U.S. Department of Transportation

Operating Strategies for Major Radial Bus Routes

May 1984

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FOREWORD

There has been renewed interest in the past few years in the design of bus routes. Planners at many transit systems have focused on the modification and sometimes elimination of poor performing routes as a way to improve system productivity. Little attention, however, has been given to long, downtown-oriented radial routes that serve high-demand travel corridors since the performance of these routes is rarely considered substandard by most conventional measures.

While it may be difficult to generate significant new ridership on these routes, it may be possible to serve the same ridership at reduced costs by implementing more efficient operating schemes. This idea has long been recognized and exploited by transit systems through the use of local, limited, and express services, short-turns, deadheading, and other operating strategies. The UMTA Office of Planning Assistance has recently initiated a project to document these strategies and to develop procedures for selecting the appropriate strategies for specific corridor applications.

This is the first report of this UMTA project. The report is a summary of operating strategies that can be used to improve the performance of radial routes in high-demand corridors. Examples are provided from real-world experience and current situations about how these strategies are being (or can be) applied. We believe this report is a good summary of strategies which should be considered by transit systems which operate high-demand routes.

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

Information on the progress and findings of this UMTA project can be obtained from Brian McCollom, Office of Methods and Support (URT-41), (202) 426-9271.

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Chapter 1: Introduction

1.1 Background

The expansion of public transit during the seventies was reflected in higher levels of service and expanded area coverage for most urban areas. This expansion, fueled in part by the emergence of federal transit operating assistance, was paralleled by growth in operating and capital costs. However, operating assistance has recently come under close scrutiny and is already being reduced in real terms. Consequently, there is a growing pressure on transit agencies and localities to narrow the gap between revenues and costs.

The traditional response to deficit reduction has been to move in the direction of service cuts and fare hikes. Transit properties across the nation are considering or implementing such measures as reducing area coverage, hours of service or service frequencies, eliminating routes, and introducing across-the-board fare increases and zone charges. The potential detrimental effects of such actions on ridership and on public mobility are significant concerns.

In contrast, measures that improve transit's productivity can reduce deficits, but generally with less detrimental effect on users. One approach that has been widely applied in recent years to improve bus transit productivity is the use of route-level service standards, such as minimum boardings per vehicle-hour. Standards are used to improve system efficiency by identifying route whose performance is substandard so that measures can be taken either to eliminate them or modify them to improve their performance. Modest improvements in system productivity have sometimes been achieved through elimination of obsolete and unproductive services.

An important class of routes typically left unaddressed in the application of service standards and innovative service design is long, CBD-oriented radial routes that serve moderate- and high-demand travel corridors. Because such bus routes serve strong natural transit markets, their performance is rarely substandard by most conventional indicators (e.g., boardings per bus-hour or average loads). Their good performance, however, does not mean that these routes have no potential for productivity improvement.

To the contrary, high demand corridors frequently offer great potential for increasing service efficiency because of the markets they serve and the large number of buses needed to meet capacity requirements. The high concentration of transit demand found in these corridors facilitates the spatial segmentation of the transit market into submarkets that can each be served very efficiently by a route designed to serve that particular submarket. The result can be a system of routes that requires fewer buses overall than the existing route. As a result, substantial cost savings can often be attained with little or no overall deterioration in the level of service. In some cases, some riders may experience an increased level of service.

Serving a heavy-demand corridor with a combination of routes and services is not new to the transit industry. This idea has been recognized and exploited by transit operators through the use of mixed local and express services, short-turns, deadheading and other operating strategies in most major transit systems. The operating strategies described in this report are, therefore, "classic" in the sense that they have been used in many large properties for years. However, documentation of these strategies is sorely lacking. As financial resources become more limited, and as the operator's ability to increase fares and introduce service cuts is constrained, all but the smallest bus transit systems will find it increasingly important to consider these service designs, and should benefit from studying the descriptions and examples found in this report.

1.2 Purpose of the Report

This report is the first of an UMTA-sponsored study with an objective to assist bus transit service planners and schedulers in designing bus routes and operating strategies in radial travel corridors. The purposes of this first report are to define alternative operating strategies and stopping policies that can improve transit productivity and to demonstrate, through examples drawn from real-world experience and current situations, how these strategies are being (or can be) applied to reduce costs and improve performance. By and large, the examples used in this report are based on routes whose performance would be judged as "productive" or "cost-effective" by conventional methods of evaluation.

The service strategies discussed are intended for moderate-to-high demand corridors that have a strong directional orientation (i.e., toward the CBD or a rapid transit station). "Corridor" is used in this report as referring not to a large sector of a metropolitan area (e.g., "the western corridor"), but rather to the narrow area served by a single route or by the system of routes that all follow the same street or sequence of streets (e.g., "the 16th Street corridor"). As a rough guide, a corridor qualifies as a "moderate-demand" corridor if the cumulative passenger volume on all the routes serving the corridor during its busiest period and in the peak direction is eight or more busloads per hours. (Therefore, if only one route operates in a corridor, its headway should be 7.5 minutes or less to qualify as a moderate-demand corridor.) The strategies discussed in this overview report are intended for use only during periods in which corridor demand meets this qualification. Such periods are broadly referred to as peak periods, though they may include midday or Saturday periods if demand is high enough. Some of these strategies also apply to crosstown corridors that lack a strong directional orientation; however, this report is targeted at the CBD-oriented corridor.

In contrast to this first overview report, which is primarily descriptive, subsequent project work on the subject of route and service design will concentrate on describing methods, procedures, and guidelines for the selection and design of operating strategies in specific high travel corridors. This detailed procedural work will lead to the development of a planning manual for bus route and service design to be used by transit properties.

1.3 Service Design Objectives

When financial resources are limited, there are two major purposes for undertaking a redesign of bus service on a route:

1. To lower the cost of providing an existing level of service; or
2. To improve the level of service provided with existing resources.

Under some circumstances, both of these purposes can be served at the same time. If large cost savings are called for, however, the quality of transit service is likely to be diminished as the efficiency of the service is improved.

The governing service design objective of this study is to reduce operating costs with as little adverse passenger service level impact as possible. When service redesign affects fare levels, revenue impacts become important as well.

The narrowness of this objective allows the report to remain tightly focused. Even if a property is not tightly constrained financially, it will still seek greater operating efficiency and, if cost savings are forthcoming, it can then look for ways to "reinvest" these savings in areas where service improvements are most needed.

It is assumed that operating cost reductions for radial service during peak periods are achieved primarily by eliminating the need for a bus. While there may be exceptions, in almost every property a reduction in the number of buses that must be operated during a peak period will result in the elimination of a substantial piece of work--a tripper, a part-timer piece, or perhaps a full run--with a consequent reduction in costs. Savings in vehicle-hours that do not result directly in vehicle savings are also considered beneficial. Such savings can often be combined with vehicle savings elsewhere to save a bus, or can be used to extend a route to attract new passengers or to lengthen layovers and thereby improve reliability. Savings in vehicle-miles by themselves, apart from vehicle or vehicle-hour savings, are considered inconsequential.

Level of service impacts of a new design must be weighed against operating cost savings. The typical impacts are considered: changes in wait time, walk distance, in-vehicle time, fare, and need to transfer. Another important consideration is how confusing some of these strategies are likely to be to the riding public.

Ridership changes can be expected to follow significant changes in service. A description of procedures for estimating these changes is beyond the scope of this study, however. Operators can use the predicted level-of-service impacts for each market segment in a corridor as a basis for estimating demand and consequent revenue changes. If large ridership changes are expected, they should also be accounted for in choosing headways for the routes being redesigned.

There are four ways to accomplish the basic objective of reducing operating costs in a corridor. These operational objectives are addressed by the service strategies described in this report.

1. Increase the average operating speeds of buses. The number of buses required on a route is a function of the speed, which in turn determines cycle (round trip) time. As the average operating speed of buses on a line is increased and cycle time is reduced, the number of vehicles and vehicle-hours needed per hour to operate at a given service headway is reduced. This increase in speed can be achieved by designing non-stop trip portions that can be performed on high-speed roads such as expressways; by scheduling buses to make certain stops and to skip others; and by making it unlikely that buses will have to stop at all scheduled stops along a route.

2. Reduce the total number of vehicle-miles of service. The number of vehicle-miles operated on a route is directly reduced by designing configurations in which some buses do not travel all the way to the end of the route to complete their trips ("short-turns"). Through-routing (joining radial routes that emanate in opposite directions from the CBD) can also reduce costly downtown mileage.

3. Eliminate unnecessary schedule slack through interlining. Allowing vehicles to make successive trips on different routes (interlining) can lead to schedules that require less layover while maintaining regular headways.

