on transfers to and from intersecting routes are ten minutes or less, transfer waiting times will exceed five minutes, which is the length of time acceptable for most transit riders. As Section 2.1.1 pointed out, short headways may be impractical to maintain in lower density areas where productivity would be low. Timed transfers are also impractical for crosstown routes due to the large number of transfer points.

With a fixed guideway system in place to perform trunk service to the CBD as well as connect major activity centers, bus transit routes can be reoriented from stations along the guideway to serve other functions besides the primary function of feeding the guideway stations. These secondary functions relate to collection and distribution of passengers between residential areas and outlying activities such as schools, shopping, and employment. Pratt (Ref. 29) observes that routing feeder bus routes through fixed guideway stations can provide new no-transfer service to passengers not using the guideway trunk service. As noted in section 2.1.2, if timed transfers are implemented at guideway stations the transit operator may have to make trade-offs between schedule coordination and minimization of travel times for through passengers.

Most discussions of the local service aspect of feeder bus routes assume that the configuration of these routes should be in a grid pattern perpendicular to the fixed guideway in order to serve the greatest area in the least amount of time. However, Smith (Ref. 34) notes a major drawback of a pure grid transit network to be the assumption of the same market potential for its entire service area, whereas transit is most attractive for travel to higher density trip generations.

A consultant study of feeder bus planning for the Southeastern Michigan Transportation Authority (Ref. 23) mentions the advantage of an angled feeder bus approach to stations. Perpendicular feeder bus routes in theory minimize the travel time involved to access stations, but they may not minimize the total travel time when demand is oriented in a certain direction, such as CBD-oriented travel during peak hours. Despite the fixed guideway system offering travel times superior to bus transit, better overall travel times may be achieved by routing feeder buses at least partially in the direction of the demand destination.

Whether perpendicular or angled routing is used for feeder bus routes will depend on the following considerations:

- Differences in travel time among specific alternative approaches to stations
- Local topography
- Availability of arterial streets
- Directions of passenger demand
- Requirements of timed transfer operation for particular round-trip speeds or route lengths

Thus, the creation of new local service as a byproduct of feeder bus network design will not be simply a mechanical application of the grid network concept, but rather by influenced by the five factors listed above.

2.4 Functional Duplication of Service

This issue concerns the provision of bus transit service on routes which parallel fixed guideway service. A related issue is the "force-feeding" of transit patrons into stations of a fixed guideway system. "Force-feeding" involves the elimination of competing bus transit routes that may offer travel times to a destination equal to or somewhat better than those offered by the combination of feeder bus and fixed guideway service.

2.4.1 The Parallel Service Issue

The start of a new fixed guideway service tends to have substantial impacts on parallel bus services. An example given by Pratt (Ref. 29) is the opening of the Lindenwold High Speed Rail Line from Philadelphia to the New Jersey suburbs in 1969. The local bus operator at the time was opposed to rail service due to the threat it posed to bus patronage; the rail operator was prohibited by statute from engaging in bus operations. Thus, rail service opened without any coordination with area bus service and without the option of establishing a bus network oriented solely to feeding the rail line.

The principal effects of this situation were threefold. First, a sharp drop in patronage occurred on the bus routes offering parallel service to the rail service. Second, because there was little connecting bus service at rail stations and no coordinated fare structure, the station patronage volumes were lower than originally predicted. The third effect was the inadequacy of station parking for the demand, which exceeded expectations, because the only ways of accessing the stations were by walking and by automobile.[7]

Elimination of some or all parallel bus service in the course of reorienting a bus network to serve a fixed guideway line can have the effect of making local transit service less convenient. For example, instead of walking to bus stops spaced every two blocks, transit patrons may have to walk five blocks or more to the nearest fixed guideway station or stop. If a high demand exists for local transit trips of short length, retention of some parallel service may be cost-effective from the transit operator's perspective. If an objective of the fixed guideway system is to serve localized as well as regional travel needs, an alternative to parallel bus service may be closer spacing of stations or stops where justified by patronage demand.

Proposals by transit operators to eliminate parallel service are motivated by the desire for efficient transit operations, with efficiency being defined as elimination of duplicating service. According to the definition of system integration given in Section 2, parallel bus service is wasteful except in situations where patronage demand warrants such service.

Taking a different view is a study by Landau et al. (Ref. 20) analyzing the issue of bus service parallel to the BART trans-Bay line in the San Francisco area. This study contends that functional duplication of service may not always be wasteful but can provide more reliable and diverse service to the traveling public. The result of parallel service can be higher overall transit ridership than could have been obtained with either service by itself.

As early as 1965, studies conducted by the Metropolitan Transportation Commission recommended the elimination of competing bus service parallel to BART lines (Ref. 15). The operator mainly affected by these and later recommendations, AC Transit, has declined to eliminate routes such as its trans-Bay lines that continue to be productive in terms of patronage and farebox recovery. A modeling simulation of

BART and AC Transit operations found that the differentiation fo the quality and price of transit services produced an overall increase in transit ridership by meeting the travel preferences of a greater number of riders (Ref. 20). The conclusions of the Landau study were that redundancy improves the general reliability of transit service offered to the public and that each transit mode should be encouraged to do what it does best.

