Working Paper No. 3

Puget Sound Transportation Alternatives Analysis

METRO

Feeder Bus Integration with Fixed Guideway Technologies

Municipality of Metropolitan Seattle

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NORTH CORRIDOR ALTERNATIVES ANALYSIS

FEEDER BUS INTEGRATION WITH FIXED GUIDEWAY TECHNOLOGIES

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November 1983

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EXECUTIVE SUMMARY

Selection of a preferred major investment in the Puget Sound Transportation Alternatives Analysis would involve changes to existing bus networks in the North Corridor. This working paper was prepared to assist in planning feeder bus service in conjunction with a light rail (LRT) alternative. The objectives of this paper are to document issues, service criteria, and experiences with both planning and operating feeder bus service integrated with LRT facilities. These also are applicable to exclusive guideway technology, should that technology be reconsidered in the future.

An integrated transit system consists of routes which perform two basic functions: linehaul and collection/distribution. The linehaul function involves service with high frequency, capacity, and performance between two geographic points in a corridor. Fixed guideway technologies such as LRT primarily perform linehaul functions on trunk routes. The collection and distribution function involves service between other points and linehaul stops. Bus routes that perform this function are called feeder routes. Figure E-1 illustrates these functions.

Modes of Access to LRT Stations

Riders of an LRT system access the guideway at stations or stops by walking, feeder bus, or automobile. The distance between a station and the transit rider's origin or destination is the principal factor determining which mode of access is chosen. Other factors include station location characteristics and the attractiveness of each mode to the rider.

Various studies have been conducted to determine what constitutes an acceptable walking distance to and from transit stops and stations. Section 1.1.1 gives the results of these studies. From the transit operator's perspective, the walk mode constitutes the most efficient form of access for short trips since it is available to most people, involves no terminal times, and costs little or nothing beyond pedestrian improvements, if needed.

Transit patrons are willing to walk a greater distance to a fixed guideway line than to a conventional bus route due to their expectation of a higher level of service (in terms of shorter trip times and headways) for their entire trip as compared with bus transit. Figure E-2 shows that, for rapid transit systems, the proportion of station access by walking begins to decline rapidly at a radial distance of approximately 2,000 feet (six blocks).

As the proportion of walk access declines, the proportion of access by feeder bus and automobile increases. Section 1.1.2 discusses the market areas of these modes. Feeder buses are the most important mode of access for trips with origins or destinations between 2,000 feet and three miles from a station.

Figure E-2 shows that, for trip origins with a radius of 1,750 feet (five blocks), the proportion of access by feeder bus is less than ten percent. For greater distances the proportion of station access by feeder bus rises rapidly. At a radius of 5,000 feet (approximately one mile) from a station, the feeder bus mode split levels off at about 85 percent and slowly declines at greater distances.

