passengers Arr	On	Off	Lv.	AM–PM Sched.	Act.	Early (+) or Late (-)
102	2	8		0	1	0	1	1039/1042	1042/1043	-3/-1
120	1	9		3	0	0	3	1046/1048	1046/1048	0/0
106	2	5		5	0	0	5	[illegible]	1048/1052	0/-4
101	1	8		2	0	0	2	1109/1112	1111/1114	-2/-2
117	2	9		6	8	0	14	1116/1118	1120/1120	-4/-2
109	3	5		5	6	1	10	1117/1118	1117/1118	0/0
102	2	8		6	2	0	8	[illegible]	1143/1143	-4/-1
120		9		0	1	0	1	1146/[illegible]	1147/1151	-1/-3
123		5		2	0	0	2	[illegible]/1147	1146/1151	+1/-3
				(P.M.)						
101		8		4	0	0	4	1209/1212	1211/1213	-2/-1
117	2	9			0	3	4	1216/1218	1220/1221	-4/-3
106	2	5		3	0	0	3	1217/1218	1216/1221	+1/-3
102	2	8		7	9	0	16	1237/[illegible]	1239/1242	0/-02
	1	9						1216/1218		
	3	5						1247/1248		

Rev. RTD 00

Exhibit III

ADJUSTMENT FACTORS TO ACCOUNT FOR ESTIMATED COUNTING BIASES IN RTD MONTHLY PERFORMANCE REPORT PASSENGER DATA

Time Period	Boulder-local	Reason
Jan 77-Oct 77	.980	Average fare method of passenger count over-estimated ridership
Nov 77	1.040	Begin registering farebox system
Feb 78	1.065	Begin free fare
March 78	1.065	Timed Transfer
April 78	1.040	Stable rate of undercounting
December 78	1.065	Change in farebox counting system
January 79 thru June 79	1.040	Stable rate of undercounting

Appendix B

QUESTIONNAIRES AND RESULTS

Exhibit I: TIMED TRANSFER QUESTIONNAIRE

Exhibit II: 1980 BOULDER ON-BOARD QUESTIONNAIRE

Exhibit III: RESULTS OF 1980 BOULDER ON-BOARD QUESTIONNAIRE

Exhibit I

TIMED TRANSFER OPINION SURVEY

Section I

Below are listed a number of statements relating to transportation, transferring, transit centers and timed transferring. You will probably agree with some of them and disagree with others. Please answer by circling the letter which best represents your feeling about each of the statements, according to the following codes:

A	means Strongly Agree
a	means Agree somewhat
o	means Neither Agree nor Disagree
d	means Disagree somewhat
D	means Strong Disagree
K	don't know

1. Transit systems should provide direct service whenever possible.
A a o d D K

2. Transferring causes severe penalties in passenger travel time and convenience.
A a o d D K

3. Timed transferring serves a unique niche in the range of transit services.
A a o d D K

4. In low-population density areas, timed transfer provides a better level of service and cost tradeoff than paratransit.
A a o d D K

5. Most transit passengers are willing to transfer once per one-way trip.
A a o d D K

6. Few transit rider will transfer more than twice per one-way trip.
A a o d D K

7. Every system should have some timed transfers.
A a o d D K

8. Timed transfer systems usually evolve from radial systems.
A a o d D K

9. Timed transfer is most useful for non-CBD oriented trips.
A a o d D K

10. There is a maximum number of transfer points that can be timed within one system. This number is ____.
A a o d D K

11. There is a maximum number of routes that can be timed through one point. This number is ____.

A a o d D K

12. Timed transfers are most valuable during off-peak periods.

A a o d D K

13. One design can serve both peak and off-peak periods.

A a o d D K

14. Timed transfer service frequency is determined more by the network rather than by demand.

A a o d D K

15. Transfer points must be located at or adjacent to major activity centers.

A a o d D K

16. Transfer centers should have automobile parking available.

A a o d D K

17. Passengers feel more secure if there is a major transfer structure.

A a o d D K

18. There is an optimum size and design for transit centers.

A a o d D K

19. The type of transit or transfer centers will determine the success of the timed transfer systems.

A a o d D K

20. The capital costs required to implement timed-transfer systems are significant.

A a o d D K

21. Timed transfers cannot be implemented without significant changes in service.

A a o d D K

22. Most timed transfer systems initially have excess capacity.

A a o d D K

23. Transit scheduling's objective should be to maximize the efficiency of individual routes.

A a o d D K

24. There is a maximum amount of scheduled bus dwell time at a transfer point. The maximum is ________.

A a o d D K

25. At timed transfer points, buses should never be held more than five minutes beyond their scheduled departure time.

A a o d D K

26. Methodologies can be developed to overcome scheduling problems.

A a o d D K

27. The most important operating issue in timed transfer systems is on-time reliability.

A a o d D K

28. Drivers usually have difficulty maintaining schedules under timed transfer systems.

A a o d D K

29. Drivers feel more pressured under a timed transfer system than under a conventional system.

A a o d D K

30. Transit riders would rather spend more time on-board one vehicle than transfer, even if transferring will reduce the total trip time.

A a o d D K

31. It is difficult to explain and market the timed transfer concept to passengers.

A a o d D K

32. Most of the initial resistance to timed transfers has come from passengers.

A a o d D K

33. The use of timed transfer will grow significantly in the next decade.

A a o d D K

34. The Gestalt Principle best characterizes the principle behind timed transfer systems (i.e., the overall effect of an inter-related system is greater than the sum of the effects of each of the individual elements).

A a o d D K

35. Timed transfer systems should be called the "rhythm method," since they are about 85% reliable.

A a o d D K

Section II

On some of the following questions, please check the box that corresponds to the best answer. On some of the others, you are asked for a more complete response - please be as specific as possible.

36. The greatest deficiency of existing transit services in medium and low density areas is:

37. The single most important factor for attracting riders to transit is to provide:
    - ☐ Reliable service
    - ☐ Fast service
    - ☐ Low-cost service
    - ☐ Direct service
    - ☐ Convenient service

38. Timed transfer has the greatest potential application for (complete A, B, C & D):

    A ☐ large systems
    ☐ medium systems
    ☐ small systems

    B ☐ all-bus systems
    ☐ bus & rail systems
    ☐ multi-modal systems (bus, rail, paratransit, park and ride, etc.)

    C ☐ urban areas
    ☐ suburban areas
    ☐ rural areas

    D ☐ peak period trips
    ☐ off-peak periods

39. What type of service area is particularly well-suited to timed transfer systems (eg., population density, size in square miles, level and pattern of existing transit services)?