4. Maintain the highest acceptable, and most uniform possible, vehicle loadings on all route segments. High and uniform vehicle loadings along a route mean that the equipment is effectively used since the service capacity is well matched to the level of demand at any point along the route.

1.4 Common Considerations in Service and Schedule Design

This section discusses a few considerations common to all service strategies (including conventional local service) that affect operating efficiency.

1. "Through-routing" is linking at their downtown ends two routes that share a common headway and that emanate from opposite ends of the downtown. In this way a single trip through downtown can serve to distribute passengers from the first route while collecting passengers for the second. Thus, through-routing can reduce downtown mileage by 50 percent if routes fully penetrate the downtown. Since downtown congestion can mean that 20 percent or more of a route's cycle time is spent downtown, through-routing has resulted in substantial vehicle savings in many cities.

In some cities, the same route number is used for either end of a through-routing pattern, while in others different route numbers are used. For example, in the former case a single "route" would begin north of the CBD, traverse the CBD, and end south of the CBD; in the latter case buses could follow the same pattern but the northern half of the pattern would be called one route and the southern half would be called another. In the latter case, buses are nominally serving two routes, and so this pattern can be confused with interlining. However, the term "interlining" is reserved in this report for buses making successive trips on different routes when both routes have the same CBD terminus, while "through-routing" is joining two routes whose downtown termini, if they were served without through-routing, would be at opposite ends of the CBD.

2. Proper supervision and adequate recovery time on congested local routes is necessary to prevent bus bunching which overcrowds and delays buses. Bunching can cause buses to face up to twice their scheduled demand if the preceding vehicle gets too far ahead of schedule. It is possible for a properly supervised route with six buses to supply better service than the same route with seven buses that bunch. Similarly, while reducing layover can allow a route to shorten its headways, it can produce service that is inferior to the service originally provided because the shorter layovers make it more difficult to maintain the schedule. Just before the start of the evening peak, while the transit system still has excess capacity, it is a good idea to

build generous layovers into the schedule so that peak period service can begin on schedule. As the peak progresses, however, layovers can be reduced to below-normal levels for the following reasons: (1) the system is operating at capacity, and vehicle-minutes are precious, and (2) many buses beginning trips during the peak will not be making a later peak period trip, and so keeping them on schedule is not so critical.

3. An accurate knowledge of run time is also essential to designing an efficient schedule. Run times may vary widely as traffic levels change throughout the day, and an improper estimate can lead to excessive or inadequate recovery time.

1.5 Structure of the Report

The balance of this overview report on bus route and service design is presented in the three remaining chapters. Chapter 2 discusses the use of express service in a corridor. Chapters 3 discusses how local bus service operation can be customized and refined to achieve more efficient operation in the peak direction of travel. Chapter 4 discusses the use of deadheading in the light direction of travel (for both local and express service) and interlining among corridor routes to reduce vehicular requirements.

Chapter 2: Express Service Design

Although it can mean different things at different properties, express service is defined for the purposes of this report to be one which operates non-stop between a designated collection area and a downtown area of distribution. Routes that meet this description except for a few stops in their line-haul portion are also considered express routes. However, there are routes known in some cities as express routes which, during their "express" portion, make regular stops less than a mile apart or permit buses to stop on demand to let passengers alight; such designs are considered to belong to the family of local route strategies and are discussed in Chapter 3. To operate express service, a reasonable concentration of trips destined for the downtown must obviously already exist. Figure 2-1 shows a hypothetical express service configuration contrasted with conventional local service.

Express service has a substantial speed advantage over local service because: (1) express routes have fewer stops, and (2) express routes are free to use the fastest path available during their line-haul and return portions. This speed advantage benefits both operator and passenger. Thus, the presence of an expressway, while not a requisite for express service, can enhance efficiency considerably.

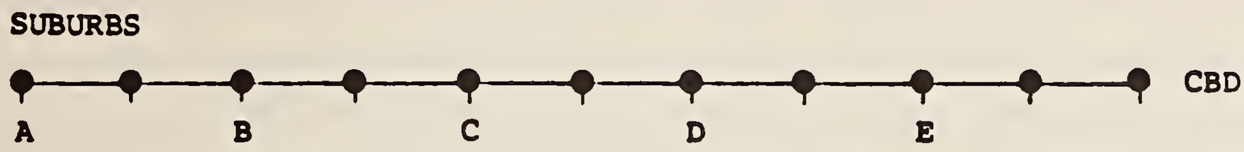
2.1 Common Considerations in Express Service Design

This section briefly discusses five common issues in express route design that can significantly affect an express route's efficiency and cost-effectiveness.

Figure 2-1

LOCAL AND EXPRESS SERVICE SYMBOLS AND EXAMPLE SCHEDULES

LOCAL SERVICE



SCHEDULE					
INBOUND					
A	B	C	D	E	CBD
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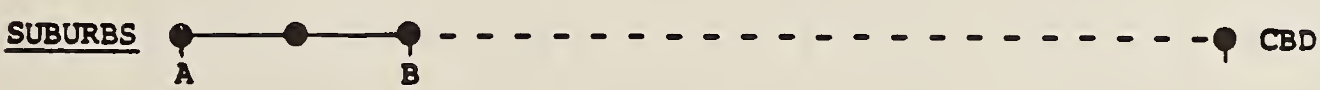
7:10	7:18	7:25	7:35	7:42	7:55
7:20	7:28	7:35	7:45	7:52	8:05
7:30	7:38	7:45	7:55	8:02	8:15
7:40	7:48	7:55	8:05	8:12	8:25
7:50	7:58	8:05	8:15	8:22	8:35
8:00	8:08	8:15	8:25	8:32	8:45

EXPRESS SERVICE



SCHEDULE					
INBOUND					
A	B	C	D	E	CBD
7:10 A.M.	7:18	---	---	---	7:35
7:30	7:38	---	---	---	7:55
7:45	7:53	---	---	---	8:10
8:00	8:08	---	---	---	8:25
8:15	8:23	---	---	---	8:40
8:30	8:38	---	---	---	8:55

1. Downtown routing. One important concern in express service design is the routing configuration downtown. In general, the downtown routing should include as little time spent on local streets as possible. Some ways of accomplishing this are extending a route only part of the way into downtown, using an expressway for half of the CBD loop, or through-routing with a local route or with an express route that makes reverse commute trips (see below).

2. Adding stops to express portion. Care must be taken when adding a few stops to the line-haul portion of an express route. These stops should serve more as destinations than origins during the inbound peak, so that they do not significantly increase vehicle loads in the inner segment of the route; otherwise these stops will raise capacity requirements and result in empty seats in the long outer portion of the route. The added stops also should have a minimal impact on travel time. Typical intermediate stops would be a university, medical complex, or other employment center near the CBD, or a junction with a major crosstown route.

3. Reverse commuting. Express service, while aimed primarily at the CBD-commuter market, should be sensitive to potential demand for reverse-commute service to outlying industrial and commercial areas. Often the reverse trip can be modified at a small extra cost to serve an outlying employment or retail center and thereby attract new passengers and gain new revenues.

4. Fares. A fourth common issue in express service design is whether express routes should have premium fares. One line of reasoning is that since passengers value express service more because of its greater speed, and hence are willing to pay more, they should be charged more than their local counterparts (at least as long as the express route does not cover all its costs). It has also been observed that express passengers can more readily afford a higher fare. However, some operators have found that passengers paying premium fares expect not just higher speeds but also less crowding and newer coaches--demands that cannot easily be accommodated without extra cost. Another line of reasoning is that since express service is a less costly way of serving downtown passengers (as long as high loads are maintained and running times are shorter), fares should be no higher (and perhaps lower!) than local fares if the two types of services are in competition with each other.

The second line of reasoning is most important when express routes are in competition with local routes. Since their higher speeds make express routes a less costly way serving downtown passengers than local routes, an operator will want to divert as many passengers from local to express service as possible, and therefore may not want to create the barrier of an express premium fare. On the other hand, if the express time savings is so great as to prevent serious competition from local service, a modest fare premium appears to be a way of reducing operating deficits with very small adverse impacts on ridership and level of service. A fare premium is all the more justified if safety considerations require that express service have few or no standees, since this requirement reduces the relative cost advantage.

5. Local service impacts. Finally, when considering expansion of the area now receiving express service into an area that now enjoys local service only, impacts to local service passengers must be considered. As some local passengers are diverted to the new express service, local service headways may have to be increased because of the smaller resulting passenger volumes. In the worst case, local service would be eliminated in the outer part of the corridor, forcing non-CBD travelers originating there to begin their trip on an express route and later transfer to a local route.