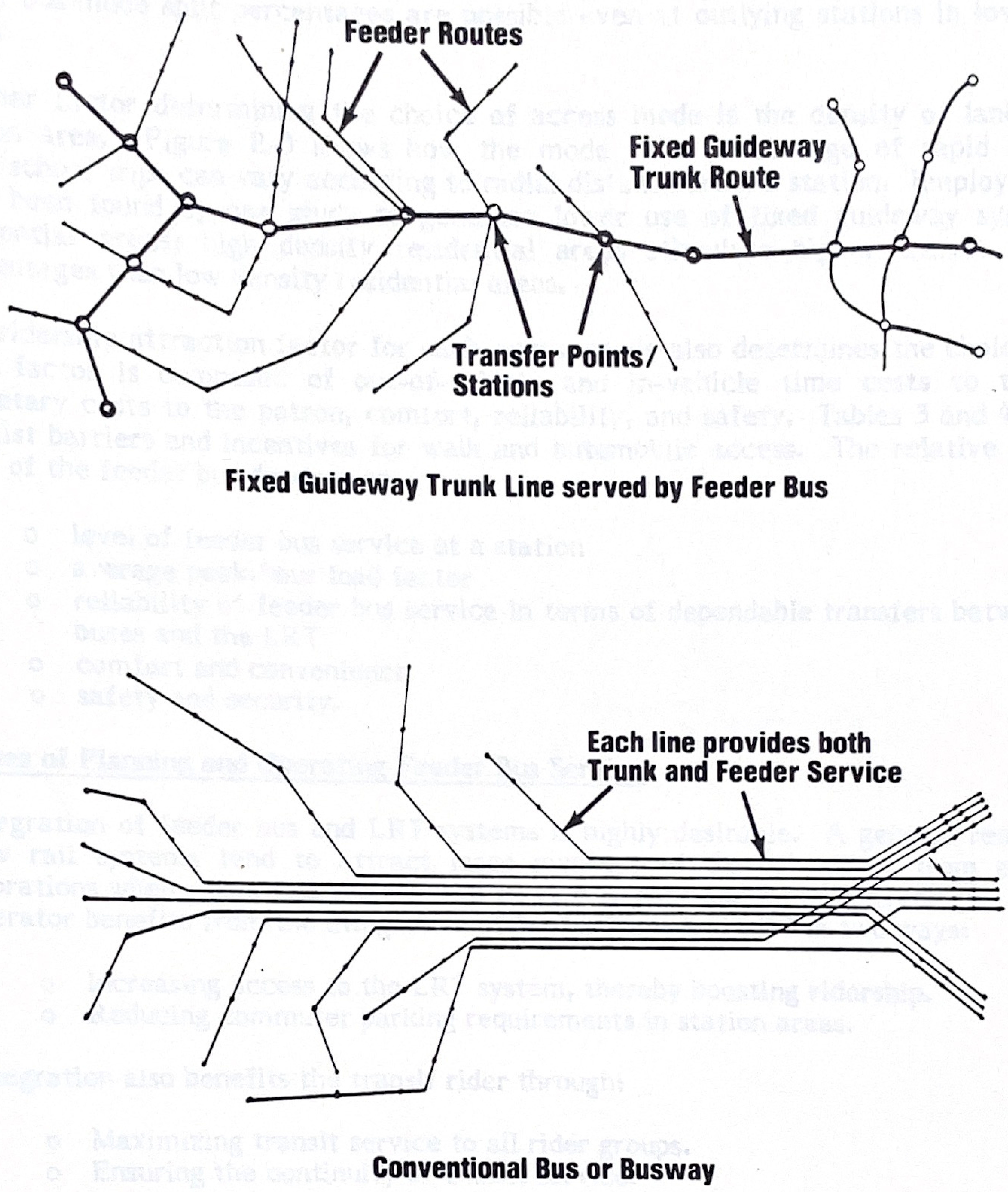

Fig. E-1 Corridor served by Conventional and Fixed Guideway Transit

Park-and-ride and kiss-and-ride forms of automobile access tend to be used for trip origins beyond 2,000 feet from a station, but the proportions remain small at most stations. At 4,000 feet the park-and-ride mode split rises to approximately ten percent, while the kiss-and-ride mode split levels off at about five percent. Although automobile access becomes more important as distance increases from a station, both park-and-ride and kiss-and-ride access represent only a small proportion of the total number of trips to and from stations. The experience of the Calgary bus-LRT system points out that high feeder bus mode split percentages are possible even at outlying stations in lower density areas.

Another factor determining the choice of access mode is the density of land uses in a station area. Figure E-3 shows how the mode split percentage of rapid transit for work/school trips can vary according to radial distance from a station. Employment areas have been found by one study to generate lower use of fixed guideway systems than residential areas; high density residential areas stimulate higher transit mode split percentages than low density residential areas.

The ridership attraction factor for each access mode also determines the choice of mode. This factor is composed of out-of-vehicle and in-vehicle time costs to the patron, monetary costs to the patron, comfort, reliability, and safety. Tables 3 and 4 in Section 1.3 list barriers and incentives for walk and automobile access. The relative attractiveness of the feeder bus depends on:

- o level of feeder bus service at a station
- o average peak-hour load factor
- o reliability of feeder bus service in terms of dependable transfers between feeder buses and the LRT
- o comfort and convenience
- o safety and security.

Issues of Planning and Operating Feeder Bus Service

Integration of feeder bus and LRT systems is highly desirable. A general reason is that new rail systems tend to attract large numbers of through riders from existing bus oeprations when riders find the new rail service quicker and more convenient. The transit operator benefits from the integration of feeder buses and LRT in two ways:

- o Increasing access to the LRT system, thereby boosting ridership.
- o Reducing commuter parking requirements in station areas.

Integration also benefits the transit rider through:

- o Maximizing transit service to all rider groups.
- o Ensuring the continuity of transit service.

Issues related to feeder bus network design and operation include:

- o Schedule integration between feeder buses and LRT.
- o Fare collection integration between feeder buses and LRT.
- o Creation of new local routes.
- o Functional duplication of service.
- o Implementation of TSM measures to enhance feeder bus service.
- o Design of station facilities.