40. The type of routes & trips that are particularly well-suited to timed transferring are (Please be as specific as possible):

41. The type of passenger attracted to timed transfer systems is:

42. Timed transfers should be implemented:

__ One route at a time
__ Several routes together
__ One center at a time
__ Several centers together
__ All at once

43. In scheduling timed transfers, time modules should be based on:

route running during the: __ peak period
__ off-peak period

44. Headways should be based on: __ high-demand, express service
__ medium demand, regular service
__ lower demand, local service

45. The major reason for building transit centers at transfer points is:

__ Passenger is psychologically reassured of transit connection.
__ Protection from inclement weather.
__ Information and marketing center.
__ Provide telephone, newspaper, other amenities.
__ Joint development opportunities.
__ Capital funds available.
__ Other, specify ________________________________

46. The main reason schedule "meets" are missed is:

__ Initial schedule always needs on-road refinement.
__ Traffic congestion.
__ Uninformed or careless drivers.
__ Uninformed passengers.
__ Increases in ridership have slowed trip times.
__ Vehicle breakdowns.
__ Other Factors, explain ____________________________

47. The most efficient and effective method of assuring "meets" is to

__ Decrease headways.
__ Schedule extra endpoint layover time.
__ Schedule additional transfer point hold time.
__ Schedule extra running time.
__ Have on-site supervision at transer "meet" points.
__ Inform and train drivers of their route "meets."
__ Adopt discretionary policy for additional transfer hold times.

__ Install radio dispatch communication.
__ Other, please specify ________________________________

48. There is not enough information on:
__ The timed transfer concept.
__ How to select timed transfer from the range of transportation services.
__ How to select appropriate timed transfer service areas.
__ How to schedule timed transfers.
__ The costs of timed transfer.
__ Other, please specify ________________________________

Section III

In this section, we are interested in your perceptions of timed transfer vs. conventional transit's potential. Please check one box in the left column. Then fill in the space(s) on the right to complete the statement.

If the same level of conventional fixed-route bus services and timed transfer bus services, in terms of equivalent coverage, were compared, one could expect the Timed Transfer services to:

49. __ Increase
__ Decrease average route layover by __%
__ Not Change (from ____ mins to ____ mins)

50. __ Increase
__ Decrease travel time of participating routes by __%
__ Not Change

51. __ Increase
__ Decrease in-service vehicle hours by __%
__ Not Change

52. __ Increase
__ Decrease total vehicle hours by __%
__ Not Change

53. __ Increase
__ Decrease vehicle miles by __%
__ Not Change

54. __ Increase
__ Decrease number of vehicles by __%
__ Not Change

55. __ Increase
__ Decrease number of vehicles by __%
__ Not Change

56. __ Increase
__ Decrease labor requirements by __%
(include operators, supervisors, schedulers, etc.)
__ Not Change

57. __ Increase
__ Decrease capital costs by __%
(include transit center costs additional, vehicles, etc.)
-- Not Change

58. __ Increase
__ Decrease operating costs by __%

__ Not Change

59. __ Increase
__ Decrease travel time for passengers __%
__ Not Change

60. __ Increase
__ Decrease total ridership by __%
__ Not Change

61. __ Improve
__ Worsen peak-to-base ridership ratio by __%
__ Not Change

62. __ Improve
__ Worsen overall productivity by __%
__ Not Change

63. __ Improve
__ Worsen on-time reliability by __%
__ Not Change

Section IV

We would now like to know a little about you.

64. I am a(n)
__ Government official
__ Operator
__ Planner
__ Scheduler
__ Manager
__ Researcher
__ Other ____

65. I have studied or worked with timed transfer strategies
__ less than 6 months
__ 6 months to one year
__ 1-2 years
__ 2-3 years
__ 3-5 years
__ 5-10 years
__ more than 10 years

66. If there were <u>one</u> piece of advice I would give someone interested in implementing timed transfer systems it would be:

Name ____

Title ____

Address ____

Phone Number ______________________________________

I would like to receive the results of this survey.

__ YES __ NO

Thank you for taking the time to complete this questionnaire. Please feel free to write any additional comments on the back of this sheet.

Exhibit II

BOULDER PASSENGER SURVEY (1980)

To Be Completed by Surveyor:

Bus route No._______
Hour____ _____AM _____PM
Direction_________________
____

To help evaluate our transit services Boulder RTD asks your help in answering the following questions. Please complete this form while on the bus and return to the surveyor before leaving. All responses will be kept confidential. Thank you.

1. What is the purpose or destination of this trip?

☐ Work
☐ School
☐ Shopping
☐ Medical or Dental Appointment
☐ Social/Recreational
☐ Home
☐ Other

2. How many buses will you use to make this trip in one direction, from initial starting point to final destination?

☐ One (skip to question #5)
☐ Two
☐ Three
☐ Four or more.

3. If more than one bus: Where will you transfer and what route will you transfer to? (If more than one transfer will be made, put the numbered order transfers will occur (e.g., 1 28th and Glenwood to Route 8, 2 Down town to Route 4.)

Transfer from Route _____ at - Downtown to Route_______________
Transfer from Route _____ at - 28th and Glenwood to Route _________
Transfer from Route _____ at - Table Mesa & Broadway to Route_______
Transfer from Route _____ at - Mohawk & Baseline to Route_________
Transfer from Route _____ at - Other, Where?__________to Route____

4. How long ☐ did you wait, or
☐ do you expect to wait, at each transfer point?

First Transfer Point	Second Transfer Point
☐ No wait, bus was or will be there already.	☐ No wait, bus was or will be there already.
☐ Less than 1 minute.	☐ Less than i minute.
☐ 1-2 minutes.	☐ 1-2 minutes.
☐ 3-5 minutes.	☐ 3-5 minutes.
☐ 6-10 minutes.	☐ 6-10 minutes.
☐ 11-15 minutes.	☐ 11-15 minutes.
☐ 16-30 minutes.	☐ 16-30 minutes.
☐ More than 30 minutes	☐ More than 30 minutes.

5. a) How did you get to the bus stop from where your trip started and how long did it take?
Walk_______minutes.
Drive_______minutes.
Given a ride_____minutes.
Other, how?______________________________, ______minutes.

b) How much time was spent waiting for initial bus? ______minutes.

c) How much time is spent aboard bus(es)?
1st Bus____minutes; 2nd Bus____minutes; 3rd Bus____minutes.

d) How will you get to your destination after getting off the last bus?
Walk______minutes.
Drive______minutes.
Given a ride______minutes.
Other, how?__________________________, _________minutes.

e) How long do you estimate this trip takes from your initial origin to your final destination? _____ minutes (Include time to get to and from bus stops).

