Wire Requirements for Trolleybus Systems

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Changes in route structure needed to develop a group of high-density trolleybus routes in a medium-sized transit system are examined. The subject areas include treatment of branches and route extensions, route changes to maximize wire utilization, and modifications of pairings in a through route structure centered on a downtown transfer point. Wire is rarely provided for express or limited-stop operation. Where such service is a sizable component of a route, wire may be justified. An example of the treatment of such a route in New York is described. The need to provide wire for infrequently used movements has become a subject of question in two situations: where service is scheduled but consists of only a few trips per day, generally in late evening or early morning hours; and where service is not regularly scheduled but a route is used on a regular basis to turn back late buses or as a detour for frequently occurring special events.

This paper describes the changes in route structure needed to develop a group of high-density trolleybus routes in a medium-sized transit system, the development of wire alternatives for limited-stop and local service on a high-density route, and the decision process for installation of relatively infrequently used wire in two situations.

In one case, Long Beach Transit (LBT), the four routes had been selected as candidates for trolleybus operation because they met the requirements of having a 15-min or better peak headway over a substantial part of the route and of having substantial route overlap. The effort to be described was intended to restructure the selected routes in order to increase the use of the trolleybus fixed plant.

In the other two cases, it had been decided that the entire routes were to be considered for trolleybus operation. This paper covers an evaluation of the amount and location of wire needed to provide trolleybus service equivalent to the existing diesel bus service.

ROUTE STRUCTURE CHANGES FOR TROLLEYBUS CONVERSION

This section describes the planning performed by LBT to develop a route package for inclusion in the trolleybus program developed by the Los Angeles County Metropolitan Transit Authority (LACMTA).

LBT operates a bus system with 17 routes serving the city of Long Beach, California, and surrounding communities. Downtown Long Beach is approximately 20 mi south of downtown Los Angeles. Although it is in the southwest part of the LBT service area, it is the center of LBT service, being served by 13 of the 17 routes.

The four routes selected for examination are shown in Figure 1. These routes all serve the area north and east of Downtown Long Beach. Figure 1 shows the current layout of the four routes as well as the route segments proposed for trolley and diesel bus operation. Each route is discussed in detail in the following paragraphs.

The 40 route consists of two branches, each with 30-min headway throughout the day, on Magnolia and Pacific Avenues. These combine at the downtown loop to provide 15-min headway on Anaheim Street. Alternate trips (30-min headway) are extended to the east of the primary terminal on Anaheim Street to provide service to California State University, Long Beach (CSULB), and an area east of the university. A supplemental service, crosstown route 45, operates on a 15-min headway along Anaheim Street during peak periods, providing additional service on the most heavily used portion of the route as well as a shorter path between the ends of the route.

This route required substantial restructuring. The branches on Pacific and Magnolia Avenues are separated into a new diesel bus route. The east extension is swapped with another route to move it from a residential to an arterial street and to position it to share wire with the 90 route to a proposed major transfer point. The easternmost end of the route is discontinued, being replaced by a combination of currently operated duplicate service and by the rerouting of a diesel bus route. The supplemental crosstown route 45 is unchanged except that it will be shortened about 1 mi on the west end to avoid the need for wire in an area of very low usage where duplicate service is available.

The resulting trolleybus route will consist mostly of segments with an average peak-period headway of $7^1/_2$ min, resulting either from the combination of the 40 and 45 routes or from joint wire use between the 40 and other routes. The exceptions are $^1/_2$ mi of wire on the west end of the 45, which will have 15-min headway and $^3/_4$ mi of wire east of the main terminal that will have a 30-min headway. This section is also needed for garage access to the east end of the 90 route.

The 50 route on Long Beach Boulevard north of the downtown loop operates at a 15-min headway throughout the day. East of downtown on Fourth Street, every other bus turns back at a point about halfway on the route, thus providing a 15-min headway on the inner end and 30-min headway on the outer end. Because of this cutback, the east end of the route has insufficient service density to justify trolleybus conversion.

The 50 route will thus be split, with the portion north of downtown being converted to trolleybus while the portion east of downtown is through routed with the new diesel bus route that will serve Magnolia and Pacific Avenues now on branches of the 40 route. The wire on the 50 route will thus be used every 15 min throughout the day except where it is shared with the 40 and 60 routes.