ACCESS TO RAPID TRANSIT STATION
RELATIVE TO DISTANCE FROM STATION

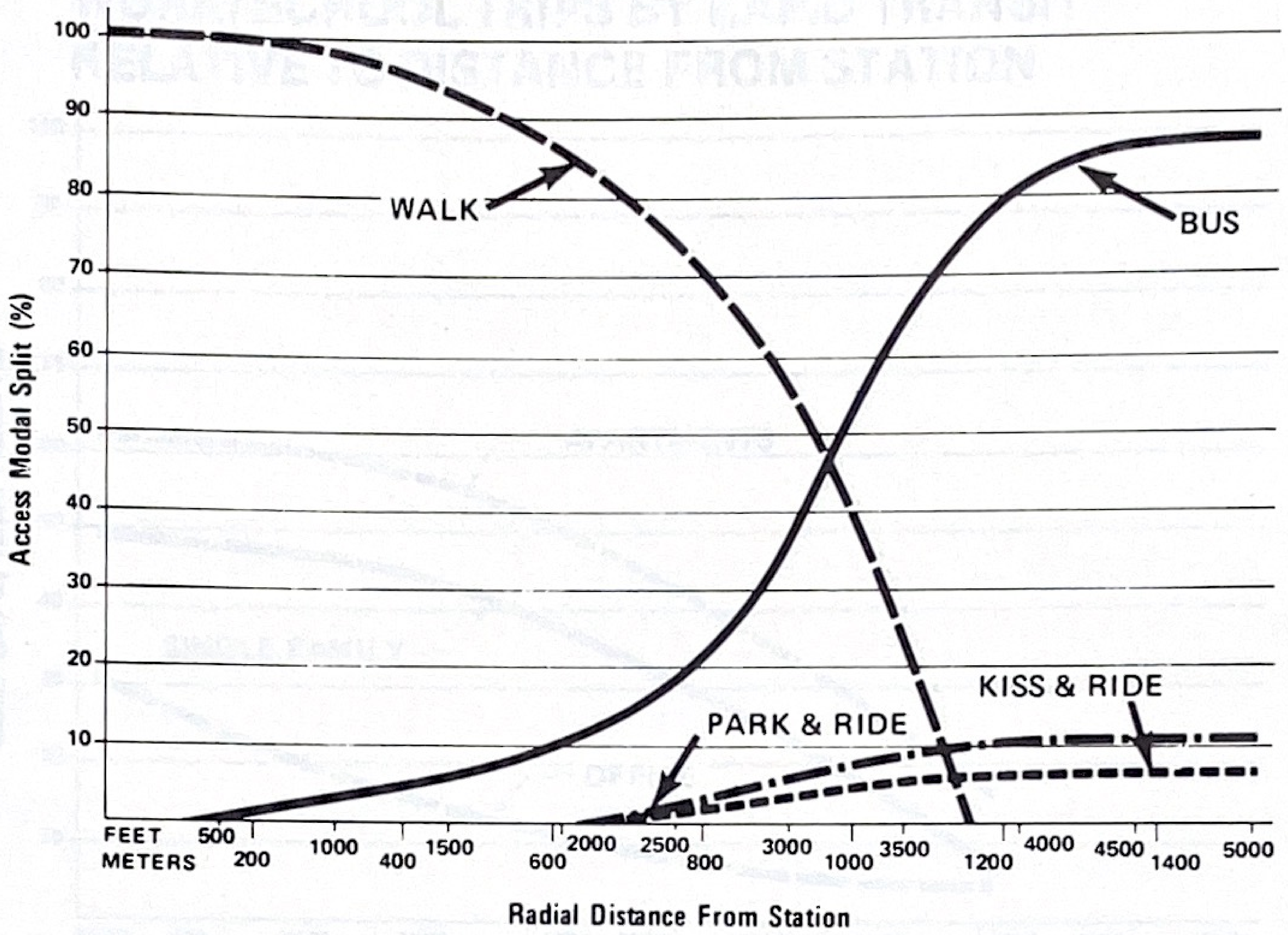

Fig. E-2 Access to Rapid Transit Station relative to distance from Station

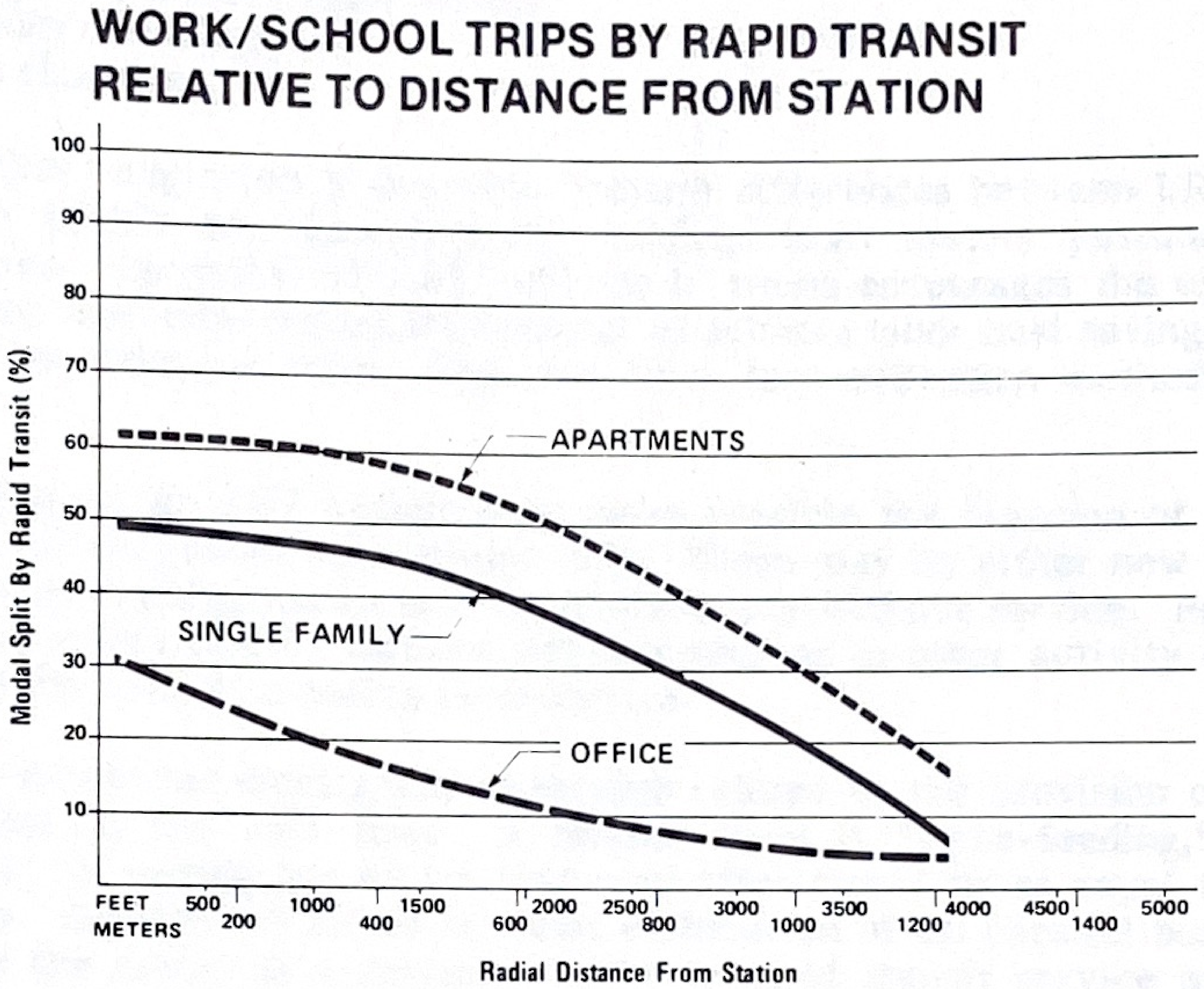

Fig. E-3 Work/school trips by Rapid Transit relative to distance from Station

Source: M.G.P. Stringham, "Travel Behavior Associated With Land Uses Adjacent to Rapid Transit Stations." ITE Journal (April 1982): 16-18

o Tradeoffs between feeder bus service and station parking.

Section 2.1 discusses means of schedule coordination between feeder bus and LRT systems. Schedule coordination of feeder and LRT services to minimize passenger waiting times is desirable when headways on either or both modes exceed ten minutes. One type of schedule coordination is the timed transfer, in which vehicles from different routes meet at the transfer point at the same time, remain at the point some fixed period of time (usually five minutes) to allow riders time to transfer, and depart simultaneously. Figure E-4 illustrates the scheduling of two groups of feeder routes.

Implementation of timed transfers may require changes in:

- feeder route headways
- round-trip feeder route speeds
- feeder route lengths
- bus fleet size.

Fare collection integration is desirable because differences between LRT and feeder bus systems can inhibit transfers (thereby holding down system patronage) or increase boarding times. Operation of LRT vehicles in trains encourages the use of self-service fare collection methods on the LRT vehicles to achieve labor cost savings through the use of only one operator per train. This and other fare collection methods are covered by Section 2.2.

Implementation of an LRT system may make possible the creation of new local routes which might not otherwise be cost effective. These may be either new crosstown routes or extensions of existing routes into areas previously without service. Feeder routes may not only carry riders to LRT stations but may also serve other activity centers. Section 2.3 discusses the issue of creating local service.