6. How often did you ride the bus last week?

☐ 5 or more days
☐ 3-4 days
☐ 1-2 days
☐ Didn't ride last week

7. In 1979 and 1980 RTD introduced new services and schedules in Boulder.

If you were using the bus in 1978 answer Part 7a.

If you were not using the bus in 1978 answer part 7b.

7a) If you were using the bus in 1978, how would you rate RTD's new services in terms of:

	Much Better	Better	About the Same	Worse	Much Worse
Convenience of Schedule	( )	( )	( )	( )	( )
Frequency of Service	( )	( )	( )	( )	( )
Convenience of Routes	( )	( )	( )	( )	( )
Directness of Service	( )	( )	( )	( )	( )
On-Time Reliability	( )	( )	( )	( )	( )
Convenience of Transfer	( )	( )	( )	( )	( )
Need for Transfers	( )	( )	( )	( )	( )
Transfer Time	( )	( )	( )	( )	( )
Comprehensibility	( )	( )	( )	( )	( )
Total Trip Time	( )	( )	( )	( )	( )
Overall Convenience	( )	( )	( )	( )	( )

7b) If you were not using the bus in 1978, why did you start using transit? (Check as many as apply)

☐ Moved to Boulder
☐ New Schedules
☐ More Frequent Service
☐ New Routes
☐ More Convenient
☐ Gas is too Expensive
☐ No Other Transportation Available
☐ Easier to transfer
☐ Changed my job, residence or trip pattern
☐ Other, please explain______________________________

8. How many cars do you have in your household? ________

9. Was a car available to you for this trip?

☐ Yes, but I prefer to take the bus.
☐ Yes, but with considerable inconvenience to myself or others.
☐ No.

10. What is your age group?

☐ Under 16
☐ 16-19
☐ 20-44
☐ 45-64
☐ 65 or over

11. Are you

☐ Male
☐ Female

12. Are you

☐ A student
☐ A homemaker
☐ Employed or Self-employed - What occupation? ________________
☐ Retired
☐ Not currently Employed
☐ Other - What?______________________________

Exhibit III

RESULTS OF 1980 BOULDER ON-BOARD QUESTIONNAIRE

Bus route surveyed (n = 1179)

2	11.2
2 or 4	2.0
3	15.8
4	11.1
5	18.7
6	19.6
7	3.9
8	6.7
9	11.0
	100.0

Direction (n = 1155)

East	4.3
West	6.4
North	40.6
South	48.7
	100.0

Time surveyed (n = 1141)

peak (6-8 AM, 4-6 PM)	64.2
off-peak	35.8
	100.0

Q.1 Purpose of trip (n = 1168)

Work	39.0
School	29.6
Shopping	6.9
Medical/dental	2.6
Social/recreational	5.1
Home	22.5
Other	4.7
	110.4*

*Some gave multiple answers

Q.2 Number of buses used (n = 1150)

one	68.2
two	29.0
three	2.3
four or more	0.5
	100.0

Q.4 Waiting time at transfer points (n = 249)

waited	48.2
expect to wait	51.8
	100.0

Waiting time at 1st transfer point (n =362)

no wait	13.0
less than 1 min	4.4
1-2 min	9.4
3-5 min	29.3
6-10 min	22.6
11-15 min	14.4
16-30 min	6.4
more than 30 min	0.5
	100.0

Waiting time at 2nd transfer point (n = 76)

no wait	15.8
less than 1 min	2.6
1-2 min	1.3
3-5 min	22.4
6-10 min	23.7
11-15 min	19.7
16-30 min	11.9
more than 30 min	2.6
	100.0

5 (a) Mode to bus stop (n = 1129)

walk	94.8
drive	2.0
given a ride	1.6
other	1.6
	100.0

Time spent getting to bus stop (n = 1102)

1 min or less	18.8	
2 min	15.9	
3 min	12.4	
4 min	3.5	
5 min	27.1	
6-9 min	4.8	
10 min	11.0	
11-15 min	4.7	
more than 15 min	1.8	
	100.0	mean = 4.89

(n = 1101) Time to bus stop (in minutes)

Mode to bus stop	<1	2	3	4	5	6-9	10	11-15	>15	Total
walk (n = 1049)	19.6	16.5	12.7	3.5	26.3	4.9	10.4	4.4	5.3	100.0
drive (n = 22)	0	9.1	9.1	4.6	36.3	4.6	22.7	13.6	0	100.0
given a ride (n = 17)	0	0	11.8	0	47.0	0	23.5	11.8	5.9	100.0
other (n = 13)	7.7	0	0	7.7	46.1	7.7	23.1	7.7	0	100.0

5 (b) Time waited for initial bus (n = 1099)
(in minutes)

0	6.8	
1	5.4	
2	9.6	
3	9.4	
4	4.3	
5	31.1	
6-10	21.8	
11-15	6.9	
16-29	2.7	
30 or more	2.0	
	100.0	mean = 6.44

5 (c) Time spent aboard 1st bus (n = 1063)
(in minutes)

5 or less	14.9	
6-10	26.8	
11-15	22.1	
16-20	15.6	
21-30	13.0	
more than 30	7.6	
	100.0	mean = 16.23

Time spent aboard 2nd bus (n = 313)
(in minutes)

5 or less	27.8	
6-10	31.9	
11-15	16.7	
16-20	11.2	
21-30	7.0	
more than 30	5.4	
	100.0	mean = 13.28

Time spent aboard 3rd bus (n = 27)
(in minutes)

5 or less	29.6
6-10	33.3
11-15	18.5
16-20	3.8
21-30	0
more than 30	14.8
	100.0

mean = 16.07

5 (d) Mode after bus (n = 1103)

walk	97.5
drive	1.2
given a ride	0.9
other	0.4
	100.0

Time to destination after bus (n = 1059)

1 min or less	21.7
2 min	16.7
3 min	12.9
4 min	3.3
5 min	28.1
6-9 min	3.1
10 min	8.7
11-15 min	3.5
more than 15 min	2.0
	100.0

mean = 4.53

(n = 1057) Time to destination after bus (minutes)

Mode after bus	<1	2	3	4	5	6-9	10	11-15	>15	Total
walk (n = 1032)	22.2	17.0	13.2	3.4	28.0	3.1	8.4	3.2	1.5	100.0
drive (n = 12)	8.3	0	8.3	0	41.8	8.3	8.3	8.3	16.7	100.0
given a ride (n = 9)	0	0	0	0	33.3	0	11.1	11.1	44.5	100.0
other (n = 4)	0	25.0	0	0	0	0	50.0	25.0	0	100.0

5 (e) Estimated total trip time (minutes) (n = 1092)