The 60 route on Atlantic Avenue will be largely unchanged. Now the route operates on a 10-min headway during peak periods and a 15-min headway in the midday with alternate trips serving two branches at the north end; it is not through routed in the

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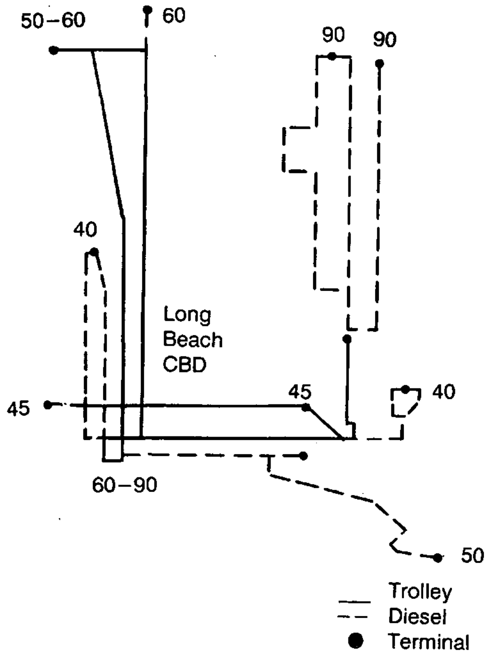

FIGURE 1 Routes considered for electrification, LBT.

downtown. One branch, about 1 mi long, will be abandoned. Two LACMTA routes also provide service to the area served by this branch. All service will be relocated to the other branch, which feeds a Blue Line rail station and shares some wire with the 50 route.

The 90 route on Seventh Street and Bellflower Boulevard currently has three branches. Headway on the trunk route is 10 min during peak periods and 12 min in the midday. Branch headways are 30 min on the Woodruff Avenue branch and 60 min on the other two branches throughout the day. A 5-min headway is provided on the trunk portion of the route during a portion of the a.m. peak on days when school service is operated.

The route is proposed to be split, with the trunk route being converted to trolleybuses and the three branches being replaced by diesel bus shuttles. At present, short-turn buses serving only the trunk route terminate about $^1/_2$ mi short of the point at which the first branch diverges. This latter point is proposed to be the new transfer point for the service. One change to the branch structure is the operation of the two branches having 60-min headways as a two-way loop, so that a round trip can be made in 1 hr.

A change may be made to the trunk route at CSULB. The present route through the campus may not be retained if CSULB does not agree to install wire on it. If this route is moved to Bellflower Boulevard, the internal campus shuttle bus service will have to be expanded as a replacement.

One factor that improves the efficiency of the proposed route changes is the layout of the downtown loop. It is short, being designed primarily to route all buses past a common transfer point. Splitting a through route adds only about $^1/_4$ mi of distance to each leg. Thus, the advantage of through routing is primarily to match headways and running times, which is much more important on routes with infrequent service than for routes with frequent service such as the proposed trolleybus routes. In addition, LBT has recently revised its schedules to move all layover time to the outer ends of routes. Thus there is no layover penalty in splitting through routes.

Figure 2 shows a wire schematic of the proposed trolley coach system. It should be noted that the only nonrevenue wire in the proposed route structure is the garage entrance and the turns at Atlantic Boulevard and Anaheim Street that are needed to provide a route between the garage and the north end of the 50 and 60 routes. At present, a right turn from westbound Anaheim Street to northbound Long Beach Boulevard is made by two early morning trips. One of these trips is needed to provide early morning Blue Line feeder service, and it was decided that it was uneconomical to provide switches for the turn for just one trip. This trip will thus have to make the turn on battery power or be rerouted to start at the downtown loop and start about 20 min earlier.

The proposed trolleybus system is estimated to require 37 vehicles to provide the current level of peak service. The diesel bus routes that serve segments that will not be equipped with wire are estimated to require 12 vehicles for peak service. Thus, 76 percent of the service on the restructured system is provided with trolleybuses. Only a $^3/_4$-mi segment of the trolleybus system fails to meet the goal of a 15-min peak headway, as compared with approximately 29 route-mi of the four selected routes before restructuring.