The issue of functional duplication of service relates to the provision of bus service on routes parallel to the LRT line. A related issue is "force-feeding," defined as the elimination of competing bus routes that may offer travel times equal to or better than the LRT line. Section 2.4 points out that elimination of all parallel bus service may be perceived by the public as a decrease in the level of transit service available to their neighborhood. Resolution of the issue should be on a case-by-case basis where public acceptance is balanced against patronage demand and operating requirements.

Implementation of TSM measures to give feeder bus movements preferential treatment can increase bus travel speeds, boost service reliability, and offer the potential for reduced bus operating costs and increased safety. Discussed in Section 2.5 are two measures of particular relevance, bus lanes on streets and channelization/signalization at intersections.

Station facilities along an LRT line must have sufficient capacity to accommodate the demands from walking, feeder bus, and automobile modes. Section 2.6 discusses considerations of station design. Important measures used to evaluate station designs include:

- Connectivity, accessibility, and continuity of a station layout.
- Passenger travel distances, times and delays.
- Passenger flow conflicts.
- Pathway availability.

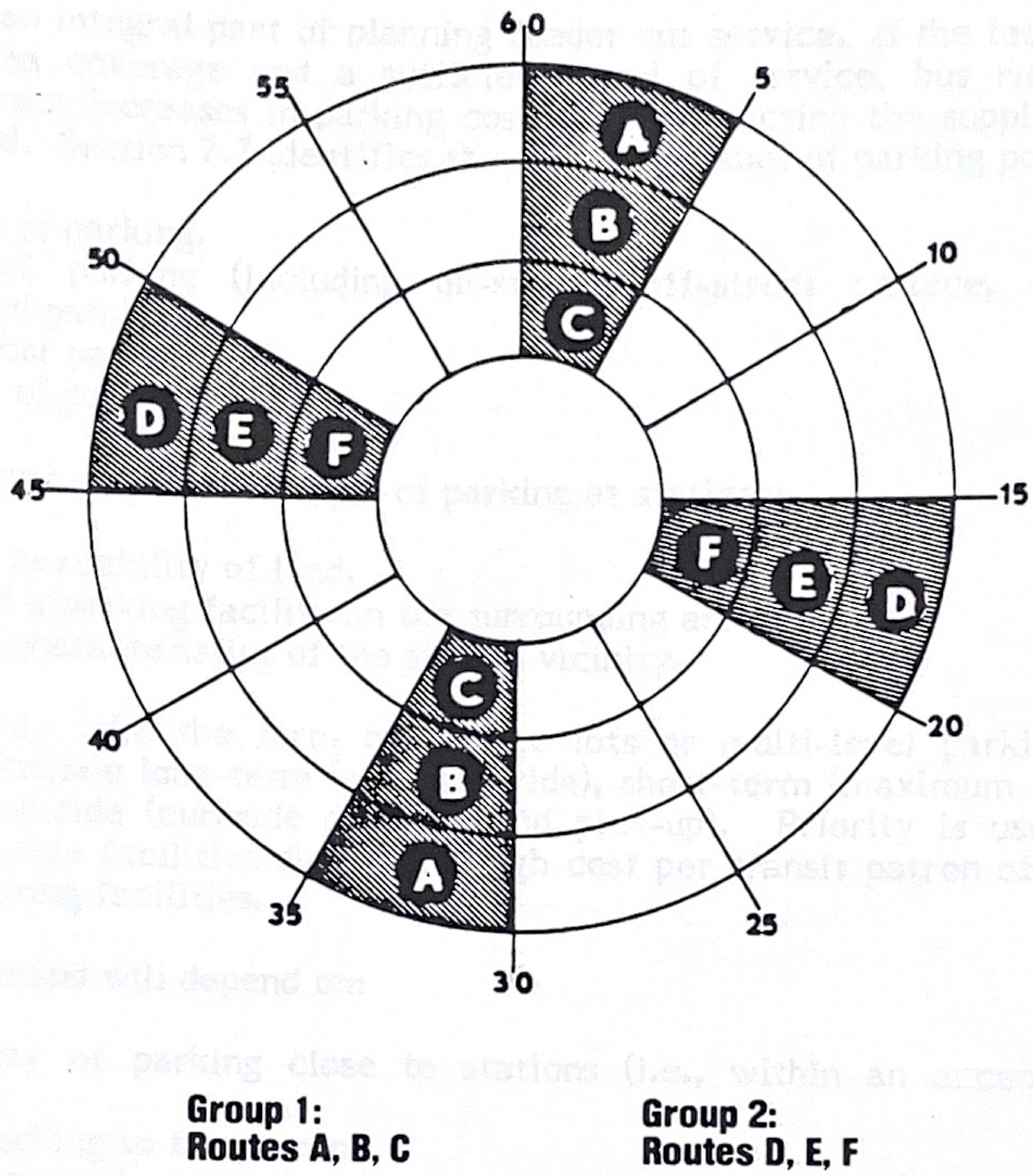

Fig. E-4 Clock Schedule for a Transit Center with staggered pulses of two groups of routes

Source: Vuchic et al., Timed Transfer System
Planning, Design and Operation
Report No. PA-11-0021 (Philadelphia: Department of Civil and Urban Engineering, University of Pennsylvania for UMTA, October 1981).

- Queueing locations.
- Security considerations.

A successful station design requires that the supply of the functional components meets the transit travel demand at a specific station location, both by total passenger volume and by time of day. Demand at a station location varies according to the station's locational characteristics (adjacent densities and land uses, market area size and composition) and the level of service provided by the fixed guideway and feeder bus routes to the station.

Parking policy is an integral part of planning feeder bus service. If the feeder bus system provides good area coverage and a sufficient level of service, bus ridership can be encouraged by direct increases in parking cost or by restricting the supply of parking in relation to demand. Section 2.7 identifies the following issues of parking policy:

- Location of parking.
- Supply of parking (including on-street, off-street surface, and off-street structured parking).
- Charges for parking.
- Duration of parking.

The following factors govern the supply of parking at stations:

- Cost and availability of land.
- Impact of a parking facility on the surrounding area.
- Land use characteristics of the station vicinity.