Proposals to eliminate or decrease parallel bus service may be perceived by the public as proposals to decrease the level of transit service available to their neighborhood or community. Resolution of the parallel service issue should be on a case by case basis where public acceptance is balanced against patronage demand and operating requirements.

2.4.2 The "Force-Feeding" Issue

"Force-feeding" is a related issue in the design of feeder bus networks. In certain situations a transit operator may decide to eliminate bus routes traveling to the same destination as the fixed guideway system in order to reduce bus operating costs and to maximize patronage on the fixed guideway system. Not only may some transit patrons experience no travel time savings or somewhat longer travel times on the feeder bus-fixed guideway system, but patrons also will be required to transfer between modes whereas previously they may have had a no-transfer trip.

An account by Bakker (Ref. 3) of Edmonton's conversion of CBD-bound express bus routes into feeder routes serving the northeast LRT line noted that the integrated bus-LRT system reduced travel time for most patrons located reasonably close to stations. However, no travel time savings occurred for the Abbotsfield area. When the LRT line opened in 1978, most complaints from the public came from this area due to the resentment over having to transfer with no advantage in travel time. Most areas served by the LRT had travel time savings of eight to eleven minutes.

2.4.3 Conclusions

Parallel bus route may mean redundant but superior service to some patrons, while in other localities patrons may perceive the exclusive guideway as the superior mode. Guidelines for dealing with the parallel service and "force-feeding" issues include:

- Avoidance of "force-feeding" as much as possible, since one objective of an integrated transit system is an improvement in transit travel times for most patrons.
- Identification of areas where elimination or reduction of parallel service will be an issue.
- Estimation of how many and what type of users will be affected by proposed changes in services.

Judgments will need to be made as to how patronage will respond to the elimination or reduction of parallel service and to the introduction of feeder routes. A strong public participation process is advisable prior to making route changes.

2.5 Implementation of Transportation System Management Measures

The discussion on timed transfer implementation in Section 2.1.3 mentioned transportation system management (TSM) measures as a means of enhancing feeder bus operations. Measures giving preference to bus movements over those of general traffic are classified as TSM. These are defined as less capital-intensive actions designed to improve the operation of existing transportation facilities.

Preferential measures for transit can benefit feeder bus operations by increasing bus travel speeds, increasing service reliability, and offering the potential for reduced bus operating costs and increased safety. These measures can improve the competitive position of transit with respect to the automobile. Improved bus speeds and service reliability are vital to a timed transfer operation of feeder bus routes at fixed guideway stations. The ridership attractiveness of an integrated bus and fixed guideway transit system depends on minimizing transfer waiting times and making those connections reliable.

Two priority measures of particular relevance to feeder bus operations are bus lanes on streets and channelization/signalization preference at intersections. Bus lanes may be either exclusive (for bus use only) or shared with other high occupancy vehicles (HOV's). These lanes can be further categorized as peak-direction with-flow, peak-direction contra-flow, or two-way. An important application of two-way bus lanes is access to stations, where separation of feeder buses from pedestrians, automobiles, and other modes would act to minimize bus/pedestrian and bus/auto conflicts.

Preferential measures at intersections include channelization and signalization treatments. Channelization provides special bus-only lanes for turning or through bus movements. Signalization treatments may include a leading or lagging green signal phase or a special transit-only signal. Signalization in combination with channelization may reduce the waiting time for feeder buses at signals, allow feeder buses to bypass long queues of general traffic, or permit feeder buses to make turns prohibited for other vehicles. Signalization measures can be especially useful to enhance access and egress in the vicinity of fixed guideway stations.

In planning feeder bus service, problem areas should be identified as candidates for preferential measures. Of particular importance are arterial street approaches to stations, where congestion could impair the reliability of feeder bus operations.

2.6 Design of Station Facilities

Station facilities along a fixed guideway must have sufficient capacity to accommodate the demands from walking, feeder bus, and auto modes, the three principal modes of access. Feeder bus and auto modes require provision for passenger boarding and alighting, vehicle storage, and access to the surrounding street and freeway networks. This section focuses on aspects of passenger circulation and handling at stations and how these aspects affect feeder bus operations.

2.6.1 General Considerations of Station Design

Passenger circulation and handling objectives deal with transit users (non-mobility impaired), special users (elderly and handicapped who are mobility impaired), and the transit operator. Table 5 lists station planning and design objectives by interest group. The design process should seek to achieve tradeoffs among these objectives through careful consideration of major functional components, defined as combinations of space and devices (Ref. 10). Functional components include:

- o Transit vehicle access (fare collection methods, boarding and alighting)
- o Internal passenger circulation (pathways, stairs, escalators, elevators)
- o Intermodal passenger circulation (ramps, doors)
- o Communications (signage, public address system)
- o Special user facilities

Measures to evaluate how effectively the functional components of a particular design meet the passenger processing objectives of Table 5 include:

- o Connectivity, accessibility, and continuity of a station layout
- o Passenger travel distances, times, and delays
- o Passenger flow conflicts
- o Pathway availability
- o Queueing locations
- o Security considerations

Supply, layout, and sizing of the functional components define the arrangements for passenger circulation and handling at a station (Ref. 10).

