that it could never afford rapid transit systems extensive enough to serve its metropolitan regions. San Francisco's BART and San Diego's light rail system have put the lie to these suppositions.

San Diego's accomplishment is particularly embarrassing for Los Angeles because the San Diego-Tijuana capital works have been accomplished for about the same sum as Los Angeles public agencies have spent over the past 25 years on alternative analyses and engineering for never-built rail lines.

Whatever the eventual outcome of the Los Angeles debates over transportation policy, it should be obvious that population density is a not an issue in coastal California. The Los Angeles-Long Beach line has roughly twice the density of San Diego-Tijuana and roughly 20 times the density of the Belgian coast or the Karlsruhe area in West Germany, where the Albtalbahn operates.

Beyond about 100 passengers per trip, the economics of electric rail transit are superior to that of the bus, regardless of population density, length of the travel corridor, or category of traffic. There is little hope of fares ever covering 80 percent of bus system operating costs. San Diego's light rail system is already achieving this coverage rate, largely because of "recreational" traffic, such as tourists and intercity travelers.

Highway and air transportation systems derive a large percentage of their traffic from recreational travel, a trade that currently gives the airline industry its only profitable seasons. The transit industry's failure to attract a substantial noncommute traffic with buses shows the public's lack of acceptance of the all-bus mode. The recreational and intercity connection markets are particularly lucrative ones for the transit industry, because the trips are most often made during nonpeak hours when there is ample excess capacity. When transit systems were privately run, there was more promotion of recreational travel, and amusement parks and other traffic-generating facilities often were purpose-built by the companies. If public transit enterprises are to be operated in a more businesslike manner in the future, the industry must recognize that off-peak discretionary traffic is good for business no matter what its purpose.

Finally, the potential revenues from freight haulage should not be overlooked. Even lines with marginal carloading levels and lines that railroads consider abandoning may, with more efficient labor practices, offer a net gain by continuing freight service. The successful mixing of freight and transit on the Köln-Bonner Elsenbahn, the Albtalbahn, the Wiener Lokalbahn, the South Shore, and the San Diego Trolley shows that this practice is not hazardous and is by no means innovative.

## CONCLUSIONS

The electric railway is a flexible, versatile, and inexpensive means of providing transportation of people and materials. Only when inadequate conceptions of its parameters and capabilities are applied do its form and abilities become limited. When conceived and constructed as a street-railway, it becomes limited in speed and passenger attraction because of traffic congestion. When conceived as a subway with full grade separation, it becomes unduly expensive to construct and limited in range. Under either conception, it loses the ability to provide freight haulage or attract significant recreational traffic and also becomes limited in its applicability to modern cities.

The term "light rail transit" has been moderately successful in breaking through the inadequate conceptions of what rail transit can be. To continue the breakthrough, a definition of light rail that incorporates all the capabilities and potential uses of the electric railway must be applied.

# Maintaining Transit Service During Light Rail Rehabilitation in Newark: A Case Study

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**The Newark City Subway is a 4.3-mile (6.9-km) light rail system with 11 stations and an average weekday ridership of 12 600 passengers. As part of the $15 million rehabilitation of this New Jersey Transit Corporation line, alternative transit service will be required during off-peak periods when rail service must be suspended. Suspension of service at night and on weekends is necessary to accommodate rehabilitation of the track, stations, and right-of-way. In developing alternative service options, the advantages of light rail service along the corridor became apparent, both from the perspective of the passenger (travel time) and the operator (operating cost). This paper documents the planning methodology used to develop ridership data and operating plans for alternative bus service. As a result of the alternative service planning, it was determined that the light rail system required significantly fewer vehicle and crew hours than did buses to provide equivalent service and capacity.**

The Newark City Subway is one of the few streetcar subways remaining in operation in the United States. Completed in 1935 and operated continuously to the present time, the line has gradually deteriorated as the financial problems of its owners and operators limited the resources available for maintenance and rehabilitation.