EXPRESS OR LIMITED-STOP OPERATION

As part of a study of the feasibility of converting the M15 route to trolleybuses, approaches to providing both local and limited-stop service on this route with trolleybuses were examined. This route is operated by the New York City Transit Authority (NYCTA) and primarily serves First and Second Avenues in Manhattan. It is one of the three most heavily used transit routes in the United States. Limited-stop service is currently offered on the portion of the route on First and Second Avenues north of Houston Street.

The decision to operate both local and limited-stop service with trolleybuses was based primarily on the amount of limited service, which is much more frequent than on most such routes. There are 210 weekday limited trips, which is more service than is operated on most transit routes. Another reason is that local and limited service is scheduled as one route, and operating costs would increase if the services were scheduled separately.

There are several alternatives for the wire layout on First and Second Avenues north of Houston Street. These include

- A single pair of wires in each direction,
- A single pair of wires in each direction with periodic passing segments,
- A double pair of wires in each direction with separate wire for local and limited service, and
- A double pair of wires in each direction with crossovers between wires so that local and limited service can use either wire.

The single-wire pair alternative was rejected because it is incapable of supporting the existing limited/local service pattern. As shown in Figure 3, limited buses are scheduled to pass five to seven local buses on Second Avenue during the morning peak. It would be feasible only if local service is operated with trolley coaches and limited service with diesel buses, or if limited service is eliminated.

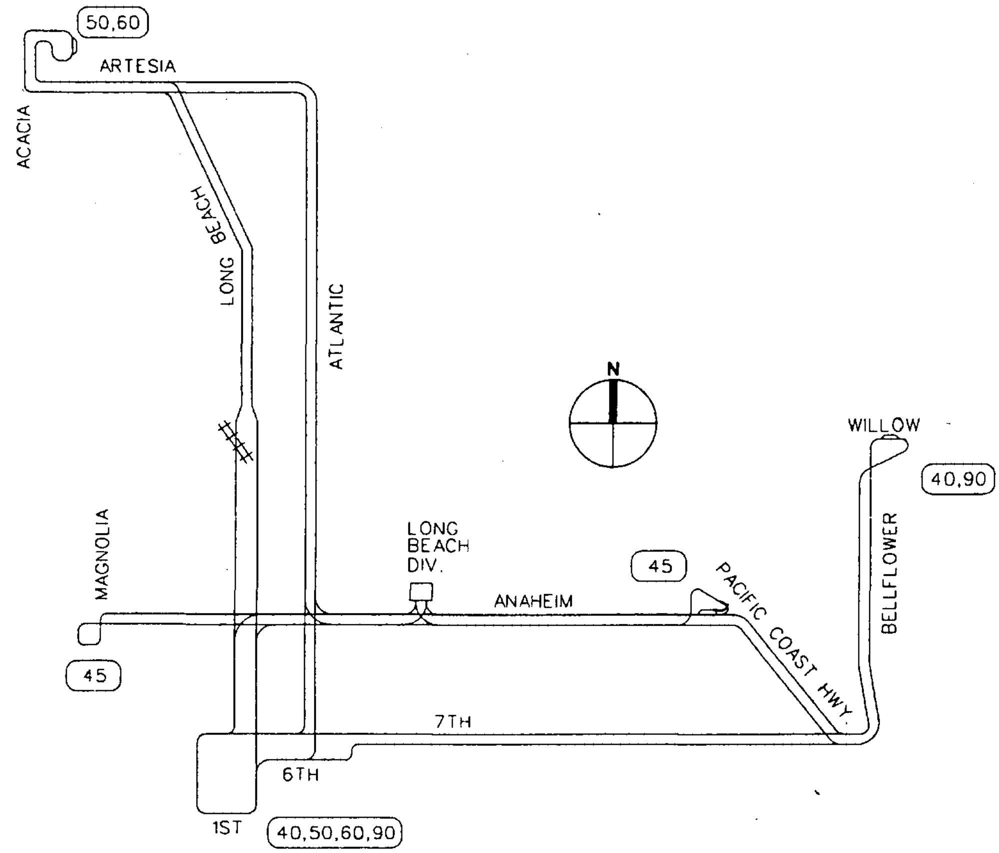

FIGURE 2 Proposed wire map, LBT.