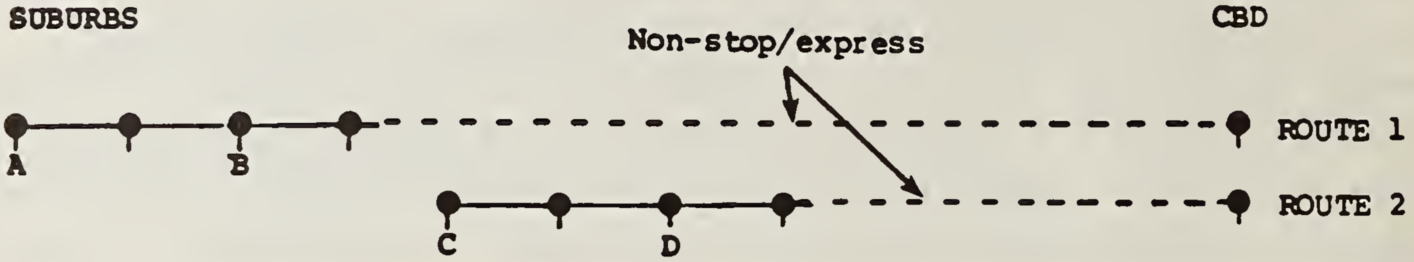
2.2 Zonal Express Service

An efficient way of providing express service in a corridor is through a zonal express service, shown schematically in Figure 2-2. For zonal service, the express service area of the corridor is split into two or more zones, with a different express route designed to serve each zone. Each zonal route then provides collection/distribution service only within its particular service zone, and travels non-stop between the closest-in stop of its service zone and the downtown. If the non-stop portion of the route is on an expressway, it is natural for expressway access points to serve as zonal boundaries.

Zonal operation has two major advantages and two disadvantages compared to conventional express service (a single express route serving the entire express service area). One disadvantage is that as the corridor is split into zones, the average route market size decreases, and so average headways must

Figure 2-2

ZONAL EXPRESS SERVICE



SCHEDULE - ROUTE 1					
INBOUND					
A	B	C	D	E	CBD
7:00 AM	7:08	---	---	---	7:32
7:20	7:28	---	---	---	7:52
7:40	7:48	---	---	---	8:12
8:00	8:08	---	---	---	8:32

SCHEDULE - ROUTE 2					
INBOUND					
A	B	C	D	E	CBD
		7:05	7:13	---	7:30
		7:20	7:28	---	7:45
		7:35	7:43	---	8:00
		7:50	7:58	---	8:15
		8:05	8:13	---	8:30

increase if peak bus loadings are to be kept up. With longer headways come longer wait times and, possibly, a loss in passengers. This factor serves to limit the number of zones into which a corridor can be split without making headways exceed tolerable limits.

A second disadvantage of zoning is that it may confuse riders, particularly in the outbound direction when they must be careful to board only their zone's bus.

A major advantage of the zonal system is that the average speed increases, since buses make fewer stops and spend less time in collection/distribution. This speed increase translates into shorter travel times for passengers (except those in the innermost zone) and lower operating costs through shorter turnaround time for the transit agency. This travel time savings serves to partially (in some cases, totally) offset the longer wait times caused by zoning.

Another major advantage of the zone system is that, as with short-turning, the number of vehicle-miles (and consequently vehicle-hours) of operation in the corridor is reduced since only the route serving the outermost zone covers the full length of the corridor, and buses serving the inner zones travel only a fraction of the corridor's full length. This reduction in vehicle-miles can result in the savings of one or more vehicles.

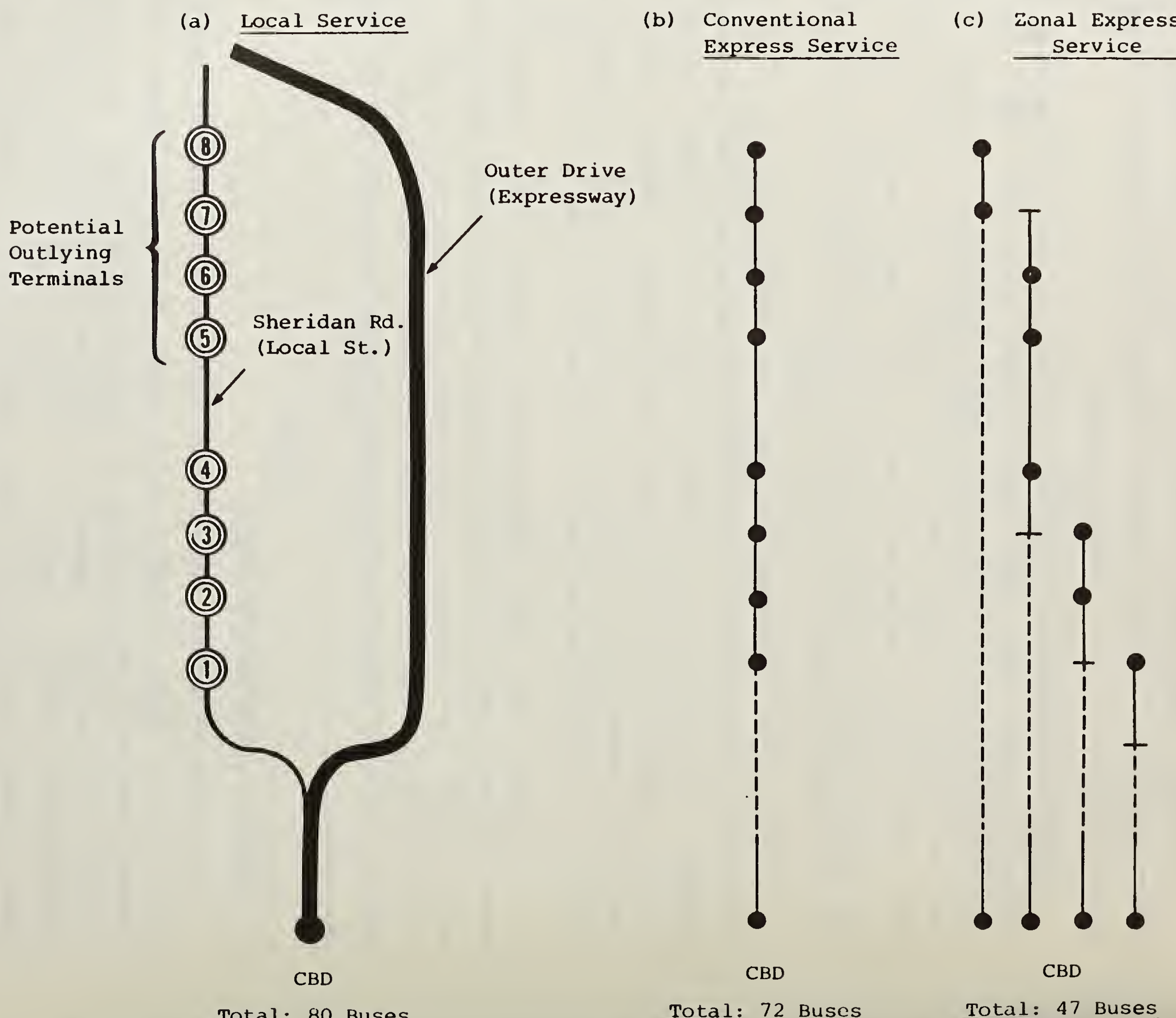
In summary, then, zonal express service produces higher average speeds for buses and reduced in-vehicle time for most travelers. Zonal express service results in a reduction in the number of vehicle-hours of peak period service needed and can thereby reduce the number of peak vehicles required. However, zoning of express service leads to longer wait times and can confuse some riders.

2.3 Example: Zonal Express Service

An example of express route zoning is found in the Sheridan Road-Outer Drive corridor along Chicago's north shore, where the Chicago Transit Authority operates a complex system of zoned branching routes. For the sake of illustrating potential savings of this service strategy, a simplified routing system is shown in Figure 2-3. Because of this simplification, the number of buses required for each route configuration do not exactly match the

Figure 2-3

ZONAL EXPRESS SERVICE IN THE SHERIDAN ROAD CORRIDOR (Simplified)



current operating requirements in the corridor, but reflect a realistic approximation of the resources needed to serve the demand were it a simple (i.e., non-branching) corridor.

The Sheridan Road corridor consists of a local street (Sheridan Road) and an expressway (Outer Drive). Local service in the corridor would require roughly 80 buses to meet capacity requirements. In contrast, conventional express service, pictured in Figure 2-3(b) as a single express route, would require about 72 buses; and the zonal express service with four routes, as depicted in Figure 2-3(c), would require only 47 buses. The zoned system reduces overall average passenger wait time plus in-vehicle travel time by 22 percent compared to conventional express service. As these figures are based on a simplified routing system compared to the one actually operating in the corridor, they are only suggestive of the size of operating savings achieved with existing service. Actual savings attributable to the current route design may be somewhat more or less than those estimated with the simplifying assumptions.