During the 1970s, state agencies' increased concern with mass transit led to renewed interest in preserving the mass transit infrastructure of urban areas. This concern caused state and local officials to take a fresh look at the Newark subway and to include it in an overall program of transit rehabilitation in New Jersey called "Transpac." Under the terms of Transpac, funds from a bond issue and from the Port Authority of New York and New Jersey would be used as a local matching share for an UMTA capital grant. Approximately $14 million was earmarked for improvements to the Newark City Subway.

The subway rehabilitation program was to stress renewal of the fixed facilities of the system. Procurement of new vehicles was to be included in the program's later phases. During the planning of the rehabilitation design and engineering work, it became obvious that normal service would need to be suspended for extended periods to expedite the trackwork and right-of-way rehabilitation. As part of the engineering design, an operations planning task was undertaken.

This paper reports on the methods used to plan for

maintaining service during the rehabilitation process. In the course of this analysis, some of the operating efficiencies of light rail were highlighted. This paper has the following goals:

- To document some of the characteristics of the Newark City Subway,
- To report on the operations planning methodology, and
- To compare the operating characteristics and costs of the LRT with alternative bus service.

## LINE CHARACTERISTICS

The Newark City Subway is a 4.3-mile (6.9-km), 2-track streetcar subway that starts at Penn Station in downtown Newark and extends northward to Franklin Avenue within a mile (1.6 km) of the city limit. From Penn Station, the system operates in subway for approximately 1.4 mile (2.2 km) and serves 4 underground stations. For the remaining 2.9 mile (4.6 km), the line runs in open cut and at grade and serves 7 (3 at-grade and 4 in-cut) stations. At the terminal stations (Penn Station and Franklin Avenue), loop tracks are used to reverse the cars for the return trip. The system has only one grade crossing, located adjacent to the Orange Street station.

The line operates approximately 20 hours a day. Cars operate at 2-minute headways during peak hours, at 5- to 6-minute headways during the midday period, and at 10- to 15-minute headways during the early morning (5:00-6:30 a.m.) and early evening hours. From 11:00 p.m. to shutdown at 12:47 a.m., service is provided at half-hour headways. On weekends, Saturday headways vary from 7 to 10 minutes during the day and extend to 30 minutes in the late evening. Sunday service is provided on 15- to 20-minute headways during most of the day.

At Penn Station, the subway offers connections to Amtrak's northeast corridor trains, the Port Authority Trans-Hudson (PATH) services to lower and midtown Manhattan, NJ Transit commuter trains to the north Jersey shore and central New Jersey, and to numerous local and intercity bus lines. At several other stations, transfer service is provided to NJ Transit bus lines. The line serves downtown Newark, several local colleges and universities, and the densely populated North Ward of the City of Newark. Average weekday ridership is 12 600 passengers.

Service is provided by a fleet of 30 Electric Railway Presidents' Car Conference (ERPCC) streetcars built between 1945 and 1947 and purchased secondhand from Minneapolis in 1954. Average line speed is 21.5 miles per hour (34.4 km/hr). Cars are single-ended with doors on the right side only and have 55 seats. Stored underground on layover tracks at Penn Station, the cars appear to be in remarkably good condition, with fresh paint both inside and out. They are kept clean and do not suffer from the graffiti epidemic that plagues other northeastern transit properties. Direct current for traction power is distributed from an overhead trolley wire. Station lighting is also fed from the traction power system.

Fare collection is a curious mixture of both on-board and in-station that changes throughout the course of the day. Passengers boarding cars southbound to Penn Station pay upon boarding; outbound passengers on northbound cars pay on-board as they leave. However, at the downtown stations during the afternoon peak, fares for northbound passengers are collected on entry to the station. At certain other stations, attendants are present during the morning peak to collect transfers and cash fare receipts from southbound passengers.