Station parking may take the form of surface lots or multi-level parking structures. Types of parking include long-term (park-and-ride), short-term (maximum of four to five hours), and kiss-and-ride (curbside drop-off and pick-up). Priority is usually given to providing kiss-and-ride facilities due to the high cost per transit patron of park-and-ride and short-term parking facilities.

Station parking demand will depend on:

- Availability of parking close to stations (i.e., within an acceptable walking distance).
- Cost of parking to the patron.
- Availability and attractiveness of alternative mdoes of access (walking and feeder bus).

Outlying station locations tend to have greater demand for parking due to the lower level of feeder bus service or the travel time savings involved in transferring to the fixed guideway system from the automobile. An inadequate supply of parking in relation to demand may result in a "spillover parking" problem, i.e. severe impacts on residential and business areas adjacent to fixed guideway stations. These impacts are not limited to shortages of on-street parking but can include a lower level of service on area streets, excessive noise and air pollution, and hazardous conditions for pedestrians. Spillover parking can be prevented by providing an adequate level of feeder bus service and sufficient station parking capacity. Where additional station parking cannot be provided, spillover parking control strategies may be necessary. These strategies may include residential parking sticker programs, daytime parking bans, metered parking during daytime hours, and other measures.

Case Studies

The four North American cities which have implemented feeder bus services in conjunction with new rail facilities over the last decade offer the most useful experiences in regard to feeder bus network design and operation. Operations in Atlanta, Calgary, and Edmonton show that feeder buses remain the predominant mode of access even at outlying stations. Feeder buses are, overall, the most important access mode for the Metrorail system in Washington, D.C.

Examples of barrier-free station design for feeder bus passengers can be found in Atlanta. Calgary illustrates the beneficial effects of feeder bus-LRT integration on local transit patronage. Edmonton demonstrates the possibility of systemwide timed transfer operations. The importance of dealing with local parking impacts is shown by the experience of the Silver Spring Metrorail station in the Washington, D.C. area.

Also reviewed are those metropolitan areas planning feeder bus systems to serve new fixed guideway facilities. These case studies include Buffalo, Detroit, Miami, Portland, Sacramento, San Jose, and Vancouver.

Feeder Bus Planning for the Puget Sound Transportation Alternatives Analysis

As part of the Task 3 travel and transit patronage forecasting process performed by the Puget Sound Council of Governments (PSCOG) for the Puget Sound Transportation Alternatives Analysis, Metro Transit in Spring 1983 developed transit networks to be coded to simulate each of the alternatives under consideration. The design and coding of the networks included feeder bus routes, park-and-ride lots, and transfer facilities needed to support each of the major investment LRT alternatives. This work covered routes opeated by Metro Transit in King County, Metro contract service in South Snohomish County, and routes operated by Community Transit in South Snohomish County.

The feeder bus networks were developed for patronage forecasting and cost analysis purposes only and are not intended to represent specific proposals for individual routes and service levels. A detailed analysis of bus routes and headways would be performed during preliminary engineering of a preferred alternative.

Design of feeder bus networks to serve the LRT alternatives began with the routes and service levels anticipated for September 1983 as a base. The present configuration of Metro service in the North Corridor was modified to serve the major investment alternatives. Considerations guiding feeder bus network design were:

- LRT feeder routes cover the same service areas as routes in the TSM Alternative.
- No existing route was diverted from its present alignment unless the diversion resulted in an overall travel time savings on trips to the Seattle CBD.
- Local bus service was preserved in the feeder bus network designs; the modified routes are those currently using I-5 to the Seattle CBD.
- An attempt was made to through-route or extend routes where possible to take advantage of opportunities to provide new crosstown (east-west) service.

Changes to the Community Transit bus network were limited to headway adjustments. Figure E-5 illustrates the feeder bus network developed for the I-5 LRT alignment.