TABLE 5

STATION DESIGN OBJECTIVES RELATED TO PASSENGER CIRCULATION AND HANDLING

User

1. Minimize travel impedences (time, distance)
2. Minimize delays (queues)
3. Minimize conflicts (crossing movement paths)
4. Minimize crowding
5. Minimize disorientation
6. Maximize safety
7. Maximize reliability
8. Provide for efficient fare collection
9. Minimize level changes

Special User

1. Eliminate level changes
2. Reduce fare collection barriers
3. Avoid crowding
4. Eliminate physical barriers
5. Provide locational guides

Operator

1. Maximize equipment reliability
2. Efficiently control entry
3. Maximize safety
4. Process passenger flows efficiently
5. Provide adequate space

Source: Lester A. Hoel, Michael J. Demetsky, and Mark R. Virkler, Criteria for Evaluating Alternative Transit Station Designs, Report No. DOT-TST-76-68 (Washington D.C.: U.S. Department of Transportation, Office of University Research, February 1976), pp. 8-9.

A successful station design requires that the supply of the functional components meets the transit level demand at a specific station location, both by total passenger volume and by time of day. Demand at a station location is determined by 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 (Ref. 16).

Stations may be located either along a fixed guideway line or at the end of the line. Because most station will be bus transfer points, adequate bus access and boarding capacity are important design considerations. The number of bus bays for passenger boarding/alighting at station platforms depends upon the following factors:

- Number of feeder bus routes serving a station
- Peak-hour headways of feeder routes
- Use of timed transfer schedule integration
- Reliability of feeder operation
- Station dwell times of feeder buses

More frequent headways and overlapping dwell times will require a greater number of bus bays to be incorporated into a station design (Ref. 42).

Another design element related to bus operations is the provision of bus turnaround capability. This may involve either a special area adjacent to the station or the surrounding street system, depending on environmental and street maintenance considerations.

Timed transfer operation involves bringing a number of routes into the station simultaneously. Because each route arriving for a particular meet or pulse requires its own boarding/alighting area, the station design capacity should accommodate the maximum number of buses anticipated for any pulse.

End of line stations usually have special requirements in terms of the supply and arrangement of functional components. End stations usually have a large number of feeder bus routes serving an area beyond the fixed guideway corridor. Also, the outlying location of most end stations requires an adequate supply of parking due to the greater importance of the automobile as a mode of access. If construction and operation of a fixed guideway system is staged, the interim end of line station should have adequate provisions for feeder buses and automobile commuters. These provisions may exceed those necessary to meet ultimate demand when the station is no longer the terminating point for the fixed guideway system.

2.6.2 Fare Collection Methods and Station Design

The type of fare collection method chosen for the fixed guideway and feeder bus systems will impact station design. If transfers between the fixed guideway and buses are free, and if a barrier fare collection system is employed for the fixed guideway, the station design must separate passengers using the feeder bus system from those passengers arriving at the station by other modes such as walking or automobile.

In Atlanta the Metropolitan Atlanta Rapid Transit Authority (MARTA) has designed two stations in such a way as to allow feeder bus passengers to bypass the fare gates, whereas passengers arriving by automobile or walking must pass through a separate entrance and a barrier free collection system (Ref. 5). Figure 7 illustrates the design of one of the MARTA stations.

Separation of feeder bus passengers from other passengers is unnecessary if self-service fare collection is used on one or both transit modes. Tri-Met in Portland intends to use self-service fare collection on its Banfield LRT line in 1986. This will be compatible with self-service fare collection already in use on its buses.

San Diego, California and both Calgary and Edmonton, Alberta use self-service fare collection on their LRT lines only. According to a recent report, the Southern California Rapid Transit District in Los Angeles is considering self-service fare collection on its planned Metro Rail System (Ref. 32).

2.7 Tradeoffs Between Feeder Bus Service and Station Parking

As Table 4 in Section 1.3 pointed out, the availability of station parking and the ease of automobile access are two factors that influence the choice of station access mode. Availability of parking is more important as station distance to the CBD and other major activity centers increases. Providing no parking or inadequate parking at stations may have one of two effects. Either potential patrons may be discouraged from using the fixed guideway system in areas with little feeder bus service, or excess parking demand may result in spillover parking on neighborhood streets close to a station.

A 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. A report produced for Miami's rapid transit project (Ref. 27) lists 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

This section will first review the determinants of station parking supply and demand and then discuss elements desirable in a station parking policy. Strategies for dealing with spillover parking will be treated separately due to the importance of this problem. The conclusion relates parking policy elements to the provision of feeder bus service.