0-10	4.8
11-15	9.7
16-20	15.4
21-25	12.0
26-30	18.4
31-40	14.7
41-50	12.4
51-60	7.2
more than 60	5.4
	100.0

Q.6 Bus use frequency (n = 1100)

5 or more days	61.0
3-4 days	22.4
1-2 days	10.7
did not ride	5.9
	100.0

7 (a) Ratings of RTD's new services

Convenience of schedule (n = 415)

much better	18.8
better	35.4
about the same	37.9
worse	6.0
much worse	1.9
	100.0

Frequency of service (n = 409)

much better	15.6
better	32.0
about the same	47.0
worse	4.2
much worse	1.2
	100.0

Convenience of routes (n = 401)

much better	15.7
better	30.9
about the same	45.7
worse	5.7
much worse	2.0
	100.0

Directness of service (n = 392)

much better	12.2
better	27.3
about the same	52.3
worse	6.4
much worse	1.8
	100.0

On-time reliability (n = 396)

much better	12.1
better	28.0
about the same	46.5
worse	9.6
much worse	3.8
	100.0

Convenience of transfer (n = 369)

much better	13.3
better	20.6
about the same	56.4
worse	7.8
much worse	1.9
	100.0

Need for transfer (n = 375)

much better	9.9
better	18.4
about the same	64.8
worse	5.3
much worse	1.6
	100.0

Transfer time (n = 370)

much better	9.5
better	20.8
about the same	55.1
worse	11.9
much worse	2.7
	100.0

Comprehensibility (n = 355)

much better	12.4
better	22.8
about the same	53.8
worse	9.0
much worse	2.0
	100.0

Total trip time (n = 385)

much better	8.6
better	27.0
about the same	52.2
worse	9.9
much worse	2.3
	100.0

Overall convenience (n = 397)

much better	17.9
better	34.0
about the same	40.0
worse	6.3
much worse	1.8
	100.0

7 (b) Reasons for using RTD (n = 623)

moved to Boulder	49.3	
new schedules	6.7	
more frequent services	7.5	
new routes	7.5	
more convenient	20.5	
gas is to expensive	28.6	
no other transportation	34.0	
easier to transfer	1.3	
changed job/residence/trip pattern	16.4	
Other	11.4	
	183.2	respondents gave multiple answers.

8. Cars in household (n = 1046)

0	20.0
1	32.9
2	29.9
3	11.8
4 or more	5.4
	100.0

9. Car availability (n = 1063)

yes, but prefer bus	30.5
yes, but inconvenient	13.1
no	56.4
	100.0

10. Age (n = 1083)

under 16	15.4
16-19	18.2
20-44	54.9
45-64	9.0
65 or over	2.5
	100.0

11. Sex (n = 1075)

male	41.4
female	58.6
	100.0

12. Work status (n = 1077)

student	48.4
homemaker	5.1
employed/self-employed	52.6
retired	2.4
not currently employed	1.6
other	1.4
	111.5*

*123 respondents gave multiple answers.

Appendix C

TIMED TRANSFER PASSENGER ACTIVITY

Exhibit I: TIMED TRANSFER ACTIVITY (ANN ARBOR)

Exhibit II: TIMED TRANSFER ACTIVITY (BOULDER)

Exhibit III: TIMED TRANSFER ACTIVITY (PORTLAND)

Exhibit I

TIMED TRANSFER ACTIVITY (ANN ARBOR)

		MEAN PASSENGER ACTIVITY PER BUS								
		AM PEAK			OFF PEAK			PM PEAK		
Timed Transfer Point	Bus Route	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus
Ann Arbor CBD	1	12.8	2.9	5.0	4.5	5.0	6.2	6.3	9.0	12.5
4th & William	2	3.8	5.9	7.4	6.7	4.8	5.9	4.7	4.7	5.3
	3	11.4	16.4	21.0	4.6	6.0	6.6	2.6	8.5	9.3
	4	3.5	5.8	6.9	4.5	10.1	11.9	5.3	8.2	10.4
	5	3.9	3.6	3.8	6.9	8.3	9.0	5.5	9.9	10.5
	6	4.3	10.6	10.5	4.3	5.3	5.4	6.9	9.6	10.6
	7	2.7	2.9	5.2	3.6	5.5	6.8	4.8	5.2	6.8
	8A	17.0	4.5	3.7	4.3	7.5	8.6	4.3	13.8	13.8
	8B	12.3	2.3	2.7	4.0	5.9	6.4	5.5	21.8	23.0
	9	4.8	4.0	7.6	5.9	5.2	7.1	8.3	7.0	14.6
	12	16.3	6.6	13.5	8.0	8.2	8.9	7.4	20.3	20.4
	13A	0.3	0.8	0.8	0.4	2.4	3.0	2.0	5.3	6.0
	13B	0.8	1.8	2.0	0.1	1.9	2.0	0	6.5	6.5
	14A	1.9	0.8	1.0	0.9	0.9	1.1	0.5	2.3	2.5
	14B	0.8	3.8	4.0	0.8	1.0	1.1	0.5	1.3	1.3
Arborland	4	2.9	2.3	13.6	5.5	3.8	18.5	3.5	6.4	26.3
	6	1.3	1.2	2.9	2.1	1.6	3.9	2.1	2.9	5.1
	7	0.8	0.8	2.1	2.1	2.5	4.0	3.2	1.9	3.6
	12	2.1	2.8	2.9	1.4	0.7	1.0	1.5	0.7	0.8
Maple Village	9				3.7	4.0	7.7	2.5	3.3	7.0
	12				0.8	2.0	5.1	0.3	1.5	4.5
	15				0	1.0	1.4	0	0.8	0.8
Ypsilanti CBD	3	1.3	4.3	5.3	3.4	3.7	5.1	2.7	2.2	4.3
Michigan & Adams	4	1.1	17.3	17.8	6.0	8.7	10.0	14.8	6.2	8.0
	5	0.8	1.1	3.5	2.7	3.7	4.9	5.1	3.0	3.5
	10	16.7	2.5	2.7	8.9	4.7	6.8	6.0	11.8	12.4
	11	1.0	0.5	1.5	4.3	7.6	10.2	1.6	9.2	13.6
Pioneer High School	7				1.6	2.9	9.8	1.3	1.7	8.2
	12				0.2	1.1	2.6	0.3	1.4	2.9
	15				0.3	1.3	2.2	1.3	3.7	3.7
Huron High School	2	0.8	0.1	0.1	0.4	0.4	0.6	0.3	0.1	0.3
	3	2.1	3.5	12.6	1.1	2.8	9.7	2.5	1.3	11.4
	7	4.8	0.4	1.7	1.2	2.3	4.2	0.9	1.7	5.4