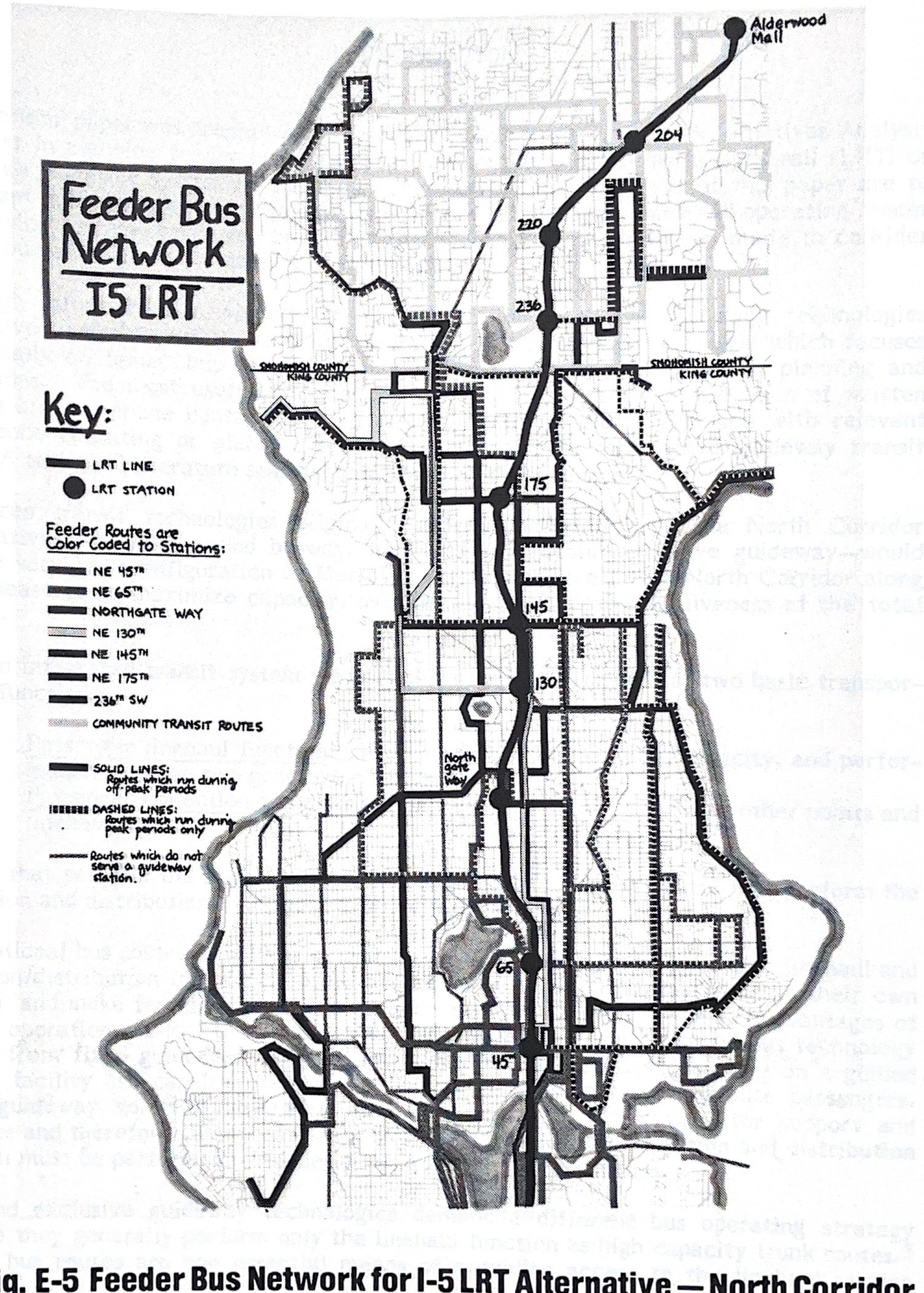

Fig. E-5 Feeder Bus Network for I-5 LRT Alternative — North Corridor Alternatives Analysis

INTRODUCTION

This working paper was prepared for the Puget Sound Transportation Alternatives Analysis to assist in planning feeder bus service in conjunction with either a light rail (LRT) or exclusive guideway system in the North Corridor.[2] The objectives of this paper are to document issues, service criteria, and experiences with both planning and operating feeder bus service to fixed guideway transit facilities. An attempt has been made to consider feeder buses in relation to other modes of access.

Although information is plentiful on the LRT and exclusive guideway technologies themselves, relatively little technical literature is conveniently available which focuses specifically on feeder bus network design, service criteria, and issues of planning and operations. The most useful information was obtained directly in the form of written reports and telephone contacts from transit agencies in North America with relevant experience operating or planning feeder bus networks to serve fixed guideway transit lines. A technical literature search complemented these sources.

All three transit technologies originally under consideration in the North Corridor Alternatives Analysis--guided busway, light rail (LRT), and exclusive guideway--would require varying reconfiguration of Metro Transit bus service in the North Corridor along with measures to maximize capacity, user benefits, and cost-effectiveness of the total system.

Such an integrated transit system would include routes that perform two basic transportation functions:

- o Passenger linehaul function: Service with high frequency, capacity, and performance between two geographic points in a corridor.
- o Passenger collection and distribution function: Service between other points and linehaul stops.

Routes that perform the linehaul function are called trunk routes; those that perform the collection and distribution function are called feeder routes.

Conventional bus routes as well as guided busway routes usually perform both linehaul and colection/distribution functions. Buses operating on a guided busway serve as their own feeders and make few, if any, stops once they enter the busway, since the advantages of busway operation are lost if too many stops are made along the busway. Bus technology differs from fixed guideway technologies in that transit vehicles operating on a guided busway facility are capable of leaving the busway to collect or distribute passengers. Fixed guideway vehicles have steel wheels on rails or rubber tires for support and guidance and therefore can operate only on the guideway. The collection and distribution function must be performed by feeder buses and other access modes.

LRT and exclusive guideway technologies demand a different bus operating strategy because they generally perform only the linehaul function as high capacity trunk routes.[3] Feeder bus routes are one essential means of providing access to the linehaul service and scheduling of transfers along with the design of facilities at transfer locations has a great bearing on how efficient transit operations will be as well as how attractive the service will be to users.

2.2.1 Headway Length and Transfers

To be successful, the operational integration of feeder bus service with fixed guideway service requires either a high degree of schedule coordination between the modes or a high frequency of service on both modes. A high frequency of service on both modes can better be provided when the transfer points or stations are also major trip destinations, and when the demand is high for access to the fixed guideway system.

Frequency of service is usually discussed in terms of headway, the time between the passing of two successive transit vehicles in the same direction on the same route. Headways are a function of the patronage on a route, the passenger capacity of the vehicles used, the number of vehicles used in a train, and the level of service specified by load factor and general transit operator policies.

Headways strongly affect the ridership attraction factor, identified previously as one of the determinants of passenger mode choice. Passenger waiting and transferring times vary with the length of the headway. The longer these out-of-vehicle travel times are, the longer the overall travel times. Longer travel times decrease the attractiveness of transit to potential users. Headways of ten minutes or less on both fixed guideway and feeder modes tend to minimize overall transit travel times by keeping the transfer waiting times at five minutes or less for a majority of riders.

However, in practice frequent headways cannot be maintained at all times on both fixed guideway and feeder modes. Most station locations will not be themselves major destinations justifying frequent service, but rather transfer points between the fixed guideways system and the feeder bus system. Suburbs and other areas of low-density development may generate enough demand for service to maintain frequent feeder bus headways during the peak weekday hours to handle work-oriented trips, but lower ridership in the off-peak hours and on weekends may require an unacceptably high level of subsidy to operate frequent feeder service.

Headways greater than ten minutes increase the transfer waiting times to an unacceptable length for most transit riders. The willingness of people to transfer is affected strongly by the amount of waiting time required between vehicles at the transfer point. Research on transit rider behavior indicates that most riders will not tolerate a transfer waiting time longer than five minutes (Ref. 43).

Long waiting times to transfer are a significant deterrent to transit travel. Because transfers are a necessary feature of an integrated transit system, the coordination of scheduling between the feeder bus system and the fixed guideway system is vital for the entire system to operate efficiently and to attract maximum patronage. One way to minimize waiting times for transferring is to implement a timed transfer system.