2.7.1 Determinants of Station Parking Supply

A review of available reports and contacts with transit operators suggest that the following factors govern the supply of parking at fixed guideway station locations:

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

Parking supplied in the vicinity of stations for use by transit patrons may take the form of surface lots or multilevel parking structures. The type of parking can be

Hightower Station

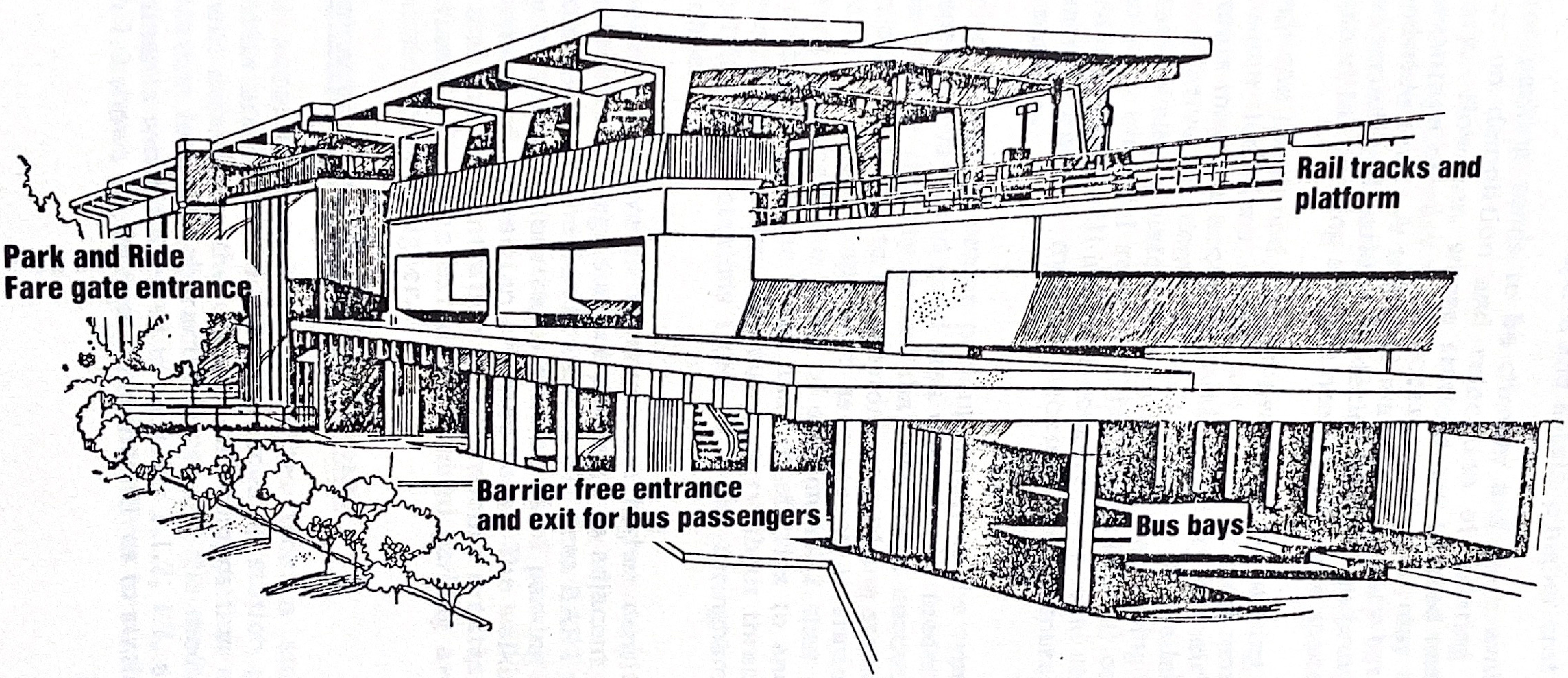

Fig. 7 Barrier-free Station for Rail-Bus Transfers (MARTA system, Atlanta, Georgia)

Source: SMD Briefs (Urban Consortium Transportation Task Force, Inc.), June 1981.

3. Case Studies

This section describes recent experiences of other transit agencies in North America with either planning or operating feeder bus service in association with fixed guideway systems. Data were collected from technical reports and telephone calls. The case studies which follow cover schedule coordination, fare collection method modifications, provisions for station parking, implementation of transit priority measures, and other details relevant to feeder bus operation.

For each case study the type of fixed guideway system in operation or under consideration has been indicated. These types include:

- o Light rail transit (LRT)
- o Light rail rapid transit (LRRT, a variant of LRT which uses LRT vehicles on generally exclusive right-of-way)
- o Heavy rail transit (high capacity systems with a completely exclusive right-of-way)
- o Intermediate capacity transit (various technologies utilizing either rubber tires or steel wheels)

Metropolitan areas covered below where feeder bus service now operates in connection with new fixed guideway systems include Atlanta (heavy rail), Calgary (LRT), Edmonton (LRT), and Washington, D.C. (heavy rail). Areas where feeder bus service will be integrated with fixed guideway systems under construction or planned include Buffalo (LRRT), Detroit (LRT), Miami (heavy rail), Portland (LRT), Sacramento (LRT), San Jose (LRT), and Vancouver (intermediate capacity transit).