Chapter 3: Local Service Design - Peak Direction Strategies

During peak periods, the travel in a radial corridor typically has directional imbalance, enabling one direction to be designated as the peak direction of travel and the other as the light direction of travel. Because demand in the light direction is often only a fraction of peak direction demand, it makes sense to design service to match the directional demands to the extent feasible in order to reduce the required number of peak vehicles. This chapter discusses a variety of strategies aimed at making peak direction service more efficient. The following chapter then discusses strategies to apply to light direction travel. If a corridor has no directional imbalance (e.g., for midday design), the strategies discussed in this chapter apply to both directions.

The mainstay of urban transit systems is the conventional local route that serves all stops from the far end of the corridor to the downtown. In a typical heavy demand corridor, two aspects of local service have potential for improvement. First, conventional local routes are slow; speeding them up by allowing buses to skip some stops would benefit the operator and most passengers. Second, because the demand for service along a route typically peak near the downtown and taper off towards the outer terminus, a conventional single route that offers uniform capacity along the entire length of the corridor provides far more capacity than is needed in the outer segments of the route in order to avoid overcrowding in the inner segments. Reducing offered capacity in the outer portions of radial corridors by turning vehicles back short of the end of the corridor can substantially reduce operator costs.

The following sections describe four peak direction strategies aimed at reducing vehicle-miles in the outer segments of a corridor or increasing speeds. These local service strategies are:

- short-turns
- restricted zonal service
- semi-restricted zonal service
- limited-stop service

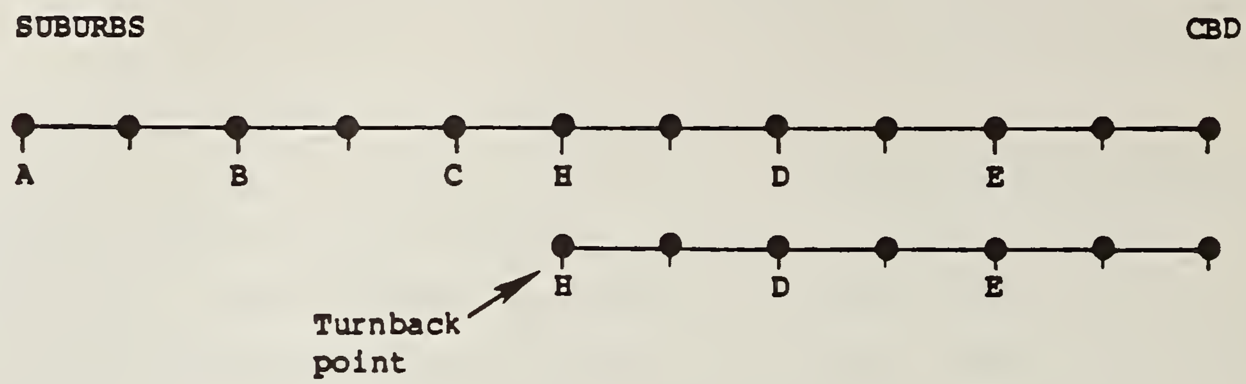
3.1 Short-Turning Local Routes

The short-turn strategy consists of a system of two or more routes that operate along the same corridor, in which the shorter routes are entirely overlapped by the longer routes. No boarding or alighting restrictions are imposed on any sections of the routes. The shorter routes are commonly referred to as "short-turn" or "turnback" variations of the longest route. Figure 3-1 illustrates a typical short-turn configuration with two routes. For our purposes, each routing is treated as a separate route, even though all the routes in a short-turn system may be considered as variations of a single route for operations or public information purposes.

With the short-turn strategy, inner segment passengers can use a bus on any of the overlapping routes, and will naturally take the first to arrive, unless it is too crowded. Inbound, buses serving the longer routes will reach the inner segments already heavily loaded, while buses serving the shorter routes will begin empty at the same point. Unless each longer route bus is closely preceded by a shorter route bus, buses on the longer route will tend to become overcrowded. Of course, once the longer route buses reach their capacity, they can no longer pick up passengers (except to replace alighting passengers), creating a natural deterrent that forces inner segment passengers to use shorter route buses. There is the same tendency for crowding to occur outbound on longer routes during the evening peak. However, in the outbound direction, this kind of systematic crowding can prevent passengers destined for the outer segments from boarding the longer routes. Therefore, route schedule coordination is necessary in the evening peak and strongly recommended in the morning peak as a means of encouraging inner segment travelers to use the shorter routes.

Figure 3-1

Short-Turning Local Service



SCHEDULE						
INBOUND						
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7:00 A.M.	7:08	7:15	7:18	7:25	7:32	7:45
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7:15	7:23	7:30	7:33	7:40	7:47	8:00
			7:40	7:47	7:54	8:07
7:30	7:38	7:45	7:48	7:55	8:02	8:15
			7:55	8:02	8:09	8:22

Efficient schedule coordination is most easily attained if each route has the same headway. In this way, each longer route bus trip can be scheduled to follow closely behind a shorter route trip so that few inner segment travelers will be waiting when a longer route bus arrives. If larger capacity vehicles (i.e., articulated buses) are used on the longer routes, the shorter routes buses should not precede them as closely, but shcedule coordination is just as important. It is also possible to efficiently coordinate schedules when the longer route headway is a multiple of shorter route average headway. In either case, the short-turn strategy restricts scheduling possibilities and requires strict schedule adherence.

Aside from the necessity of schedule coordination and adherence, this strategy poses no significant operational or public information problems. Inbound, passengers simply board the first bus that comes. Outbound, passengers must only take care to board a route whose destination lies at or beyond their desired destination stop.

The use of short-turn operation presents a good opportunity to replace a flat-fare structure with a more distance-based fare. Successively higher fares could simply be charged for the routes according to their length, since people making longer trips must use longer routes. By imposing a small fare difference (say, $0.20), inner segment passengers for whom a longer route bus arrives first would have the choice of taking that bus and paying the premium or of saving money by waiting for a shorter route bus. Depending on the percentage of passengers who would choose to pay vs. wait, the schedule offset between the longer and shorter routes would simply to be lengthened to preserve the longer route's market.

This strategy lengthens wait time for outer segment travelers since fewer trips go the entire length of the corridor. Wait times will also increase slightly in the inner segment because, although passengers can use the buses of any route, trips will not be evenly spaced since shorter route buses will closely precede longer route buses. In-vehicle time remains essentially unchanged since speeds are unaffected.

3.2 Restricted Zonal Local Service

The main difficulty with the short-turn strategy is the need for strict schedule coordination and adherence in order to prevent too many inner segment passengers from using the longer route. One way to alleviate this requirement, and at the same time to improve speed, is to use a restricted zonal strategy for local service.

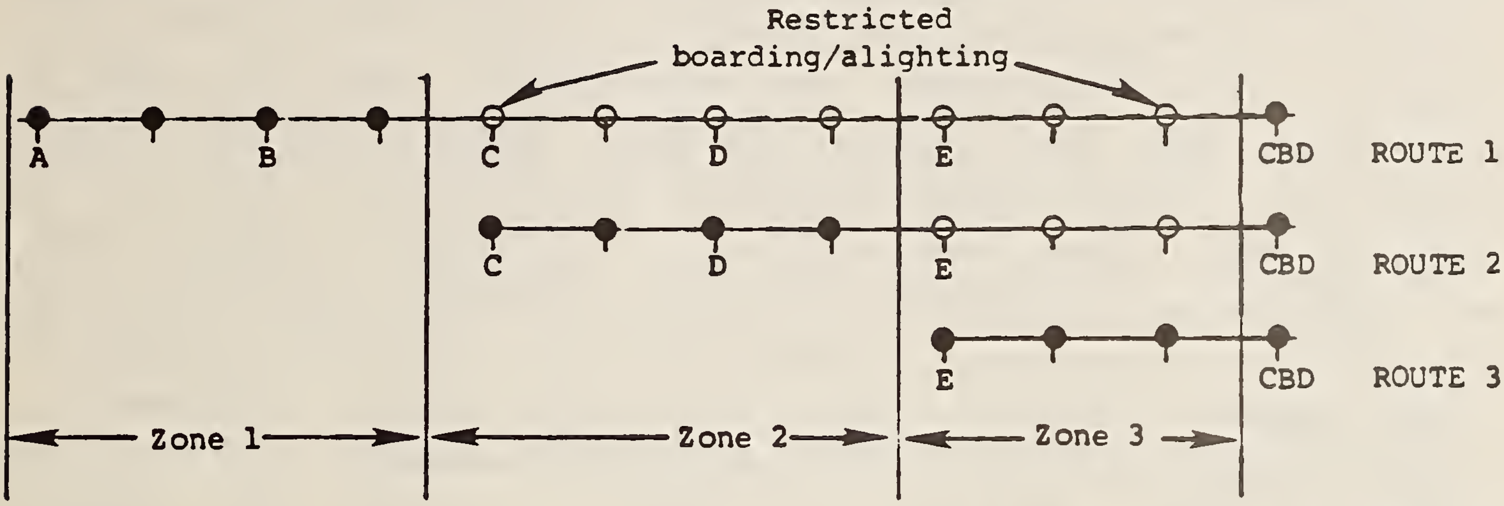
For restricted zonal local service, as for the zonal express strategy, the corridor is divided into two or more zones, with a particular route designed to serve each zone. Inbound, buses on a restricted zonal route begin at the outer boundary (farthest outlying stop) of their service zone, operate locally within the zone, and then they remain on the local street as they continue toward downtown. Unlike zonal express service, the buses may stop at any stop on the trip inbound to allow passengers to alight. Similarly, outbound, buses will stop at any stop to allow boarding only (no alighting) between the downtown and their service zone; they then operate locally within their service zone. This arrangement is called a local service strategy since it makes it still possible to travel directly between any pair of bus stops in the corridor. Figure 3-2 illustrates a restricted zonal configuration.