Exhibit II

TIMED TRANSFER ACTIVITY (BOULDER)

		MEAN PASSENGER ACTIVITY PER BUS								
		AM PEAK			OFF PEAK			PM PEAK		
Timed Transfer Point	Bus Route	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus
Boulder CBD 14th & Walnut	1	NA	NA	NA	5.4	4.8	4.8	NA	NA	NA
	2	4.9	5.5	14.6	2.9	3.7	9.8	2.7	6.5	9.9
	3	7.6	2.3	5.6	2.9	3.0	3.7	1.0	4.6	6.3
	4	6.7	2.6	9.7	5.5	3.1	6.2	1.0	4.0	8.0
	5	6.7	2.7	3.9	4.7	4.8	4.8	2.8	11.0	15.8
	7	3.8	8.0	11.2	2.3	3.4	4.7	4.7	5.1	7.8
	8	4.8	2.7	3.2	4.8	4.9	5.1	1.4	4.9	6.2
28th & Glenwood	5	1.7	0.6	9.2	0.3	0.5	3.6	0.6	1.2	9.7
	8	0.8	2.4	14.0	0.7	1.1	3.9	0.8	0.7	6.0
	9	0.2	4.6	8.4	1.0	0.5	2.3	1.6	0.7	4.5
Table Mesa & Broadway	2	0.9	2.6	14.1	1.2	0.7	8.0	NA	NA	12.7
	4	0.6	0.5	5.5	1.3	0.8	6.0	NA	NA	4.7
	6	1.1	0.4	17.8	0.4	0.5	4.8	NA	NA	6.9
Baseline & Mohawk	3	1.5	4.4	7.9	1.5	1.7	3.0	3.5	0.4	3.3
	6	0.6	1.8	11.0	0.5	0.5	3.1	2.2	1.3	6.8
	9	8.4	0.4	1.6	1.5	2.6	3.6	1.8	1.8	2.6

NA = Not Available

Exhibit III

PORTLAND TIMED TRANSFER ACTIVITY

		MEAN PASSENGER ACTIVITY PER BUS								
		AM PEAK			OFF PEAK			PM PEAK		
Timed Transfer Point	Bus Route	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus	Discharge	Board	On Board Departing Bus
Beaverton	52	15.4	3.4	3.6	7.7	6.1	6.3	3.7	15.6	15.9
	54	6.9	13.7	13.9	10.6	10.4	10.5	7.6	6.7	6.8
	57	3.9	9.8	25.2	6.9	7.7	18.8	11.9	7.4	22.7
	59	10.4	2.7	3.1	3.5	3.8	4.3	3.4	12.3	12.4
	65	2.6	9.1	9.2	6.9	4.8	4.9	4.4	4.7	5.4
	67	4.1	3.3	3.4	3.0	4.6	4.9	5.9	5.6	7.8
	77	7.9	6.3	10.4	4.7	6.5	10.8	5.7	8.1	11.6
	87	0	0	0	–	–	–	3.8	0	2.8
Cedar Hills	59	4.4	7.3	20.8	6.2	5.5	12.8	8.0	4.1	14.5
	60	1.9	3.9	4.1	6.0	6.0	6.2	9.9	4.4	7.6
	67	4.3	0.8	1.0	2.6	3.0	3.2	1.2	4.8	4.9
	77	1.7	3.1	7.2	1.7	2.4	6.6	2.3	3.1	6.6

Appendix D

TRAVEL TIMES AND SPEEDS OF ALTERNATIVE MODES

Exhibit I: ANN ARBOR SAMPLE TRIPS
Exhibit II: BOULDER SAMPLE TRIPS
Exhibit III: PORTLAND SAMPLE TRIPS

Exhibit I

ANN ARBOR SAMPLE TRIPS

Trip No.	Origin	Destination	Arrive / Depart	Time[1]	Mode[2]	Depart Time	Arrive Time	Trip Time (min)	Bus Routes	Auto Dist.	Mean Speed (mph) Auto Distance
1	Morton & Baldwin	Un. of Mich., Monroe & Tappan	A	0755	Auto	0745	0755	10		1.45	8.7
					Walk	0721	0755	34			2.6
					B.P.	0732	0755	23	#5		3.8
					B. '79	0740	0755	15	DAR		5.8
2	Hoover & Mary	5th & Liberty	A	0800	Auto	0750	0800	10		1.0	6.0
					Walk	0744	0800	16			3.8
					B.P.	0730	0747	17	#5 or #6		3.5
					B. '79	0744	0800	16	DAR		3.8
3	Gott & Hiscock	Univ. Hosp.	A	1100	Auto	1049	1100	11		1.5	8.2
					Walk	1030	1100	30			3.0
					B.P.	1036	1056	20	#12 & #4		4.5
					B. '79	1035	1056	21	#6, #1 or #3		4.3
4	Sulgrave & Barrister	5th & Liberty	A	0830	Auto	0816	0830	14		3.7	15.9
					B.P.	0759	0830	31	#2		7.2
					B. '79	0747	0830	43	DAR & #2		5.2
5	Gott & Hiscock	Parke Davis	A	0830	Auto	0817	0830	13		3.7	17.1
					B.P.	0736	0812	46	#12 & #2		4.8
					B. '79	0743	0828	45	DAR & #3		4.9
6	Hubbard & Crain	Un. of Mich., Jeff & S. State	A	1000	Auto	0947	1000	13		2.85	13.2
					B.P.	0917	0948	31	#2 or #3		5.5
					B. '79	0904	0946	42	DAR & #2		4.1
7	Foss & Fulmer	Main & William	D	0930	Auto	0930	0941	11		2.33	12.7
					B.P.	0948	1017	29	#12		4.8
					B. '79	0948	1017	29	DAR & #6 or #6		4.8
8	Gott & Hiscock	Pioneer H.S.	A	0815	Auto	0805	0815	10		2.25	13.5
					B.P.	0747	0815	28	#12		4.8
					B. '79	0743	0807	24	DAR & #2		5.6
9	Waverly & Dunmore	Bechtel	A	0800	Auto	0747	0800	13		3.25	15.0
					B.P.	0726	0755	29	#15 & #7		6.7
					B. '79	0717	0754	37	DAR & #2		5.3
10	Foss & Fulmer	Univ. Hosp.	A	1030	Auto	1019	1030	11		2.9	15.8
					B.P.	0949	1023	34	#2 & #4		5.1
					B. '79	0953	1024	31	#6 & #1		5.6
11	Morton & Baldwin	Meijers	D	1100	Auto	1100	1113	15		4.2	16.8
					B.P.	1100	1145	45	#5		5.6
					B. '79	1100	1210	70	#4		3.6
12	Oakwood & Bellwood	Ford	A	0730	Auto	0711	0730	19		6.5	20.5
					B.P. B. '79					No access to Arborland	
				0830	B.P.	0712	0812	60	#4 & #11		6.5
					B. '79	0715	0813	58	DAR, #1 & #3		6.7
13	E. Mich. University	Arborland	D	1215	Auto	1215	1229	14		3.7	15.9
					B.P.	1224	1245	21	#4		10.6
					B. '79	1220	1245	25	#5 & #1		8.9