## HISTORY

Around the turn of the century, Public Service Coordinated Transit Co. (PSCT) absorbed most of the independent trolley lines serving northern New Jersey, creating an 850-mile (1360-km) network with 2500 streetcars. Newark served as a major hub for this system; in 1910, as many as 525 streetcars per hour traversed the intersection of Broad and Market Streets.[3] This undoubtedly led to the subway development which provided ramps connecting to surface car lines at four locations to expedite through service to downtown. By 1935, when the subway was built, PSCT's network was in the process of diminishing to 8 lines and 74 miles (118 km) of route. By about 1950, the connecting surface trolley routes had been converted to bus, and the subway was operated as a closed system.

The subway itself was constructed in the bed of the abandoned Morris Canal. While the cars were owned and operated by Public Service Coordinated Transit, the subway structure was owned by the City of Newark and leased to PSCT. A separate corporate entity, Transport of New Jersey, was established to run both the subway and bus lines when PSCT sought to separate the money-losing transit operations from the profitable electric and gas utility companies. In 1979, the State of New Jersey set up NJ Transit, a public corporation, to take over all commuter rail and bus operations in the state, including the Newark City Subway.

## REHABILITATION PROGRAM

The rehabilitation program focused on renewing deteriorated system components. Specifically, the following eight objectives were identified for the program:

- Providing increased security for passengers;
- Providing increased safety and reliability of operation;
- Maximizing efficient use of energy;
- Creating aesthetically pleasing stations for the riding public;
- Providing an upgraded system with respect to track, stations, right-of-way, and maintenance facilities;
- Keeping the public well informed on the nature and progress of the work;
- Accomplishing construction with minimum impact on transit operations, patronage, and adjacent communities; and
- Completing the entire project by November 1983.

The major components of the project involve improvements to tracks and rights-of-way, stations, the maintenance shop, and the electrical power system.

Track and right-of-way rehabilitation will constitute the major portion of the project and will extend over a 2-year period. The entire track structure, from subgrade drains to rail top, will be renewed and rehabilitated. Most of the track will be rebuilt with new, continuous-welded rail.

Station rehabilitation will be the most visible aspect of the renewal program. It will include considerable work on repairing and modifying stairs to improve station access and visibility, new lighting and graphics, and resurfacing platforms. New canopies and shelters will be installed at the above-ground stations.

Improvements to the mechanical system include installing new car hoists at the Penn Station maintenance shop, new sewage injectors, and new rectifiers for the traction power system.

## RIDERSHIP AND OPERATIONS DATA

(Ed. Note: The information provided in this section was prepared during the spring of 1981. Since then a fare increase and some bus route changes have occurred. Adjustments have been made to accommodate these changes.)

The Newark City Subway carried an estimated 3 429 990 passengers in 1980, according to information supplied by the operator, Transport of New Jersey. Monthly ridership varied from a high of 317 522 in January to a low of

234 007 in August. Reduced ridership during the summer months signifies that this is the vacation season for many patrons and that the colleges served by the subway are closed for the summer.

Average weekday ridership in 1980 was 12 632, with Monday typically the highest day of the week and Wednesday the lowest. Average Saturday ridership was 3238 passengers, while Sunday ridership was typically 1381.

The estimated hourly distribution of passengers for a typical weekday, Saturday, and Sunday is shown in Figure 1. The distributions are based on information in "Weekday Bus Usage in the Tri-State Region"[5] and on-board passenger counts of ridership conducted by the Division of Commuter Services, New Jersey Department of Transportation, July to December 1980.

The hourly distribution of subway trips for a typical weekday is about what would be expected for a downtown-oriented transit route. The hourly distribution of trips for Saturdays and Sundays is more or less evenly distributed throughout the day and does not exhibit the weekday peaking characteristics.

Trip tables were developed showing estimated station-to-station passenger volumes for the subway at various periods of a typical weekday (Figure 2). Trip tables were also developed for Saturdays and Sundays. In Figure 3, for example, of the 2936 persons who boarded the subway on a typical weekday at Penn Station, 705 debarked at the Broad Street Station, 424 at the Washington Street Station, etc.