Restricted zonal local service, like zonal express service, lengthens wait times throughout the corridor since all passengers must wait for the one route that serves their origin-destination pair. However, speeds increase for outer segment travelers, since their buses will be able to skip many innter-segment stops. In long, high-demand corridors, the reduction in travel time can sometimes offset the longer wait times for outer segment travelers.

Like the short-turn strategy, the restricted zonal strategy reduces the number of trips operating in the outer segments of the corridor, thus reducing vehicle requirements. Higher speeds on the longer routes can further reduce vehicle-hours needed. However, some of these advantages are offset by the effect this strategy has on the turnover of seats. For example, once an inbound bus leaves its service zone, no one may board to replace alighting passengers. (The mirror-image behavior occurs on outbound buses.) The peak load of a restricted zonal route will therefore occur at or before the inner boundary of its service zone. Thus, the load on the bus as it enters the downtown will be less than the load it carried leaving its service zone

Figure 3-2

RESTRICTED ZONAL LOCAL SERVICE



Q = Inbound buses do not stop except to let passengers alight; boarding prohibited. Outbound buses do not stop except to let passengers board; alighting prohibited.

SCHEDULE = ROUTE 1, INBOUND

A	B	C	D	E	CBD
7:00 AM	7:08	(7:15)*	(7:24)	(7:30)	7:42
7:15	7:23	(7:30)	(7:39)	(7:45)	7:57
7:30	7:38	(7:45)	(7:54)	(8:00)	8:12

SCHEDULE = ROUTE 2, INBOUND

A	B	C	D	E	CBD
		7:10 AM	7:20	(7:27)*	7:39
		7:22	7:32	(7:39)	7:51
		7:34	7:44	(7:51)	8:03

SCHEDULE = ROUTE 3, INBOUND

A	B	C	D	E	CBD
				7:25	7:39
				7:35	7:49
				7:45	7:59

*( ) means alighting only is allowed

because of the alighting that occurs as the bus operates in a restricted mode. If there is significant travel destined for points before downtown, buses serving all but the shortest route will reach the downtown with considerable excess capacity. To transport a fixed number of people into downtown in these circumstances, more trips would be needed than would be required for other local service strategies. Therefore corridors whose markets show a strong downtown orientation stand to benefit more from the restricted zonal strategy than those with a weak downtown orientation. The semi-restricted and limited-stop strategies, discussed in Sections 3.4 and 3.5, as well as the short-turn strategy, are better suited to a corridor with a weak downtown orientation because they provide for the replacement of inbound passengers alighting before the bus reaches downtown.

Operationally, restricted zonal service is a relatively simple strategy since each route operates independently of the others (unless they are interlined). There is no need for schedule coordination, or of paying special attention to schedule adherence. This strategy does rely, however, on longer route buses being able to overtake shorter route buses, a concern in some corridors with narrow streets.

From a public information and user acceptance viewpoint, this strategy has three problems. One is that outbound passengers must be sure to board a bus whose zone includes their destination stop. Confrontations can occur between passenger and driver, as with express service, when a passenger desires to alight at a stop the bus passes because it is not supposed to allow alighting there. A second problem is that waiting inbound passengers may wonder why buses coming from more distant zones won't pick them up, particularly when they stop to allow someone to alight. (This concern motivates the semi-restricted strategy discussed in Section 3.3.) A third problem is that if the peak to base volume ratio in the corridor is high, the zonal configuration that is most efficient in the peak may differ from the preferred configuration for the base. (Unless base volumes are high, a conventional local route, which is a single-zone system, will probably be preferable.)

3.3 Semi-Restricted Zonal Local Service (Inbound Only)

Semi-restricted zonal local service operates in a zone configuration similar to restricted service, but permits buses to pick up passengers once they have stopped to allow passengers to alight (Figure 3-3). Thus, passengers who alight an inbound bus after it leaves its service zone are replaced by waiting passengers who are allowed to board as long as there is room on the bus. By allowing the longer zonal routes to carry some of the demand generated in inner zones, their loads are kept high throughout the inner segments, overcoming the inefficiency of the restricted zonal strategy.

The wait time and in-vehicle time under this strategy will be between the average wait and in-vehicle times of the short-turn and the restricted zonal strategies. This strategy is a particularly attractive alternative where there is significant demand within the corridor to destinations other than the downtown.

Unfortunately, this strategy does not work in the outbound direction of travel. The mirror image of the inbound strategy would be that outbound, a passenger traveling on a longer route bus and desiring to alight at a particular stop in the inner zone would be permitted to alight there only if his bus stops to pick up a waiting passenger. With this kind of uncertainty, nobody traveling within the inner zone could be expected to use the longer route. Outbound, therefore, some other routing strategy must be used.

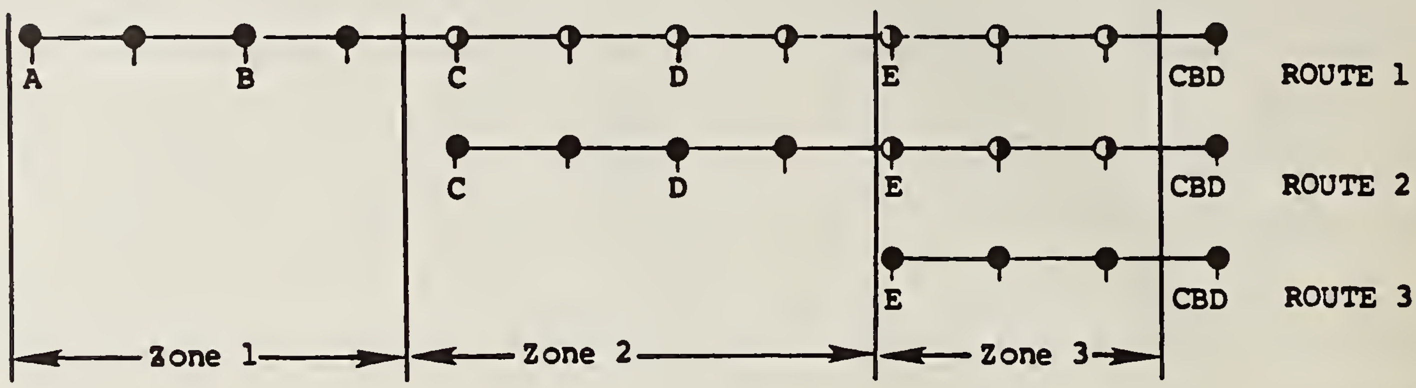
Operationally, this strategy is as easy to use as the restricted zonal strategy. Like the restricted zonal strategy, however, its public information and acceptance problems are not minor. For example, if one outer zone route in a corridor is designated Route O, inner zone travelers may wonder why Route O sometimes stops to pick them up and sometimes does not. Furthermore, if a semi-restricted zonal system is used inbound along with a different system outbound (e.g., restricted zonal, limited-stop zonal, or short-turning), confusion may result.

3.4 Limited-Stop Zonal Local Service

This strategy is a hybrid of the short-turn, zonal local, and zonal express services. Like other zonal routes, a limited-stop zonal local route

Figure 3-3

SEMI-RESTRICTED ZONAL LOCAL SERVICE (Inbound Only)



= Buses stop only to allow passengers to alight; once stopped, waiting passengers may board.