[1] Time: Scheduled Arrival/Departure
Time at Destination

[2] Mode: Auto - Automobile
Walk
B.P. - Timed Transfer Service in 1980
B. 79- Teltran Bus Service in 1979

Exhibit II

SAMPLE TRIPS (BOULDER)

Trip No.	Origin	Destination	Arrive / Depart	Time[1]	Mode[2]	Actual Depart Time	Actual Arrive Time	Trip Time (min)	Bus Routes	Auto Dist.	Mean Speed (mph) Auto Distance
1	Darmouth & 34th	Boulder Mall	D	1315	Auto	1315	1323	8		2.6	19.5
					B, P	1315	1344	29	#2		5.4
					B, '78	1315	1333	18	#2		8.7
2	Hawthorne & 8th	U. of Colorado 20th & Broadway	A	900	Auto	851	900	9		2.8	18.7
					B, P	821	849	28	#3		6.0
					B, '78	809	833	24	#2		7.0
3	4th & Cedar	Boulder H.S.	A	800	Auto	752	800	8		1.9	14.3
					B, P	745	758	13	#3		8.8
					B, '78	742	800	18	#3		6.3
4	Lincoln & Cascade	Community Hospital	A	1400	Auto	1350	1400	10		2.0	12.0
					B, P	1329	1349	20	#3		6.0
					B, '78	1333	1354	21	#3		5.7
5	Maxwell & 9th	Ball Bros. Research Corp.	A	745	Auto	731	745	14		3.2	13.7
					B, P	708	727	19	#3 & #7		10.1
					B, '78	716	736	20			9.6
6	Regent & 20th	Senior Citizen Center	A	1030	Auto	1023	1030	7		1.3	11.1
					B, P	952	1004	12	#3		6.5
					B, '78	958	1008	10	#3		7.8
7	Forest & 17th	IBM	A	800	Auto	735	800	25		15.8	37.9
					B, P	702	745	43	#8 & #5A		22.1
					B, '78	706	748	42			22.6
8	Violet & 17th	Crossroad Shopping Center	D	1000	Auto	1000	1009	9		3.1	20.7
					B, P	1000	1022	22	#4 & #0		8.5
					B, '78	1000	1050	50	#4 & #1		3.7
9	Mesa Drive & 20th	National Center for Atmospheric Research	A	745	Auto	729	745	16		4.5	16.9
					B, P	653	729	36	#4		7.5
					B, '78	659	739	40	#4		6.8
10	Hanover & 44th	Boulder Memorial Hospital	A	800	Auto	747	800	13		4.3	19.9
					B, P	714	749	35	#2 & #3		7.4
					B, '78	709	752	43			6.0
11	Madison & 36th	Boulder Municipal Airport	A	1500	Auto	1449	1500	11		3.4	18.6
					B, P	1408	1500	52	#9 & #8		4.0
					B, '78	1401	1440	39			5.2

[1] Time: Scheduled Arrival/Departure
Time at Destination

[2] Mode: Auto-Automobile
B,P -1980 RTD Bus Service
B,78-1978 Timed Transfer Bus Service

Exhibit III

PORTLAND SAMPLE TRIPS

Trip No.	Origin	Destination	Arrive Depart	Time	Mode	Depart Time	Arrive Time	Trip Time (min)	Bus Routes	Auto Dist.	Mean Speed (mph) Auto Distance
1	Rock Creek Blvd & 185th Ave	Hwy 217 & Sunset Hwy	A	8:00 AM	Auto	7:49	8:00	11		5.2	28.4
					B,TT	7:21	7:48	27	#89		11.6
					B	7:27	7:56	29	#61		10.8
2	Farmington Rd & Murray Blvd	Washington Rd & 2nd Ave (Hillsboro)	A	8:00 AM	Auto	7:39	8:00	21		8.8	25.1
					B,TT	7:31	8:00	29	#57		18.2
					B	7:34	8:01	27	#57		19.6
3	S.W. Walker Rd & Murray Blvd	Washington Square (work)	A	8:30 AM	Auto	7:15	8:30	15		6.7	26.8
					B,TT	7:45	8:19	34	#67,77		13.0
					B	7:35	8:26	51	#59,56		7.9
4	Glenridge Dr & Murray Blvd	S.W. Jenkins Rd & Murray Blvd	A	8:30 AM	Auto	8:25	8:30	5		1.5	18.0
					B,TT	8:09	8:21	12	#67		7.5
					B	8:13	8:27	14	#60		6.4
5	Oleson Rd & Beaverton-Hillsdale Hwy	Hall Blvd & S.W. Burnham St.	A	9:00 AM	Auto	8:47	9:00	13		5.4	24.9
					B,TT	8:06	8:56	50	#54,77		7.5
					B	8:16	8:56	40	#56,78		8.1
6	S.W. Shattuck Rd & S.W. Cameron Rd	Jefferson St & S.W. 4th Ave (City Hall)	A	9:00 AM	Auto	8:46	9:00	14		5.6	24.0
					B,TT	8:16	8:45	29	#1		11.6
					B	8:16	8:45	29	#1		11.6
7	6th St & Erickson Ave	S.W. 49th Ave (PCC Sylvania)	A	6:00 PM	Auto	5:43	6:00	17		7.5	26.5
					B,TT	5:16	5:56	40	#77		11.3
					B	5:18	5:58	40	#78		11.3
8	Hall Blvd & Broadway	U.S. Veterans Administration Hospital	A	10:30 AM	Auto	10:12	10:30	18		7.8	26.0
					B,TT	9:48	10:24	36	#54		13.0
					B	9:36	10:07	31	#54		15.1
9	S.W. 185th Ave & S.W. Kinnamon Rd	Beaverton Mall	D	9:00 AM	Auto	9:00	9:11	11		4.2	22.9
					B,TT	9:02	9:30	28	#52,77		9.0
					B	8:59	9:23	24	#54,56		10.5
10	S.W. Cedar Hills Blvd & Park Way	St. Vincent Hospital	A	11:00 AM	Auto	10:54	11:00	6		1.8	18.0
					B,TT	10:32	10:41	9	#77		12.0
					B	10:38	10:57	19	#60		5.7
11	S.W. Green & S.W. Hall Blvd	Portland Mall	D	9:30 AM	Auto	9:30	9:49	19		9.0	28.4
					B,TT	9:42	10:18	36	#77,57		14.6
					B	9:41	10:26	44	#56,57		12.3
12	S.W. Cashmure Lane & S.W. 87th Ave	Washington Square	D	10:00 AM	Auto	10:00	10:12	12		5.0	25.0
					B,TT	10:11	10:49	38	#57,77		8.1
					B	10:20	10:52	32	#57,56		9.4
13	Allen Blvd & Western Ave	Wilson High School (Vermont St)	A	8:00 AM	Auto	7:49	8:00	11		4.2	22.9
					B,TT	7:26	7:59	33	#54		7.6
					B	7:25	7:58	33	#54		7.6
14	S.W. Vermont St & 45th Ave	Portland State University	A	9:00 AM	Auto	8:45	9:00	15		5.1	20.4
					B,TT	8:18	8:40	22	#1		13.9
					B	8:18	8:40	22	#1		13.9