The alternative of a single-wire pair with passing segments was rejected because of the high costs of installation and maintenance. Passing segments would need to be installed at about $^1/_4$-mi spacing to come close to replicating the existing service pattern. The running time of limited service would still be somewhat longer than would be possible with double wire. The initial cost of the 24 to 25 passing segments that would be needed to provide $^1/_2$-mi spacing is likely to be as much as four times higher than the cost of double wire. In addition, maintenance requirements would be substantially increased and the system would be much more visually intrusive. Driver workload would increase because of the need to be aware of the location of many switches and the need to operate these switches on the basis of an observation of the preceding buses in the traffic stream.

The double-wire pair alternative was selected. It preserves the present limited/local service pattern with almost no effect on service. It is reasonably straightforward to design and construct, requiring special work only at the ends of the double-wire pair sections on First and Second Avenues and at turnback locations. There is a minor problem with this alternative in that although limited buses can pass local buses, neither local nor limited buses can pass another bus in the same service.

The alternative of a double-wire pair with crossovers was rejected because of the same cost and driver workload disadvantages described in the passing segment alternative. In fact, it would be substantially more costly and complex than the passing segment alternative. Each passing point requires four to six switches as compared with two for the previous alternative. Its only benefit is that it provides somewhat more operating flexibility than the double-wire pair without crossovers.

As part of the development of the double-wire pair alternative, it was necessary to determine wire placement both for the double-wire section on First and Second Avenues. The limited/local operation currently in service on First and Second Avenues is different from existing double-wire pair trolley coach operations in that all buses use curb stops. There are three options for placing the double wire on First and Second Avenues, two of which retain the curb stops. The options are

- Placing both local and limited wire in the second traffic lane. The local wire is centered 12 ft from the curb; the limited wire is centered 16 ft from the curb. This option has the advantage of being the least expensive to install if bracket arms are used. The major disadvantage is the reduction in flexibility of lane use and difficult operating conditions resulting from this scheme. Limited buses will be operating near the maximum feasible touring range at bus stops and will be unable to use the fourth traffic lane. Local buses will be near the maximum touring range when operating in the third traffic lane and may have difficulty moving to the left side of this lane to pass a large vehicle. In addition, the close wire spacing is likely to result in trolley poles' being placed on the wrong wire after a dewirement, with subsequent damage to poles and wire. This scheme was rejected because of its unsuitability to traffic conditions.
- Placing the local wire in the second traffic lane and the limited wire in the third traffic lane, with the limited wire being