SCHEDULE						
INBOUND						
A	B	C	D	E	CBD	
				7:25 AM	7:39	ROUTE 3
		7:10	7:20	(7:27)*	7:39	ROUTE 2
7:00	7:08	(7:15)*	(7:24)*	(7:30)*	7:42	ROUTE 1
				7:35	7:49	ROUTE 3
		7:22	7:32	(7:39)*	7:51	ROUTE 2
7:15	7:23	(7:30)*	(7:39)*	(7:45)*	7:57	ROUTE 1
				7:45	7:59	ROUTE 3
		7:34	7:44	(7:51)*	8:03	ROUTE 2
				7:55	8:09	ROUTE 3
7:30	7:38	(7:45)*	(7:54)*	(8:00)*	8:12	ROUTE 1

(X:YZ* means on-board passengers may alight; waiting passengers may board only if bus stops to let some one alight has a service zone in which passengers may freely board and alight at any stop. However, outside the service zone, buses stop only at designated stops, spaced at least one-half mile apart, at which passengers may board and alight. A limited stop zonal service configuration is illustrated in Figure 3-4.

The limited-stop zonal strategy differs from the other local serve strategies in that it does not provide for direct service between every pair of stops in the corridor. A passenger who boards a bus in its service zone and desires to travel to a non-designated stop within the area of limited-stop operation has the choice of: (1) alighting at a designated stop and walking to his desired destination, and (2) alighting at a designated stop and transferring to the route whose service zone includes his desired destination stop. If designated stops are spaced one-half to three-quarters of a mile apart, one can expect most people to choose the walking option.

This strategy also resembles the short-turn strategy in that inner segment travelers originating at designated stops may use either a longer or a shorter route, and will presumably try to board the first to arrive. Efficient service design requires that the number of inner segment travelers using longer routes be limited to approximately the number needed to replace alighting outer segment travelers. To accomplish this objective, route design could apply a few different measures:

1. -- If there is a lot of turnover in the inner segment, no special action may be needed because the longer route buses will have room for many inner segment travelers.

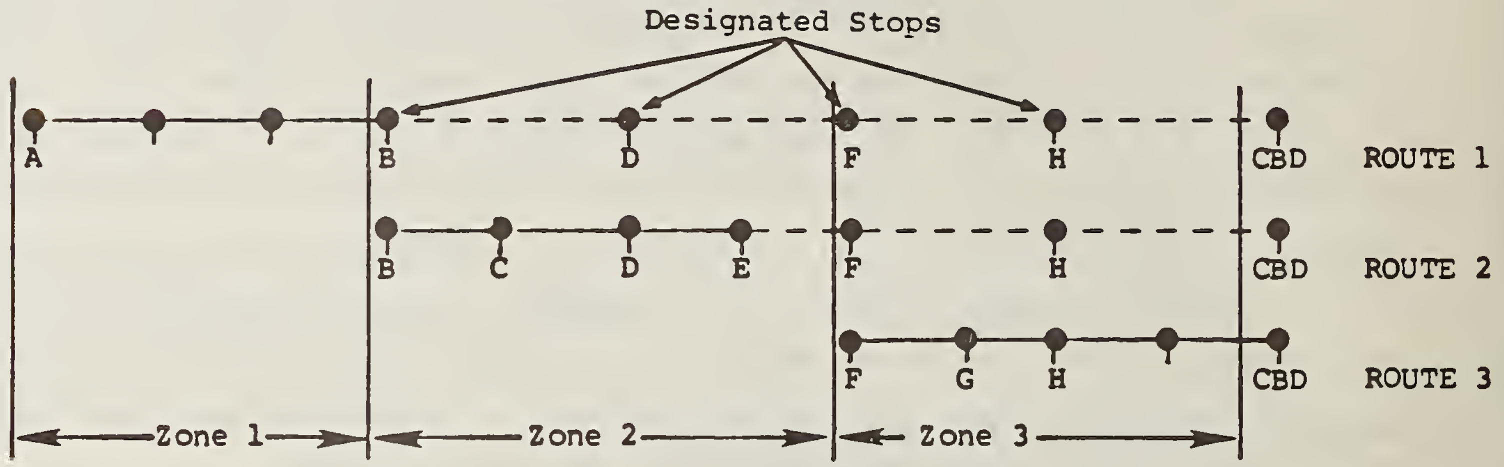
2. -- When outbound travel is dominant (the evening peak), schedule longer route buses to closely follow shorter route buses in the downtown area (where most boarding occurs), as is necessary for the short-turn strategy. This approach will not usually work in the inbound direction, however, since longer route buses will be making limited stops and hence overtaking shorter route buses.

3. -- When inbound travel dominates (the morning peak), crowding can be used as a natural deterrent, keeping inner segment travelers from boarding unless there is room for them.

4. -- Charging a higher fare on the longer route will reduce the number of inner segment travelers who will use a longer route bus if it arrives first, and will thus strengthen the above

Figure 3-4

LIMITED-STOP ZONAL LOCAL SERVICE



SCHEDULE										
INBOUND										
A	B	C	D	E	F	G	H	I	CBD	
7:00 AM	7:12	---	7:19	---	7:26	---	7:33	---	7:40	ROUTE 1
	7:13	7:17	7:22	7:27	7:31	---	7:38	---	7:45	ROUTE 2
					7:30	7:35	7:40	7:45	7:50	ROUTE 3
7:15	7:27	---	7:34	---	7:41	---	7:48	---	7:55	ROUTE 1
	7:28	7:32	7:37	7:42	7:46	---	7:53	---	8:00	ROUTE 2
					7:45	7:50	7:55	8:00	8:05	ROUTE 3

approaches. Higher fares on the longer routes will also raise revenue, of course, and will make the fare system more distance-related. They will also probably be received by the public with less objection than higher fares on longer routes in the short-turn strategy because passengers will get higher-speed service.

5. -- Increasing the spacing between designated stops, and leaving some downtown stops undesignated, will also strengthen the other approaches. However, it will increase walk distance for passengers going from the outer zone to the limited-stop area.

In most applications of this strategy, then, the operational difficulties that will be encountered are that overtaking should be possible, regular crowding can be expected during the morning peak, and schedule coordination and adherence will probably be required in the evening peak. Another operational requirement is that this strategy should not be applied on streets where traffic requires buses to stop at every intersection, since the strategy will then have no value to either passenger or operator.

The passenger impacts of this strategy are mixed. Some passengers will have longer walk distances and some may be induced to transfer to avoid these longer walks. Wait time will increase in the outer segments as in other zonal strategies, and will also increase slightly in the inner segments. However, in-vehicle time will be significantly reduced for many passengers.

Experience has shown this strategy to be relatively easy for the public to comprehend and accept, perhaps more so than other zonal local strategies. Some cities have found a gradual evolution in their high-quality local service, driven mainly by public reaction, from restricted to semi-restricted to limited-stop service.

Another advantage of the limited-stop strategy is that it can be of value in corridors that show little peaking, and thus can be used to increase the efficiency of midday and crosstown services as well as the typical peak period, CBD-oriented services.

3.5 Example: Restricted Zonal Service

Local service along Massachusetts Avenue between Arlington Heights and Harvard Square in suburban Boston is provided by two restricted zonal routes operated by the Massachusetts Bay Transportation Authority (MBTA). The shorter route, Route 77A, operates locally between the North Cambridge terminal and Harvard Square. The longer route, Route 77.4, acts as a local route between Arlington Heights and North Cambridge and then goes into restricted operation between the North Cambridge terminal and Harvard Square. Figure 3-5 illustrates these two routes. During the morning peak, Route 77A, which uses trolleybuses, makes 12 trips per hour with a cycle time of 40 minutes, requiring eight trolleybuses. Route 77.4, using diesel buses, makes 20 trips per hour with a cycle time of 75 minutes, requiring 25 buses.

The benefits of this service design can be seen by comparing it to the operation of a hypothetical single local route in the same corridor. This full-length local route would have a cycle time of about 80 minutes, and would have to make 30 trips per hour. (The frequency of this single route is slightly lower than the combined frequencies of Routes 77A and 77.4 since it would not prevent alighting passengers from being replaced as the restricted zonal system does). Thus, a single local route would require about 40 buses, 21 percent more vehicles than the dual route restricted zonal system now in place.

The passenger impacts of the restricted zonal service, as compared to the conventional local service, are also worth noting. Average wait time in the corridor is only one minute longer under the zonal service than it would be under the alternative local service (2.2 minutes vs. 1.2 minutes), while in-vehicle time is about five minutes less under the zonal service for passengers originating upstream of the North Cambridge terminal and unchanged for those originating inbound from North Cambridge.