3.1 Feeder Systems in Operation

3.1.1 Atlanta (Heavy Rail)

Atlanta voters approved a referendum plan in 1971 for a heavy rail rapid transit system consisting of 53 miles of rail transit and 1,500 miles of bus transit. The configuration of the rail system is in the shape of a cross with major North-South and East-West lines crossing in the Atlanta CBD. Average station spacing is 1.2 miles; spacing ranges from 0.5 mile in the CBD to almost 3.0 miles for the outermost stations. The initial stage of the rail system, or Phase A, is 14 miles in length with 17 stations. Phase A became completely operational in late 1981. Phase B, the North-South Line, is under construction with a completion year of 1985. Phase C will be constructed after 1985 (Ref. 40). All three phases of the Atlanta system are illustrated by Figure 8.

The Metropolitan Atlanta Rapid Transit Authority (MARTA) redesigned many radial bus routes into the CBD to form a new feeder bus network to serve the rail stations. Rail service on the East Line began in June 1979 without feeder bus service and carried about 10,000 daily weekday passengers. When feeder service was added three months later, weekday boardings increased to 17,000 daily. The West Line began service without feeder buses in January, 1980 and carried 48,000 passengers per weekday initially. Subsequent addition of feeder service increased boardings to about 80,000 per weekday (Ref. 46).

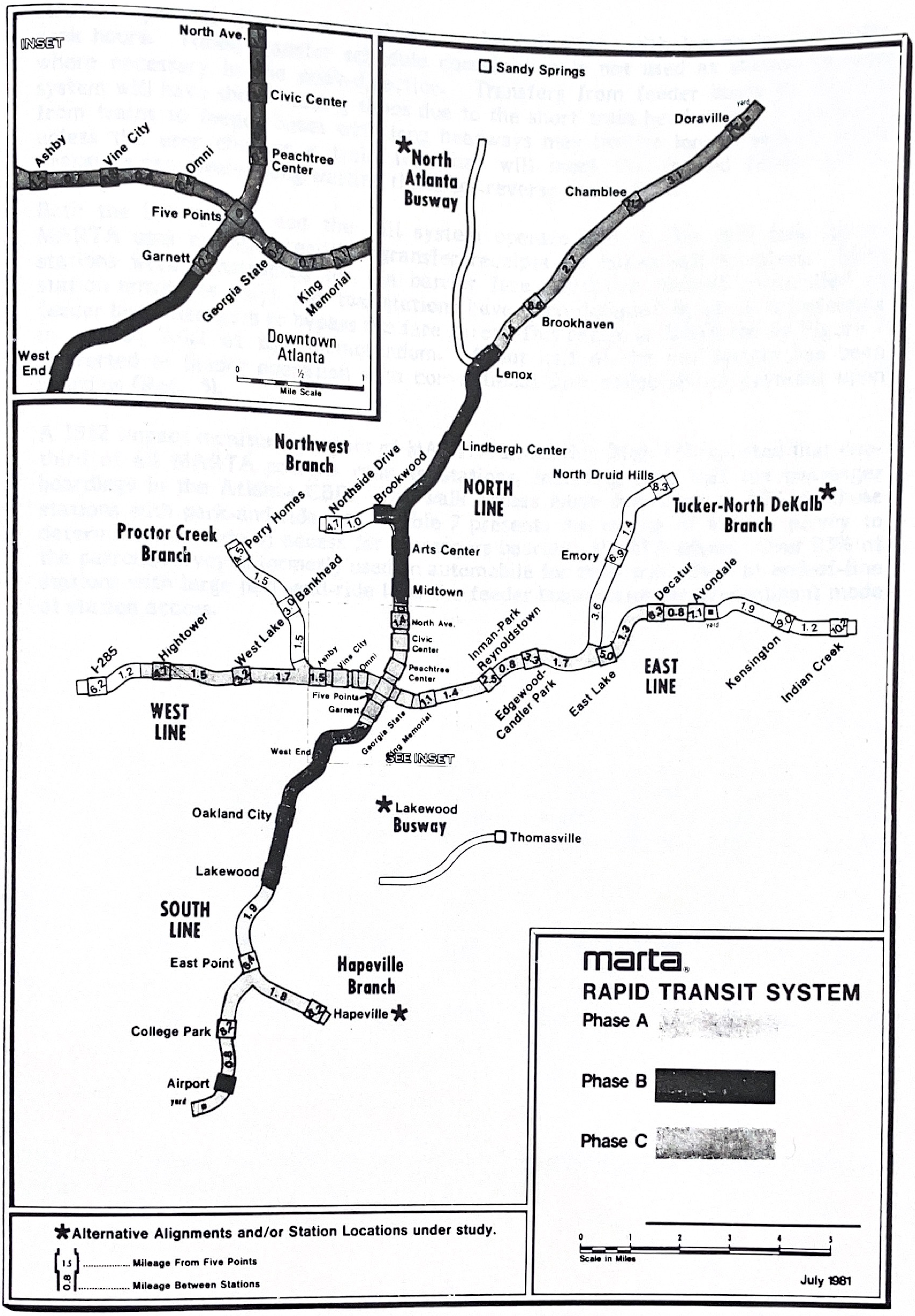

Fig. 8 MARTA Rapid Transit System Route Network, Atlanta, Georgia.