A timed transfer involves vehicles from different routes meeting at the transfer point at the same time, remaining at the transfer point some fixed period of time (usually five minutes) to allow riders to transfer among the converging routes, and departing simultaneously for various destinations. Instead of occurring randomly with generally long waiting times, transfers under a timed transfer system require minimal waiting time and occur on a reliable basis.

A study by Vuchic, Clarke, and Molinero (Ref. 43) provides a useful basis for discussing the relationship between transfers and length of headways. Three cases define the relationship:

Case 1: Short-to-Short Headway

Frequent service on both routes (headways of ten minutes or less) involves minimal waiting times for transfers. This situation may occur between any two heavily traveled routes, typically during peak hours. Schedule coordination in the form of timed transfers is not necessary.

Case 2: Long-to-Short/Short-to-Long Headway

Transferring from one route with long headways (greater than ten minutes) to another route with short headways (ten minutes or less) involves minimal waiting times. This situation may occur between feeder bus service with long headways and fixed guideway service with short headways. Schedule coordination is not necessary because waiting times are short. The reverse situation, transferring from one route with short headways to another route with long headways, may involve short to long waiting times on a random basis, with the longest waiting times equal to the long headway. Schedule coordination would allow certain trips of the route with short headways to meet all trips of the route with long headways by means of timed transfers.

Case 3: Long-to-Long Headway

Transferring from one route to another when both have infrequent service (headways greater than ten minutes) involves long waiting times. This situation corresponds to off-peak hours when the level of patronage does not require frequent service on either the fixed guideway or the feeder bus routes. Schedule coordination is necessary to minimize waiting times.

When headways are longer than ten minutes on connecting routes, one of two types of schedule coordination are possible. The first is called sequential coordination and involves vehicle arrivals on two connecting routes always being in the same time sequence. An example would be a feeder bus route always arriving five minutes before the fixed guideway route at a transfer point. With this type of coordination, transfer waiting times may be minimized from one route to another in one direction but not in the opposite direction, because no overlapping layover time is provided on both routes. Sequential coordination may be acceptable when most of the patronage flow is in one direction, as typically occurs during peak hours.

The other type of schedule coordination is the timed transfer, which involves overlapping layover times for both routes in order to minimize passenger waiting times. Timed transfer operation requires headways to be compatible on all coordinated routes. If the headways are not identical, then they must be even clock multiples of each other, such as 30:60, 20:40, or 15:30:60.

Some transit operators have implemented schedule coordination not only between feeder bus routes and a fixed guideway route, but also among feeder bus routes. In effect, each station becomes a timed transfer transit center. Timed transfer operation among feeder bus routes can be advantageous if the fixed guideway operates on short headways while the feeder buses operate on long headways, and if a significant number of transfers occur among the feeder routes.

2.1.2 Route Type and Transfers

The type of route(s) involved also affects transfers and is therefore important to operational integration of feeder bus service. Routes may be analyzed according to whether they are terminating or through routes, and whether they are trunk routes or feeder routes. Terminating routes end at the transfer point, whereas through routes pass through the transfer point on their way to another destination. Trunk routes and feeder routes were distinguished in the introduction of this memorandum. Fixed guideway systems usually represent trunk routes, which are dominant in terms of service frequency, capacity, and performance characteristics in comparison to feeder bus routes.

Where a number of feeder routes with long headways terminate at a station served by a fixed guideway trunk route with short headways (Case 2), implementing a timed transfer system may minimize transfer waiting times along feeder routes but might create uneven passenger loadings on the trunk route at certain stations. Becaue the trunk route typically operates more frequently, many of its trains will meet no feeder routes at certain transfer points, whereas a few trains will receive all the feeder bus passengers from these points.

The study by Vuchic et al. (Ref. 43) recommends that timed transfer operation should be used only if a significant number of transfers among the terminating feeder routes is expected. As the discussion under Case 2 pointed out, a timed transfer system is not necessary for transfers between feeder buses (long headways) and the fixed guideway system (short headways). If timed transfer operation is used for transfers among feeder routes, the routes should be scheduled to arrive in groups in order to provide even loading on the trunk route. Such a pattern of staggered meets, or "pulses," is illustrated by Figure 6.

Where a number of feeder routes pass through a station, a timed transfer operation may be desirable among feeder routes wtih long compatible headways and significant numbers of transferring passengers. The problem with through routes is the delay caused for non-transferring passengers by the typical five-minute layover at the transfer point. A trade-off may be required between minimizing the waiting time for transferring passengers and minimizing the delay for through passengers. The Vuchic et al. study (Ref. 43) recommends only "precise scheduling, reliable operation, and convenient design of transfer points" to minimize inconveniences to through passengers.

Another possible station situation may be a combination of terminating and through feeder bus routes. If the headways are long on the feeder bus routes and short on the fixed guideway trunk route, the best coordination may be scheduling and terminating routes to arrive before and leave after the through routes. In this way the delay to through passengers is minimized by only operating the terminating routes with timed transfers. However, passengers transferring from the trunk route with short headways to through feeder routes with long headways may face long waiting times if the trunk and feeder routes are not coordinated. Whether to implement timed transfers will depend on the relative levels of patronage and the directions of transfers, both of which may vary through a day.

2.1.3 Implementation of Timed Transfers

Alteration of an existing bus network to feed fixed guideway stations with timed transfers may require changes in:

- Feeder route headways.
- Round-trip feeder route speeds.
- Feeder route lengths.
- Bus fleet size.

Implementation of timed transfers requires that the intersecting routes share the same headway or use a headway which is an exact multiple of headways on other routes. Headways usually are divisible into 60 minutes for ease of schedule comprehension. Thus, timed transfer routes have headways of either 15 and 30, 15-30-60, or 20-40-60 minutes. As previously mentioned, headways of ten minutes or less do not require timed transfer operation because waiting times are already short.

Feeder route round-trip speeds can be increased through reductions in terminal layover times, improvements in passenger boarding and alighting, changes in fare collection methods, and selective application of preferential transit measures. Fare collection methods are discussed in Section 2.2. For a discussion of preferential transit measures, see Section 2.5. The amount of reduction possible in layover time may be constrained by labor contracts, but improvements in route reliability can result in reduced delay recovery time.