PORTLAND SAMPLE TRIPS (Cont.)

Trip No.	Origin	Destination	Arrive Depart	Time	Mode	Depart Time	Arrive Time	Trip Time (min)	Bus Routes	Auto Dist.	Mean Speed (mph) Auto Distance
15	Farmington Rd & 170th Ave	Washington Park (OMSI)	D	2:00 PM	Auto	2:00	2:16	16		7.7	28.9
					B,TT	2:08	2:42	34	#52,57		13.2
					B	2:19	2:59	40	#54,57		11.6
16	Hall Blvd & Pacific Hwy	Washington Park (zoo)	D	10:00 AM	Auto	10:00	10:17	17		9.4	33.2
					B,TT	9:59	10:43	44	#77,57		12.5
					B	9:59	10:40	41	#78,57		13.8
17	S.W. Green & Hall Blvd	Lloyd Center	D	9:30 AM	Auto	9:30	9:53	23		11.7	30.5
					B,TT	9:42	11:04	82	#77,46, 9B		8.6
					B	9:45	11:04	79	#56,46, 9B		8.9
18	Main St & Commercial St (Trigard)	Portland International Airport	A	4:00 PM	Auto	3:36	4:00	24		13.8	34.5
					B,TT	2:43	4:03	80	#44S, 14S,72		10.4
					B	2:43	4:03	80	#44S, 14S,72		10.4
19	Vermont St & Capitol Hwy	Cedar Hills Blvd & Walker Rd	A	10:00 AM	Auto	9:43	10:00	17		6.5	22.9
					B,TT	9:22	10:01	39	#54,77, or 65		8.3
					B	9:26	10:02	36	#54,59		10.8
20	Washington Square	185th Ave & Tualatin Valley Hwy	D	3:00 PM	Auto	3:00	3:15	15		6.7	26.8
					B,TT	3:05	3:34	29	#77,57		12.2
					B	3:04	3:45	41	#56,57		9.8

Appendix E

BUS SCHEDULE PERFORMANCE

Exhibit I: MEAN SCHEDULE PERFORMANCE (ANN ARBOR)
Exhibit II: MEAN SCHEDULE PERFORMANCE (BOULDER)
Exhibit III: ACTUAL LAYOVER CHARACTERISTICS (ANN ARBOR AND PORTLAND)
Exhibit IV: PERFORMANCE VARIABILITY (ANN ARBOR, PORTLAND AND BOULDER)

Exhibit I

MEAN SCHEDULE PERFORMANCE (ANN ARBOR)

Timed Transfer Point	Route	Avg. Minutes Early or Late (-)		Mean Layover Time (minutes)
		Arrivals	Departures	
Ann Arbor CBD	1	4.09	-1.93	6.02
	2	2.88	-3.07	6.00
	3	2.48	-4.26	6.76
	4	1.98	-2.36	6.05
	4X	-6.67	-5.33	5.33
	5	2.90	-2.68	5.52
	6	3.11	-2.61	5.73
	7	3.43	-1.85	5.28
	8A	4.14	-3.50	7.64
	8B	4.67	-3.00	7.67
	9	5.05	-1.98	7.02
	12	2.07	-2.53	4.68
	13A	-0.32	-4.18	3.86
	13B	-0.77	-3.86	3.09
	14A	1.12	-2.67	3.79
	14B	0.72	-3.64	4.31
Arborland	4	0.60	-2.59	3.17
	4X	-1.33	-3.33	2.00
	6	0.56	-1.94	2.54
	7	2.69	-2.89	5.57
	12	2.16	-1.27	3.43
Maple Village	9	-1.60	-2.50	1.10
	12	1.58	0	1.58
	15	2.67	-1.22	3.89
Ypsilanti CBD	3	0.58	-2.41	2.91
	4	-0.59	-2.74	4.98
	5	-0.13	-2.45	2.22
	10	2.84	-2.88	5.72
	11	0.20	-4.80	5.00
Pioneer High School	7	2.59	1.61	1.14
	12	2.06	1.17	0.89
	15	4.00	1.33	2.67
Huron High School	2	1.95	-1.81	11.09
	3	1.48	-1.37	2.88
	7	3.59	-1.59	5.12

Exhibit II

MEAN SCHEDULE PERFORMANCE (BOULDER)

Timed Transfer Point	Route	Schedule Time—Arrival Time (min.)	Schedule Time—Departure Time (min.)	Mean Layover Time (min.)
28th & Glenwood	5	−1.34	−1.58	1.36
	8	−1.79	−1.16	1.34
	9	−1.86	−1.83	0.98
Table Mesa & Broadway	2	−1.69	NA	NA
	4	−1.57	NA	NA
	6	−2.64	NA	NA
Baseline & Mohawk	3	−0.58	−0.29	4.33
	6	−0.77	NA	2.20
	9	0.00	−0.76	5.70
14th & Walnut	1	−1.00	−1.30	5.33
	2	−1.54	−2.97	2.25
	3	−1.67	−1.50	2.20
	4	−2.95	−3.37	1.37
	5	0.00	−1.43	8.94
	7	−0.69	−1.28	2.65
	8	−2.08	−0.29	4.82