Source: Operating and Capital Development Plan For Fiscal years 1982-86 (Atlanta: Division of Planning and Marketing, Metropolitan Atlanta Rapid Transit Authority, September 1981).

MARTA operates 10-minute headways on its rail lines, with longer trains during peak hours. Timed transfer schedule coordination is not used at stations except where necessary in the peak-direction. Transfers from feeder buses to the rail system will have short waiting times due to the short train headways, but transfers from trains to feeder buses with long headways may involve longer waiting times unless the user chooses a train trip that will meet the desired feeder route. Transfers can involve long waiting times for reverse commuters.

Both the bus system and the rail system operate with a flat fare (one zone). MARTA uses machine readable transfer receipts for bus-to-rail transfers. Most stations were constructed for the barrier fare collection method (controlled at station entrances only), but two stations have been designed to allow transferring feeder bus passengers to bypass the fare gates. This design is illustrated by Figure 7 in section 2.6.2 of this memorandum. About half of the bus system has been converted to feeder operation with conventional fare collection of payment upon boarding (Ref. 5).

A 1982 impact monitoring report of MARTA rail service (Ref. 46) reported that one-third of all MARTA patrons walk to stations, including over half the passenger boardings in the Atlanta CBD. The walk access mode decreases to 16% at those stations with park-and-ride lots. Table 7 presents the results of a rider survey to determine the mode of access for passengers boarding MARTA trains. Over 25% of the patrons surveyed formerly used an automobile for their trip. Even at end-of-line stations with large park-and-ride lots, the feeder bus remains the predominant mode of station access.

All of the rail stations will use the barrier free collection method for riders arrivng by walking or automobile, but most will incorporate a barrier-free area for riders arriving by feeder bus. Transfers between rail and bus services will be free. Feeder bus routes will use the conventional fare collection method.

Station parking has been the subject of several studies by the Kaiser Transit Group (Ref. 27, 35). The Metrorail line will serve twenty stations. Structured parking is planned for eight stations, surface parking for seven stations, and no parking for five CBD stations (Ref. 27). These plans are tentative, since firm sources of funding have not been identified as of April 1983. Some parking may result from joint development projects at certain stations and from the availability of additional federal money. A moderate parking charge of $1 to $3 per day is currently being debated for any parking facilities that are built (Ref. 52).

Two stations will have exclusive feeder bus access lanes. One represents major construction and will provide direct access to Interstate 95. The other project connects the station to a major freeway interchange (Ref. 52).

3.2.4 Portland (LRT)

Tri-Met in Portland, Oregon is currently constructing a 15-mile LRT line between the Portland CBD and the suburban community of Gresham. The entire alignment will operate at grade and will have 25 stations. A portion of the right-of-way follows the Banfield Expressway, hence the use of the term "Banfield Transitway." According to the latest construction schedule, the entire line will be in revenue service by summer 1986. Figure 11 illustrates the LRT alignment and locations of stations and park-and-ride lots.

Tri-Met already operates timed transfers at a number of suburban transit centers. Along inner portions of the LRT line, timed transfers will be unnecessary due to anticipated frequent headways for both LRT and connecting feeder bus service (i.e., five to ten minutes). Timed transfers between the LRT and feeder bus routes would be used on outer portions of the line and during late evening periods (Ref. 54). Bus-LRT transfers will be possible at 12 of 18 non-CBD stations (Ref. 4).

Only four park-and-ride lots are planned, with three of these located on the outermost portion of the line. An initial policy decision was not to displace any existing structures in order to provide parking. The four lot locations are based on the availability of vacant land. Provisions for kiss-and-ride space will be made only within the existing right-of-way. No special transit priority measures are being planned for the feeder bus operation. Tri-Met recently converted many east Portland route from radial to grid operation in anticipation of eventually providing service to the LRT stations (Ref. 54).

3.2.5 Sacramento (LRT)

In January 1982, the Sacramento City Council and the Governing Board of the Sacramento Transit Development Agency approved a final LRT alignment and list of station locations. The proposed development program calls for construction of an LRT line in the Interstate 80 and Folsom Boulevard corridors of northeast and east Sacramento respectively. In the LRT corridors the bus system will be redesigned to provide coordinated rail-bus service. If additional funding becomes available, the bus system will be expanded to year 2000 levels (Ref. 25, 55).

ranged between 10 percent and 40 percent. Attainment of desired patronage levels will require employer shuttles and a high proportion of walk-ons.

In several cases, station locations have been moved north or south to avoid interference at intersections between LRT and general traffic and to facilitate feeder bus movements. No specific preferential measures for feeder buses are being considered (Ref. 56).