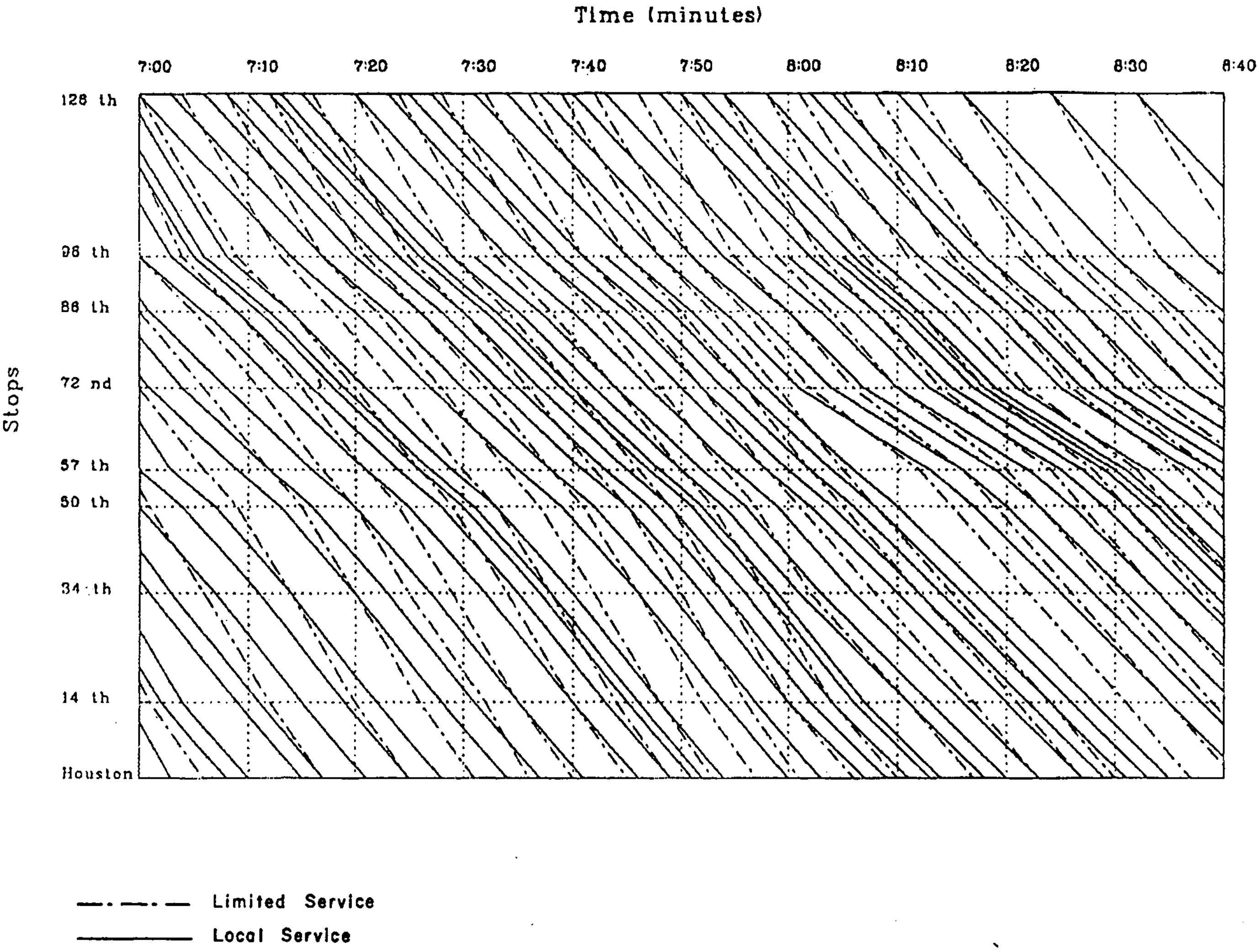

FIGURE 3 A.M. peak service density service diagram layout landscape, NYCTA Route M15.

located closer to the curb at limited stops. The local wire is centered 15 ft from the curb and is moved to 11 ft from the curb at limited stops; the limited wire is centered 26 ft from the curb and is moved to 15 ft from the curb at limited stops. It is necessary to shift the location of the local wire at limited stops in order to bring the limited wire to a position at which a bus can stop at the curb. Angular deflection is limited to 7 degrees at the shift points to minimize the effect on bus speed. This scheme provides adequate flexibility for local buses, which can operate in Lanes 1 through 3, as well as limited buses, which can operate in Lanes 2 through 4 except at limited stops. Disadvantages are that if bracket arm construction is used, the long arms are more costly and visually massive and that there is a small increase in cost and visual clutter due to the additional hardware and pulloffs needed to shift the wire at limited bus stops. This was the accepted option.

- Placing the local wire in the second traffic lane and the limited wire in the third traffic lane, with limited stops being made at traffic islands. The local wire is centered 15 ft from the curb; the limited wire is centered 26 ft from the curb. This option has the flexibility advantages of the previous scheme and would reduce passenger congestion at limited stops. It would be necessary to stagger local and limited stops at opposite sides of a cross street to avoid parallel stopped buses from impeding street traffic. The disadvantages of this scheme include the fact that the stop islands may be an unacceptable street traffic obstacle although adjustments in lane widths and shallow curb cuts could be used to avoid the loss of a traffic lane in most locations. In addition, the separation of local and limited stops is likely to be a problem for waiting passengers, because many are planning to take whichever bus arrives first. This option was rejected because of these two disadvantages.

Figure 4 shows the proposed wire layout for the M15 route including scheduled and unscheduled turnbacks.