3.6 Example: Limited-Stop Zonal Local Strategy

A partial application of limited-stop zonal local service strategy is used in the Wilshire Boulevard corridor of Los Angeles, where Route 308 is a limited-stop local zonal route between Santa Monica and downtown Los Angeles, 12 miles east (see Figure 3-6). Between Beverly Hills and downtown, a distance of six miles, Route 308 stops only at designated stops about one-half mile apart. Route 308 is overlapped by a system of short-turning local routes that originate at points between Santa Monica and Beverly Hills and do not have limited stop operation. Nevertheless, during most of the morning peak,

Figure 3-5

BUS ROUTES IN ARLINGTON HEIGHTS CORRIDOR: A.M. PEAK PERIOD

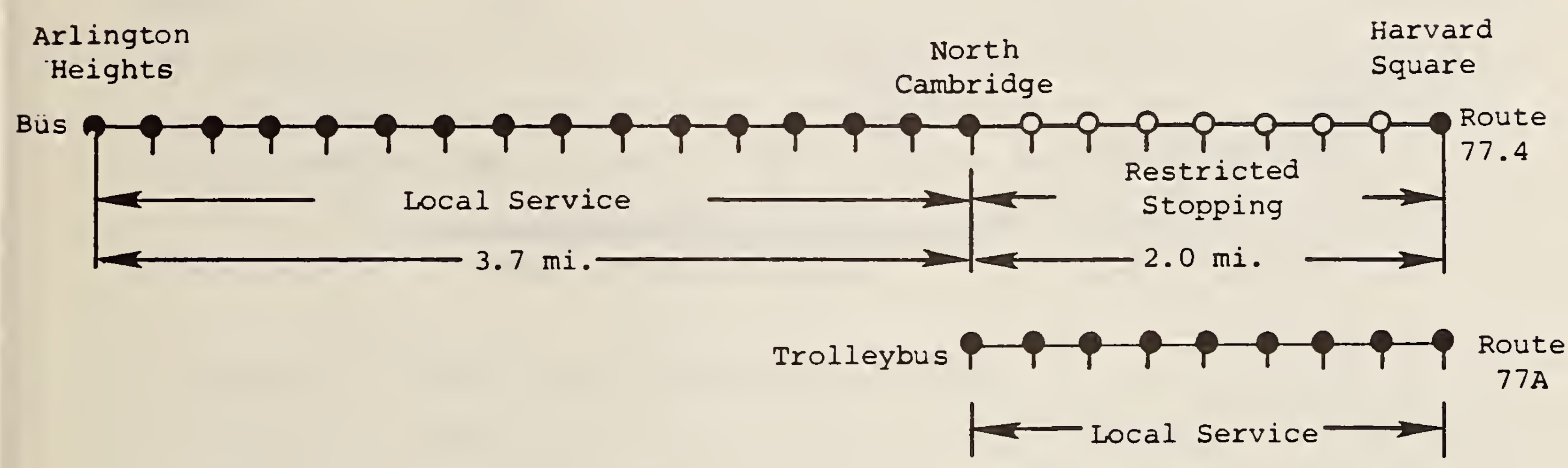
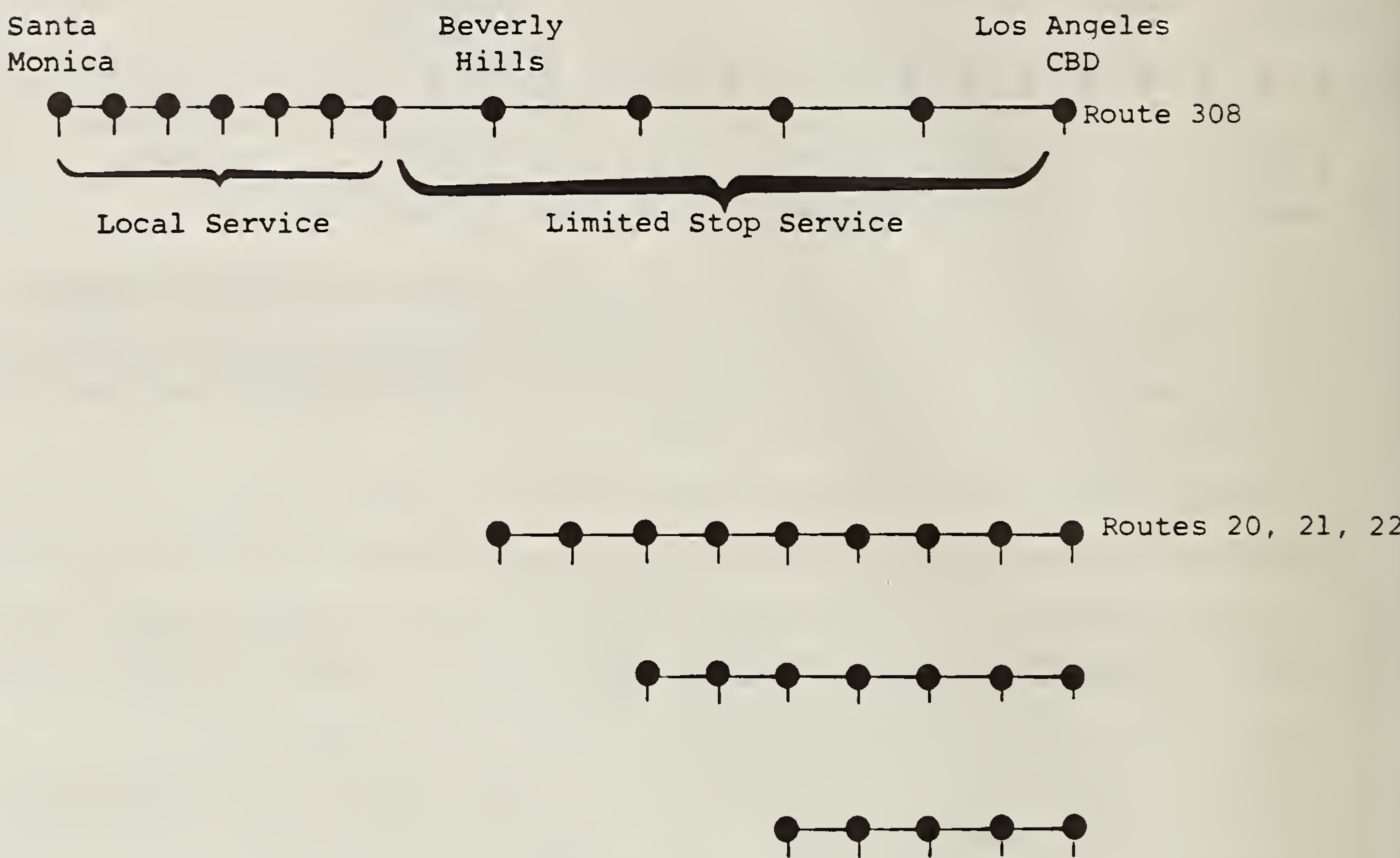


Figure 3-6

BUS SERVICE IN WILSHIRE BOULEVARD CORRIDOR



Route 308 provides the only local service on Wilshire Boulevard in Santa Monica, so that travelers going from Santa Monica to points on Wilshire Boulevard between Beverly Hills and downtown must use Route 308 and either walk a (potentially) longer distance from one of the designated stops or transfer at Beverly Hills to one of the other local routes in the corridor. Compared to a simple short-turning route system, the limited-stop configuration has the benefit that it discourages inner segment travelers from using Route 308 and encourages them instead to use the shorter local routes, enabling the operator to reduce vehicle-miles in the outer part of the corridor. It also reduces one-way bus travel time by 12 minutes, resulting in reduced passenger travel time and significant cost savings for the operator.

3.7 Summary of Local Service Operating Strategies

Table 3-1 summarizes the advantages and disadvantages of the four operating strategies described in this chapter. Both operator and passenger considerations are included. Actual wait time impacts are highly dependent upon the specific route design; the impacts given in the table are for a typical application. The table also summarizes the conditions under which each strategy would be the most promising for reducing vehicluar requirements.