The trip tables are based on data from passenger counts taken on board the subway by the Division of Commuter Services, during July to December 1980, and on

Figure 1. Hourly distribution of subway ridership.

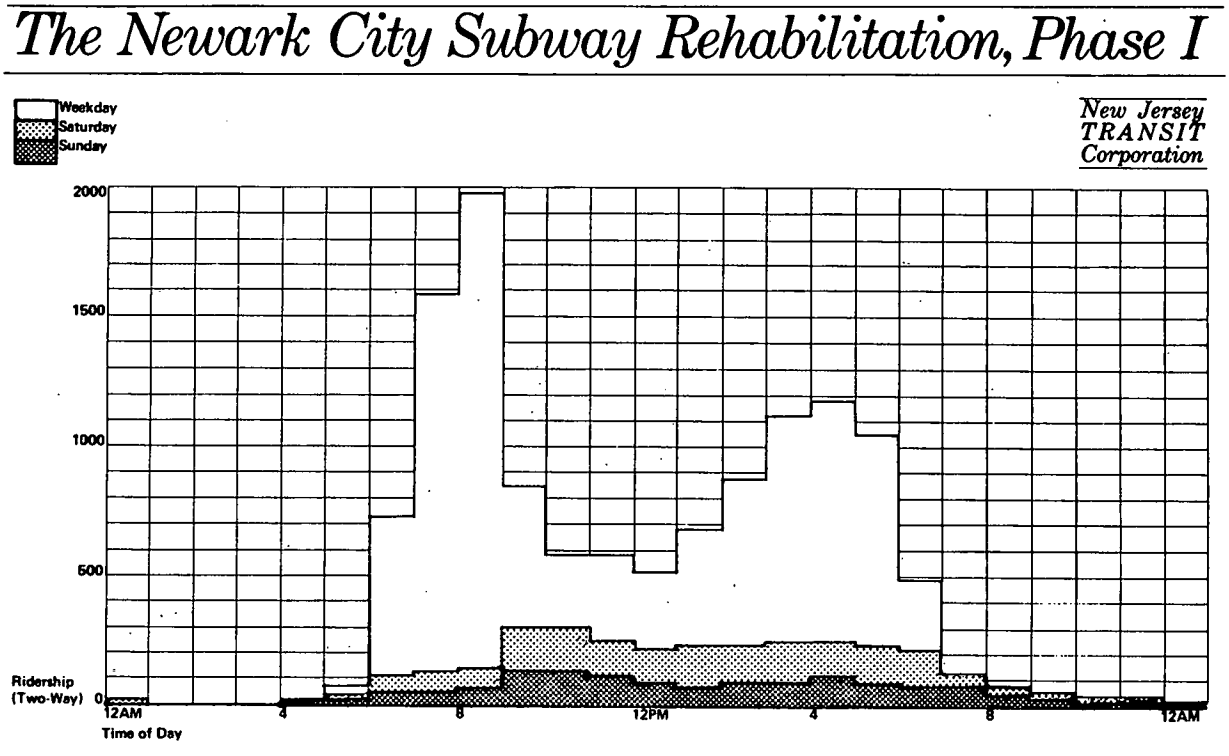


Figure 2. Station-to-station passenger volumes, typical weekday, all day.