REQUIREMENTS FOR INFREQUENTLY USED WIRE

Since some level of auxiliary power unit (APU) capability has become a standard feature in the specifications for new trolleybus

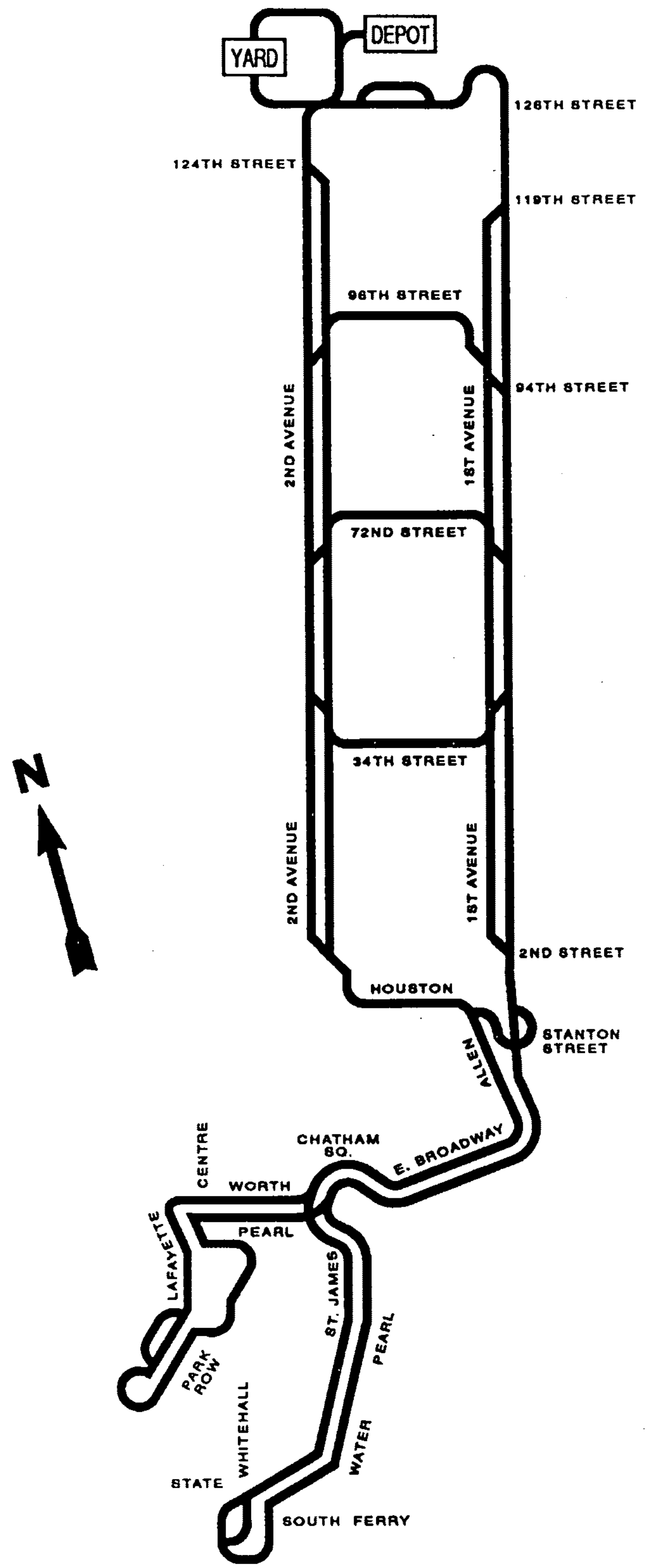

FIGURE 4 Wire layout for local and limited service, NYCTA Route M15.

systems, the need to provide wire for infrequently used movements has become an issue in the development of trolleybus routes. In this section, this issue is examined in two contexts: the need for wire to accommodate unscheduled but regularly used turnbacks and the need for a large number of scheduled turnback points.