3.2.7 Vancouver (Intermediate Capacity Technology)

Presently under construction in the Vancouver, B.C. area is a 13.3-mile line between downtown Vancouver and the suburban Municipality of New Westminster. The adopted technology is the intermediate capacity transit system developed by UTDC of Canada. BC Transit has termed this system Advanced Light Rapid Transit, or ALRT. Scheduled date for revenue service is January 1986, in time for the world's fair Expo 86.

Fifteen stations are planned for the first ALRT segment. All will offer connections with intersecting feeder buses either directly or within easy walking distance. Within the city of Vancouver, most bus transit service already operates with headways of 15 minutes or less in a grid system. Although timed transfers are currently operated in a number of locations in the Vancouver area, they are not thought to be necessary at stations where headways on both the ALRT and connecting buses will be short. Timed transfers will be used at suburban station locations where the bus network is not so dense and bus headways are longer (Ref. 56).

Self-service fare collection is planned for both the ALRT system and the bus system. Currently the bus system uses the conventional fare collection method. BC Transit plans a totally integrated multiple zone fare structure (Ref. 1).

For the initial line, no parking facilities are planned at stations. The ALRT will pass through relatively dense land uses with a high level of bus service. However, BC Transit acknowledges that the interim station terminal in New Westminster will be a problem in terms of both accommodating large numbers of feeder buses and a large demand for park-and-ride facilities (Ref. 57).

Funding approval has been received for an extension across the Fraser River into Surrey, but this segment may not be completed until 1987 at the earliest. A second segment is to proceed northeast from New Westminster to Coquitlam. The present plan is to operate some feeder buses from Surrey into New Westminster pending extension of the line, but to continue to operate express buses between Coquitlam and Vancouver rather than diverting them to New Westminster (Ref. 57).

When the ALRT is extended across the Fraser River, a large park-and-ride lot (1,000 spaces) is to be constructed at Scott Road on the east bank of the river. Nevertheless, there is also a shortage of feasible sites for park-and-ride lots in Surrey (Ref. 57). Thus, the first segment of the Vancouver system will be almost totally dependent on walk and feeder bus access to stations.

4. Feeder Bus Planning for the Puget Sound Transportation Alternatives Analysis

As part of the 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. These alternatives are intended to serve the North Corridor area between the Seattle CBD and the vicinity of Alderwood Mall in Lynnwood, Snohomish County. The alternatives include:

- o No-Build.
- o TSM with a transit mall in the Seattle CBD.
- o Advanced Technology Bus with dual propulsion buses operating outside the CBD as diesels and through the CBD in a guided bus tunnel as electric trolley buses.
- o LRT on Interstate 5 with CBD surface operation and a terminal either at the Seattle city limit or at Lynnwood, Snohomish County.
- o LRT on Interstate 5 with CBD tunnel operation and a terminal either at the Seattle city limit or at Lynnwood, Snohomish County.

Separate transit networks were developed for each major investment alternative as well as for the No-Build and TSM alternatives. These networks included routes operated by Metro Transit in King County, Metro contract service in south Snohomish County, and routes operated by Community Transit in south Snohomish County. The information used for coding comprised a set of route sheets with headway and service information, a list of transfer facilities, and an analysis of transit center links. The design and coding of the networks for each alternative included system features (feeder bus routes, park-and-ride lots, and transfer facilities) that are necessary to support the linehaul element of each alternative. A detailed analysis of bus routes and headways would be performed during the preliminary engineering stage of a preferred alternative.

Bus-only alternatives under consideration for the North Corridor include No-Build, Transportation Systems Management (TSM), and Advanced Technology Bus. Most bus routes in these alternatives combine the linehaul and collection/distribution functions and offer the same level of service over the entire route length. Some bus routes perform primarily a linehaul function, as, for example, an express route operating between a transit center and the Seattle CBD.

The LRT technology demands a different bus operating strategy because LRT lines generally perform only the linehaul function as high capacity trunk routes. The collection and distribution function in the bus-LRT alternatives must be performed by feeder bus routes and other access modes intercepting the LRT line at stations along the guideway.

The bus networks developed for the North Corridor Alternatives Analysis are based on Metro's existing service configuration in the North Corridor. This configuration was modified as necessary to serve the LRT alternatives. The following considerations guided the design of alternative bus networks:

(1) Feeder bus routes in the LRT alternatives cover the same service areas as routes in the TSM alternative.

(2) No existing or TSM route was diverted from its alignment unless the diversion resulted in an overall travel time savings on trips to the Seattle CBD.

(3) Local bus service was preserved in the feeder bus network designs; the modified routes are those currently using I-5 to the Seattle CBD. No community in the North Corridor experiences a reduction in local service as the result of any of the alternatives under consideration.

(4) Wherever possible, attempts were made in the feeder bus networks to through-route or extend routes to take advantage of opportunities to provide new crosstown (east-west) service. In some cases new no-transfer service can be provided to passengers not using the trunk service of the LRT line.