Table 3-1

ADVANTAGES AND DISADVANTAGES OF LOCAL SERVICE OPERATING STRATEGIES

	Short-Turn	Restricted Zonal	Semi-Restricted Zonal	Limited-Stop Zonal
Need for schedule coordination and strict adherence	valuable in a.m. vital in p.m.	none	none	unnecessary in a.m. valuable in p.m.
Reliance on overtaking	none	strong	moderate	strong
Wait time impact*	up by 90% in outer segment, by 20% in inner segment	up by 90% throughout	up by 90% in outer segment, by 20% in inner segment	up by 90% in outer segment, by 20% in inner segment
In-vehicle time reduction	none	considerable	moderate	considerable
Walk-distance impact*	none	none	none	up by 0.2 mi. for some outer segment passengers
Difficulty in public comprehension	little	considerable	considerable	moderate
Most favorable conditions for vehicle savings:				
corridor length	short	long	any	long
fraction of local (non-CBD) travel	moderate to high	small	moderate	moderate to high
outer segment volume	low	low	low	any

*Average impact to peak direction travelers in typical application

Chapter 4: Light Direction Strategies

In the preceding chapter, strategies to improve the operation of local service routes in the peak direction were discussed. In this chapter, means by which to improve local service efficiency through service adjustments in the light direction of travel are discussed. These primarily involve vehicle "deadheading," the practice of running a bus non-stop, out-of-service from terminal to terminal in the light direction of travel, and "interlining", the practice of scheduling buses to make successive trips on different routes.

4.1 Complete Deadheading of Selected Routes

If local service is provided by a system of short-turning or zonal routes, it is often possible to have all buses on some routes deadhead in the light direction of travel, while buses on the remaining routes remain in service. For example, in a corridor that has both a short-turning local route and a longer local route, all the short-turning trips could deadhead, leaving only the longer route buses to provide light direction service. This policy will reduce the round trip time of the shorter route, saving vehicle-hours and possibly saving one bus or more.

4.2 Partial Deadheading

If a local route has a particularly short headway, it may be advantageous to have only a fraction of the runs on this route return in service in the light direction while the remainder deadhead. This strategy is called "partial deadheading."

One simple partial deadheading configuration is to keep every second or third bus in light direction service while the others deadhead, the choice depending on the travel demand in the light direction. In some ways, such a partial deadheading route operates as two separate routes (one of which deadheads while the other provides service). Coordinated scheduling is necessary to keep in-service departures in each direction regularly spaced.

More finely tailored partial deadheading schedules can also be designed to respond to changes in demand levels and traffic congestion during the peak period. These schedules would not be systematic in their use of deadheading, but would deadhead runs selectively whenever (1) the light direction demand allowed it, and (2) the run time savings could be effectively used to enable the deadheading vehicle to more quickly begin another peak direction trip.

4.3 Considerations in Deadheading Design

Whether applied completely or partially, the use of deadheading should recognize the following considerations.

First, deadheading a vehicle that cannot be scheduled to make a subsequent trip saves no operator cost in many cases because labor contract provisions often require that the driver be paid the same whether his trip ends a few minutes earlier or not. In such cases, it is usually wiser to return the vehicle in service, improving passenger service and perhaps generating a little revenue.

Second, many properties have made it a practice to deadhead only on streets that have no local service to avoid angering waiting passengers by passing them with an empty out-of-service bus.

Third, deadheading facilitates interlining since vehicles that are returning out-of-service can be rerouted directly to other terminals without inconveniencing or confusing passengers. Therefore, opportunities for effective interlining should be sought when contemplating the application of deadheading.

4.4 Example: Partial Deadheading of Local Service

A heavily used bus route in a certain major American city stands out as a good candidate for partial deadheading. During the morning peak this route (called Route X to preserve its anonymity) operates at four-minute headways, with a run time of 54 minutes inbound and 47 minutes outbound. With a minimum scheduled layover of two minutes downtown and 11 minutes at its suburban terminal, the route needs 29 buses (runs) to maintain its schedule, which is shown in Table 4-1. The route is paralleled by a freeway, making it possible for deadheading vehicles to make the return trip in 21 minutes. A simple partial deadheading schedule is one in which every other bus deadheads on the return trip. The resulting eight-minute headways in the outbound (light) direction, still provide an acceptable service level, although the higher loads per trip would raise the outbound run time by two minutes for buses that do not deadhead. Less recovery time (nine minutes overall rather than 13) is required for deadheading vehicles, since their return trips are faster and less subject to traffic delays. The resulting schedule, shown in Table 4-2, requires only 25 buses, for a savings of four runs or about 14 percent of operator cost. (The number of runs saved roughly equals the time saved per trip by deadheading, half an hour, multiplied by the number of deadheading trips per hour, 7.5.)

4.5 Interlining Among Corridor Routes

Both approaches to deadheading discussed so far preserve each individual route intact as an autonomous, separate operation. However, it may be possible to increase scheduling efficiency (i.e., eliminate unnecessary schedule slack) by shifting buses among some local and express routes in a corridor or, for that matter, among different routes operating out of the same terminal. This practice is referred to as "interlining."

For example, a vehicle may begin its run with an inbound express trip on a zonal express route, deadhead outbound to a different route terminus in the corridor, and then make an inbound trip on a different express or local route.

4.6 Example: Interlining Deadheaded Buses

A number of examples of how deadheaded buses are interlined to improve operating efficiency are found in the Oakland-San Francisco area on the "K" and "R" routes operated by AC Transit. Here, peak buses that could not be returned to the originating terminal in time for a second peak trip are used to advantage in alternate services.

For example, the R line, extending from Hayward through East Oakland to San Francisco, runs an a.m. peak express bus departing Hayward at 6:02 a.m.

Table 4-1

SCHEDULE FOR ROUTE X WITHOUT PARTIAL DEADHEADING

Run	Leave Suburban Terminal (time)	Arrive Downtown (time)	Leave Downtown (time)	Arrive Suburban Terminal (time)	Leave Suburban Terminal (time)
1	621 a.m.	715 a.m.	717 a.m.	804 a.m.	817 a.m.
2	625	719	721	808	821
3	629	723	725	812	825
4	633	727	729	816	829
5	637	731	733	820	833
6	641	735	737	824	
7	645	739	741	828	less
8	649	743	745	832	frequent
9	653	747	749	836	service
10	657	751	753	840	
11	701	755	757	844	
12	705	759	801	848	
13	709	803	805	852	
14	713	807	809	856	
15	717	811	813	900	
16	721	815	817	904	
17	725	819	821	908	
18	729	823	825	912	
19	733	827	829	916	
20	737	831	833	920	
21	741	835			
22	745	839			
23	749	843			
24	753	847			
25	757	851			
26	801	855			
27	805	859			
28	809	903			
29	813	907			
1	817	911			
2	821	915			
3	825	919			
4	829	923			
5	833	927	less frequent service		

Table 4-2

SCHEDULE FOR ROUTE X WITH PARTIAL DEADHEADING
(EVERY OTHER OUTBOUND TRIP DEADHEADED)

Run	Leave Suburban Terminal	Arrive Downtown	Leave Downtown		Arrive Suburban Terminal	Leave Suburban Terminal
1	621 a.m.	715 a.m.	717 a.m.		806 a.m.	817 a.m.
2	625	719	721	-DH-	742	749
3	629	723	725		814	825
4	633	727	729	-DH-	750	757
5	637	731	733		822	833
6	641	735	737	-DH-	758	805
7	645	739	741		830	841
8	649	743	745	-DH-	806	813
9	653	747	749		838	849
10	657	751	753	-DH-	814	821
11	701	755	757		846	857
12	705	759	801	-DH-	822	829
13	709	803	805		854	905
14	713	807	809	-DH-	830	
15	717	811	813		902	less
16	721	815	817	-DH-	838	frequent
17	725	819	821		910	service
18	729	823	825	-DH-	846	
19	733	827	829		918	
20	737	831	833	-DH-	854	
21	741	835				
22	745	839	less frequent service			
2	749	843				
23	753	847				
4	757	851				
24	801	855				
6	805	859				
25	809	903				
8	813	907				
1	817	911				
10	821	915				
3	825	919				
12	829	923				
5	833	927				

The bus travels 25 miles in 51 minutes, arriving at San Francisco at 6:53 a.m. After this inbound trip, the bus deadheads outbound via expressway as far as East Oakland, covering 13 miles in 25 minutes. At East Oakland, the bus is short-turned and is again placed in inbound service, this time on AC Transit's K line, departing East Oakland at 7:33 a.m. and arriving at San Francisco at 8:05 a.m. On the last leg, the bus operates on expressway for about one-half the trip.

Similarly, the 6:32 a.m. bus from Hayward travels express to San Francisco, after which it is deadheaded back to East Oakland. Rather than being placed in inbound express service on the K line, however, this bus provides inbound local service into Oakland on Route 34 over an eight-mile distance.

The use of interlining and deadheading is used extensively during both peak periods on the AC Transit system, with an estimated 2,530 deadhead miles expended each weekday on over 200 trips. Even though the examples used here involve express routes and services, they demonstrate that more productive use of equipment and labor is a likely by-product if opportunities for interlining deadheaded buses are sought out and exploited to full advantage on local, express or hybrid combinations of routes.

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