The first issue will be examined in the context of a very high density route, the M15 in Manhattan. As can be seen in Figure 4, this route has four turnbacks. The two at 96th and Houston Streets are frequently used in scheduled service, with 82 and 107 weekday trips respectively. The turnbacks at 72nd and 34th Streets are not used in scheduled service. The NYCTA requested these turnbacks in order to provide a convenient means of turning back buses that are running substantially behind schedule on either side of the most heavily used and most congested part of the route in midtown Manhattan. Wired turnbacks were desired in these locations because (a) they are expected to be used on a regular basis, (b) traffic conditions in these locations make manual pole raising difficult and hazardous, and (c) the speed restriction and time used for pole handling inherent in the use of the APU are serious impediments to use of these turnbacks as a means of rapidly responding to minor service interruptions and delays.

The issue of whether to wire intermediate turnbacks is typified by the 66/67 route of the LACMTA. This route is shown in Figure 5. This route has six intermediate turnbacks and APUs will be used. Their location and use are shown in the following:

- Western Avenue: 87 weekday trips, all weekend service;
- Figueroa Street (Francisco Street): one daily trip;
- Boyle Avenue/Soto Street: 38 weekday trips, 9 Saturday trips;
- Mirasol Street (Calzona Street): shown in route description, not used in current schedule;
- Eastern Avenue: 31 Saturday trips, 23 Sunday trips; and
- Atlantic Boulevard: 38 weekday trips, 1 weekend trip.

The turnback at Mirasol Street is not needed, because it is not currently in use. The turnback at Figueroa Street is used by one trip at the end of the service day. It is likely that rescheduling this trip would be more cost-effective than installing wire, if the operating department does not want to use the APU in regular service. The turnbacks at Western Avenue and Boyle Avenue/Soto Street are used enough to be included in any wire plan. The turnbacks at Atlantic Boulevard and Eastern Avenue seem to serve the same purpose, turning alternate midday trips, on different days of the week. These turnbacks are only 1 mi and 4 min running time apart, and it is likely that only one of them is needed. Thus, it appears that the number of turnbacks can be reduced from six

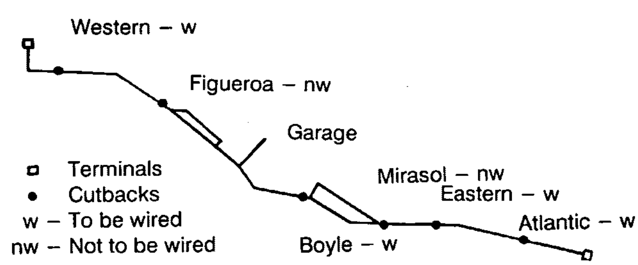

FIGURE 5 Turnback wiring requirements, LACMTA Route 66/67 East Olympic.

to three without significantly affecting service. The need to use these cutbacks for emergency service can be accommodated by using the APUs, which greatly increase operational flexibility in such situations.

The LACMTA project also analyzed the amount of wire needed in a garage location for a trolleybus system in which all vehicles are equipped with APUs. Four alternatives were developed:

- Installing wire from the garage entrance to the pole inspection location, in the parking lanes, and for all exit movements from the parking area;
- Installing a complete circulation loop through the garage property, in addition to the wire in the previous alternative;
- Adding wire through the bus cleaning facilities and switches to permit entrance to the parking lanes under wire; and
- Fully wiring the garage area, including access to the maintenance bays.

It has been decided that the complete circulation loop will be included in the garage wiring plan. Although it is not needed for normal garage operation, it provides a way to clear the main aisle in case of an APU failure as well as a place to test buses. It has not been decided if the additional wire through the bus cleaning facilities and the parking area entrance switches will be built. There is some feeling that this wire will decrease the time needed to service and park buses and thus reduce queueing of buses in the servicing process. There appears not to be any need for wire to access the maintenance bays.

It should be noted that LACMTA plans to use a battery APU. However, it is likely that the same considerations would apply to any type of APU system. For example, the higher speed that is achieved by an engine-driven APU is balanced by the time needed to start the engine as well as the additional servicing time.

CONCLUSIONS

There is no one answer to the question of how much wire is needed for a particular trolleybus system. In fact, this question will take a substantially different form in various situations. In one situation, the question may be how to restructure routes to create a system with enough service density to justify wire installation. In another situation, the question may be how much wire in addition to the basic route structure is needed to make the service function effectively. In a third situation, the question may be whether all of the route variations currently in use are really needed.

Publication of this paper sponsored by Committee on Rail Transit Systems.