The LRT feeder networks build upon the system developed for the TSM Alternative. This alternative includes bus routes bypassing the Seattle CBD, new transit facilities, and new routes serving those facilities. The new facilities represent a "best guess" by Metro's capital facilities planners of what is realistic to expect to build by the year 2000.

Since mode split forecasts and service levels affect each other, an initial service level was required purely as a starting point. For this prupose, the planned September 1983 system was used as a base. To this base, trips were added to existing routes and new routes were established for both CBD and key non-CBD destinations. The basis for these additions was the growth in transit ridership to Seattle CBD, University District, Duwamish Industrial and First Hill destinations forecast by 1990 for the Downtown Seattle Transit Project. PSCOG ran a mode split model for this system and made screenline volumes and Production and Attraction tables available to Metro. The total ridership projected by the 1990 model was 115 million annually. Because this number if close to estimates of year 2000 ridership, it was considered an adequate representation of the year 2000 service level. Since the original PSCOG 1990 forecast, Metro has revised its projection of 1990 ridership to 90 million.

The Production and Attraction data were tabulated for 38 Traffic Analysis Zones in the 1990 model. Initial service levels in the North Corridor bus network alternatives were established based on the 38-zone Production and Attraction matrix.

The number of trips to add or delete to the existing system for the initial TSM alternative headway adjustment was computed by dividing the change in travel demand between Production and attraction zones by 57. The number 57 was based on the number of seats filled per trip in a fleet composes of 50 percent articulated coaches operating at 90 percent of capacity. This calculation tended to add service conservatively.

When patronage data became available from PSCOG, Metro staff repeated the process of headway adjustments for the TSM network only, using a similar Productions and Attractions matrix made up of 20 zones based on population and employment estimates for the year 2000. The process for determining the number of trips to add or delete was altered to use more realistic load factors.

Separate load factors were calculated for trips attracted to the University District and for trips to all other attraction zones. The increase in peak and midday load factors from 1982 to 2000 was assumed to be proportional to the increase for trips to the Seattle CBD from the 1982 level of .77 to the given year 2000 level of .90. For each production and attraction pair, the peak and midday passengers per trip were determined by multiplying average seats available by the appropriate peak or midday load factor.

Lists of routes were prepared for each production-attraction zone pair of interest. These lists included service level data showing existing and previously added trips per hour by route. The projected number of passengers per trip was computed by multiplying the number of seats by the projected load factor for each zone pair and time of day (see Table 12). In order to determine the number of trips to be added or deleted for each zone pair, the projected travel demand between each set of Production and Attraction zones was divided by the computed number of passengers per trip.

The trips to be added or deleted were then allocated to specific routes by District Planners familiar with growth patterns in their respective geographical areas. Essentially, the growth in demand divided by the assumed load factor (productivity) yielded the number of trips to be added. It was also assumed that some of the increased demand could be absorbed by excess capacity on existing service.

Allocation of additional trips resulted in revised trips per hour for a peak hour and a midday hour. Daily trips added are computed by assuming that the peak hour represents 63 percent of the peak two hours and that the "edge of the peak" service levels, which are higher than midday, are approximated by extending each peak period to two-and-a half, or a total of five daily hours, including both peak periods.

A simplifying assumption for weekday off-peak trips added is that they operate for ten hours at midday frequency. In actuality, night service tends to extend for a longer period at lower frequencies on the average. A similar assumption for weekend service additions allowed computation of a "budget" for additional trips at ten times the weekday midday hourly additions. These additional trips were also allocated to specific routes by District Planners in order to best anticipate how growth would occur.

All of these assumptions were applied to additional trips. Daily totals for existing trips were derived directly from Metro's Schedule Information Data Base. Existing and additional trips were then added to derive new total trip figures. Changes to the Community Transit bus network in south Snohomish County were limited to headway adjustments.

For the LRT alternatives, headways on feeder routes were the same as the headways on routes serving the same neighborhoods in the TSM and Guided Bus alternatives.

Bus routes in the TSM network primarily serving park-and-ride lots adjacent to Interstate 5 were deleted, since these routes would be replaced by the LRT. The effect of higher total system ridership on bus load factors in the LRT alternatives was offset by a shift of ridership from neighborhood bus routes to direct pedestrian and park-and-ride access to the LRT. Leaving the LRT bus network headways unchanged resulted in realistic load factors and did not bias the results.

Figure 13 illustrates the feeder bus network developed for the I-5 LRT maximum length alignment in the North Corridor. This alignment would use two of the I-5 express lanes between the Seattle CBD and Northeast 65th Street, where it would proceed through a mile-long tunnel and continue along the east side of I-5 north to Snohomish County. Most of the Snohomish County right-of-way would be the I-5 median.

Ten stations outside the Seattle CBD would be transfer locations between the LRT and feeder routes of the Metro Transit and Community Transit bus systems. Crosstown service to the University District, Northgate and other activity centers was improved in the course of modifying existing routes or adding new feeder routes.