NA = Not Available

Exhibit III

ACTUAL LAYOVER CHARACTERISTICS

Site		Route	Layover Time			
			Mean	Std. Dev.	5%* Value	95%† Value
ANN ARBOR	DOWNTOWN	1	6.02	2.22	3	10
		2	6.00	2.27	3	10
		3	6.76	2.55	2	11
		4	6.05	1.95	3	9
		5	5.52	2.01	2	9
		6	5.73	2.44	2	10
		7	5.28	2.52	2	10
		8	7.66	3.27	3	13
		9	7.02	3.66	3	12
		12	4.68	1.86	2	9
		13	3.48	1.92	1	7
		14	4.05	2.18	1	9
		Average	5.63	2.65	2	12
	ARBORLAND	4	3.17	1.96	1	7
		6	2.54	1.79	1	5
		7	5.57	2.63	1	9
		12	3.43	1.58	2	7
		Average	3.75	2.42	1	8
	YPSILANTI	3	2.91	1.67	1	5
		4	4.98	4.97	1	15
		5	2.22	1.62	1	5
		10	5.72	2.81	2	11
		11	5.00	2.36	2	9
		Average	4.10	3.47	1	12
	MAPLE V.	9	1.10	0.74	1	2
		12	1.58	1.35	1	4
		15	3.89	2.52	2	7
		Average	2.00	1.89	1	5
	HURON	2	11.09	8.44	1	22
		3	2.88	2.22	1	7
		7	5.12	3.21	1	10
		Average	5.70	5.74	1	19
	PIONEER	7	1.14	0.79	1	2
		12	0.89	0.83	1	2
		15	1.75	1.04	1	3
		Average	1.33	1.55	1	3
	TRUNK	2	8.50	6.62	1	20
		3	3.86	2.77	1	9
		4	4.42	3.18	1	10
		5	4.37	2.45	1	9
		6	3.65	2.54	1	9
		7	5.01	2.95	1	10
		9	5.93	4.05	1	12
		12	3.22	2.10	1	7
		15	3.28	2.72	1	9

Site		Route	Layover Time			
			Mean	Std. Dev.	5%* Value	95%† Value
PORTLAND	BEAVERTON	52	9.75	3.28	3	15
		54	8.17	3.94	2	15
		57	3.25	1.89	1	7
		59	7.91	4.10	2	15
		65	10.22	2.16	6	14
		67	11.22	5.10	1	20
		77	4.49	2.69	1	10
		87	2.36	2.73	1	6
		Average	6.44	5.00	1	15
	CEDAR HILLS	59	4.35	2.19	1	9
		60	7.65	3.58	1	12
		67	7.45	3.67	1	13
		77	4.25	3.14	1	9
		Average	5.36	3.38	1	12
	TRUNK	59	4.93	3.54	1	13
		67	9.39	4.83	1	15
		77	4.38	2.91	1	9

* † This measure eliminates extremely early arrivals and extremely late departures. The five percent represents the arrival time that is later than or equal to the arrival time of the earliest five percent of all arrivals for that route. The 95 percent represents the departure time that is later than or equal to the departure time of the earliest 95 percent of all departures for that route.

Exhibit IV

PERFORMANCE VARIABILITY

Site	Route	Length Mi	Trip Time (min)	Mean Layover (min)	Sched Speed	Psngr per		Arrival					Departure					
						Trip	Hour	Standard Deviation of Actual Time to Scheduled Time										
ANN ARBOR	1	6.2	30	6.02	12.3	17.1	34.2	1.89					1.42					
	2	16.5	75	17.09	13.2	29.4	23.5	2.03		3.28			1.48		3.44			
	3	19.2	90	12.55	12.8	31.1	20.7	3.15		2.71	2.39		1.75		1.51	1.85		
	4	16.9	90	14.20	11.3	58.7	42.8	4.64	4.71		3.51		1.93	4.50		2.61		
	5	25.9	90	7.74	17.3	34.8	27.9	2.25			1.93		1.72			1.63		
	6	22.4	90	8.27	14.9	28.2	18.8	2.83	2.41				1.65	2.39				
	7	25.6	120	17.11	12.8	32.6	16.3	2.70	4.46	3.11		2.58	1.41	3.93	2.03		2.54	
	8	4.7	30	7.66	9.3	18.5	36.9	3.35					2.34					
	9	6.2	30	8.12	12.5	17.6	35.3	3.66			1.65		1.44					2.07
	10	8.8	30	5.72	17.6	10.5	21.0				2.29					2.37		
	11	4.9	30	5.00	9.7	12.5	24.9				3.32					2.78		
	12	23.2	90	10.58	15.5			1.80	1.94		1.95	2.13	1.62	1.28			2.09	1.45
	13	6.9	30	3.48	13.7			1.86					1.66					
	14	7.5	30	4.05	14.9	3.0	5.9	2.18					1.54					
	15	7.7	30	5.64	15.4						2.29	4.03					3.77	0.83
PORTLAND	52	17.8	60	14.75	17.8	12.0	20.9	3.07					1.03					
	54	22.1	90	21.17	14.7	11.8	14.9	4.39					1.79					
	57	51.8	150	20.25	20.7	53.6	30.2	3.24					4.48					
	59	34.1	120	21.26	17.1	30.6	27.1	3.98	2.39				2.61	1.40				
	60	15.0	60	17.65	15.0	6.7	11.2		2.60					1.06				
	65	20.2	60	13.22	20.2	8.7	15.1	3.16					3.57					
	67	18.1	60	18.67	18.1	9.5	16.5	2.52	2.02				1.15	1.07				
	77	59.6	240	23.74	14.9	39.9	19.4	2.51	3.75				2.19	2.92				
	87	16.9	54	9.36	18.8	12.0	23.0	6.58					4.30					
BOULDER	1	5.4	40	5.33	8.1	14.4	21.6	3.39					1.98					
	2	16.2	75	10.25	13.0	64.6	51.7	5.00		3.82			2.47					
	3	16.0	75	20.53	12.8	29.1	23.3	2.28			3.65		2.03		2.75			
	4	17.4	75	17.37	13.9	55.5	44.4	2.32		3.40			2.13					
	5	30.3	90	19.30	20.2	27.5	18.3	5.18	4.54				1.53	1.93				
	6	13.8	60	2.20	13.8	26.6	26.6			3.79	2.21							
	7	12.0	60	7.65	12.0	20.5	20.5	2.09					2.15					
	8	12.3	60	17.16	12.3	28.0	28.0	3.84	2.03				3.80	1.69				
	9	13.6	60	15.68	13.6	27.9	27.9		2.40		1.63			2.43	1.97			

APPENDIX F

REPORT OF NEW TECHNOLOGY

A thorough review of the work performed under this contract has revealed no significant innovations, discoveries, or inventions at this time. In addition, all methodologies employed are available in the open literature. However, the findings in this document do represent new information and should prove useful throughout the United States in designing and evaluating future transportation demonstrations.

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