Passenger boarding and alighting can represent a significant source of delay in transit operation for both feeder and trunk routes. A study of San Francisco's MUNI LRT surface operations reported by Straus (Ref. 36) indicates that passenger stop times accounted for 20 percent to 33 percent of LRT running time and were a far more significant cause of delay than traffic signals. The same study noted the experience of Toronto, where signal delays were found to account for the largest portion of total delay, although boarding and alighting delays were found to be almost as significant. Passenger loading delays are largely related to the fare collection methods used.

Alterations in feeder route length may be necessary if large changes in route cycle times must be made to fit the requirements of timed transfer operation. A reduction in cycle times may be possible only if a portion of a route is deleted. However, a feeder route which otherwise would have excessive layover time may be lengthened to serve a new area at little additional cost.

The fourth way to adapt service to timed transfer operation, changes in fleet size, may be necessary if alterations to round-trip speeds or route lengths are inadequate to permit the desired headways. To shorten a headway, additional vehicles usually must be added to a route. In cases where instituting a common headway on feeder buses for timed transfer purposes results in uneven load factors on the feeder routes, vehicles of different sizes can be employed to adjust for differences in patronage levels.

2.1.4 Conclusions

Timed transfers are a form of schedule coordination which can play an important part in the integration of feeder bus service with fixed guideway trunk service. Timed transfer scheduling requires definition of route length, operating time, terminal time, round-trip time, headways, frequency of terminal departures per hour (the inverse of headway), round-trip speed, average speed of operation between terminals, and number of vehicles per route. Whether timed transfers should be offered among feeder routes and/or between feeder routes and fixed guideway trunk service depends on an analysis of conditions at each specific station.

2.2 Fare Collection Integration

Compatibility of fare structure, fare collection methods, and transfer ticket handling are desirable features of a feeder bus and fixed guideway system, since transfers are a necessity for a majority of patrons and because incompatibilities can inhibit transfers and thereby hold down system patronage. Also desirable are the minimization of the collection cost per passenger and the flexibility to accommodate future fare system changes, which may include zone fares, pass cards, multiple-ride and single-ride tickets, concession fares, and time-variable fares (Ref.42).

Principal methods of fare collection include conventional fare collection, barrier-controlled fare collection, and self-service fare collection. Conventional fare collection requires payment of fare or display of pre-payment card at the entrance of the vehicle with confirmation by the vehicle driver. Barrier methods control access to transit loading areas to ensure payment of fares. Self-service methods depend on passengers purchasing tickets or passes and retaining them for proof of payment; access to and from vehicles is uncontrolled. Enforcement of fare payment in self-service fare collection is by means of roving fare inspectors (Ref. 28).

Operation of fixed guideway vehicles in trains encourages the use of barrier or self-service fare collection methods in order to achieve operating cost savings through the use of only one operator per train. Conventional fare collection methods require an operator aboard each vehicle to verify fare payment.

Because barrier systems are capital-intensive and impractical for bus operations, the following options appear reasonable as fare collection methods for fixed guideway and feeder systems:

1. Conventional fare collection for both fixed guideway and feeder bus systems (sometimes used in LRT systems where an operator is aboard each vehicle).

2. Barrier fare collection for the fixed guideway system, conventional fare collection for the feeder bus system.

3. Self-service fare collection for the fixed guideway system, conventional fare collection for the feeder bus system.

4. Self-service fare collection and conventional fare collection for both fixed guideway and feeder bus systems; those patrons without pre-purchased tickets are required to enter transit vehicles by the front doors in order to pay fares in the conventional way.

5. Self-service fare collection for both fixed guideway and feeder bus system.

The case studies in section three of this memorandum indicate that the third option is most common in North American cities operating or planning LRT systems, with a few cities planning or studying self-service fare collection for their entire systems.

The method of fare collection affects the ease of transfer between feeder buses and the fixed guideway system. Use of conventional fare collection methods has the disadvantage of slower passenger boarding and alighting movements compared to self-service fare collection. As previously mentioned in the discussion of timed transfer implementation under Section 2.1.4, boarding and alighting delays can adversely affect the reliability of bus service as well as increase bus operating costs.

A study by Higgins (Ref. 15) on the coordination of feeder buses with the Bay Area Rapid Transit System (BART) in the San Francisco Bay area show how the division of operating authority among three agencies has inhibited fare collection integration and made transfers between BART and the area's bus systems more difficult than originally envisaged. BART planners originally chose an automated barrier fare collection without adequate consideration of how transfer tickets would be issued to patrons traveling from feeder buses to BART. The two bus operators, San Francisco's MUNI and the East Bay's AC Transit, have declined to impose upon their drivers the task of issuing tickets to BART riders.

The outcome has been to install specialized equipment in BART stations to issue transfer tickets to patrons traveling from train to bus. For MUNI, a two-way ticket allows a transfer from BART to buses and back to BART again. For AC Transit, a transfer ticket is valid only for travel from BART to buses. Both AC Transit and MUNI utilize fare structures different from that used by BART. Transfers to BART require patrons to pay a separate fare at BART stations.[6]

A review of LRT fare collection methods by Parkinson (Ref. 28) notes that barrier free collection requires that bus transfer passengers pass a staffed fare payment booth before boarding a fixed guideway system if they are not charged an additional fare. Such a requirement negates the labor savings possible with unstaffed stations and automated fare collection equipment. The only alternatives for handling free transfers under a barrier fare collection system are issuing machine-readable transfer tickets to transferring passengers or physically separating patrons arriving at the station by feeder bus from those arriving by other modes such as walking and automobile. Two cities - Atlanta and Montreal - have adopted machine-readable transfers (Ref. 28). The impact of fare collection methods on station design will be discussed in Section 2.6.

2.3 Creation of New Local Routes

Implementation of a fixed guideway system may make possible the creation of new local routes that would not otherwise be cost-effective. These may be either new crosstown routes or extensions of existing routes to outlying areas previously without service.

Most transit systems with a radial orientation to the regional CBD have few crosstown routes. Sometimes crosstown routes can be designed to serve multiple activity centers with high patronage potential, but usually crosstown routes depend