| FROM (ON) \ TO (OFF) | PENN STATION | BROAD ST. | WASHINGTON ST. | WARREN ST. | NORFOLK ST. | ORANGE ST. | PARK AVE. | BLOOMFIELD AVE. | DAVENPORT AVE. | HELLER PARKWAY | FRANKLIN AVE. | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PENN STATION | | 705 | 424 | 251 | 94 | 197 | 443 | 325 | 133 | 123 | 241 | 2936 |
| BROAD ST. | 717 | | 102 | 116 | 44 | 94 | 212 | 158 | 64 | 59 | 443 | 2111 |
| WASHINGTON ST. | 809 | 442 | | 29 | 10 | 25 | 54 | 39 | 15 | 15 | 183 | 1611 |
| WARREN ST. | 362 | 286 | 62 | | 5 | 5 | 10 | 10 | 5 | 5 | 29 | 759 |
| NORFOLK ST. | 100 | 77 | 15 | 8 | | 5 | 10 | 5 | 0 | 0 | 44 | 272 |
| ORANGE ST. | 362 | 262 | 62 | 15 | 8 | | 10 | 10 | 5 | 5 | 39 | 778 |
| PARK AVE. | 416 | 293 | 77 | 15 | 8 | 0 | | 0 | 0 | 0 | 34 | 843 |
| BLOOMFIELD AVE. | 470 | 324 | 77 | 23 | 8 | 0 | 0 | | 0 | 0 | 10 | 912 |
| DAVENPORT AVE. | 54 | 31 | 8 | 0 | 0 | 0 | 0 | 0 | | 0 | 10 | 103 |
| HELLER PARKWAY | 162 | 108 | 23 | 8 | 0 | 0 | 0 | 0 | 0 | | 0 | 301 |
| FRANKLIN AVE. | 948 | 809 | 177 | 47 | 15 | 0 | 15 | 15 | 0 | 0 | | 2026 |
| TOTAL | 4426 | 3347 | 1127 | 514 | 192 | 326 | 794 | 562 | 222 | 207 | 1003 | 12 632 |

NORTHBOUND : 4926
SOUTHBOUND : 7706

Figure 3. Station-to-station passenger volumes, typical weekday, all day.

| FROM (ON) \ TO (OFF) | PENN STATION | BROAD ST. | WASHINGTON ST. | WARREN ST. | NORFOLK ST. | ORANGE ST. | PARK AVE. | BLOOMFIELD AVE. | DAVENPORT AVE. | HELLER PARKWAY | FRANKLIN AVE. | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PENN STATION | | 705 | 424 | 251 | 94 | 197 | 443 | 325 | 133 | 123 | 241 | 2936 |
| BROAD ST. | 717 | | 102 | 116 | 44 | 94 | 212 | 158 | 64 | 59 | 443 | 2111 |
| WASHINGTON ST. | 809 | 442 | | 29 | 10 | 25 | 54 | 39 | 15 | 15 | 183 | 1611 |
| WARREN ST. | 362 | 286 | 62 | | 5 | 5 | 10 | 10 | 5 | 5 | 29 | 759 |
| NORFOLK ST. | 100 | 77 | 15 | 8 | | 5 | 10 | 5 | 0 | 0 | 44 | 272 |
| ORANGE ST. | 362 | 262 | 62 | 15 | 8 | | 10 | 10 | 5 | 5 | 39 | 778 |
| PARK AVE. | 416 | 293 | 77 | 15 | 8 | 0 | | 0 | 0 | 0 | 34 | 843 |
| BLOOMFIELD AVE. | 470 | 324 | 77 | 23 | 8 | 0 | 0 | | 0 | 0 | 10 | 912 |
| DAVENPORT AVE. | 54 | 31 | 8 | 0 | 0 | 0 | 0 | 0 | | 0 | 10 | 103 |
| HELLER PARKWAY | 162 | 108 | 23 | 8 | 0 | 0 | 0 | 0 | 0 | | 0 | 301 |
| FRANKLIN AVE. | 948 | 809 | 177 | 47 | 15 | 0 | 15 | 15 | 0 | 0 | | 2026 |
| TOTAL | 4426 | 3347 | 1127 | 514 | 192 | 326 | 794 | 562 | 222 | 207 | 1003 | 12 632 |

NORTHBOUND : 4926
SOUTHBOUND : 7706

the Inventory Report, Newark-Elizabeth Local Bus Study.[2] Station-to-station trip factors were developed from the data and applied to estimated passenger volumes for the various time periods to produce the trip tables.

The results of this analysis show that Penn Station is the busiest of the 11 stations. Broad Street, Washington Street, and Franklin Avenue are also heavily used. The stations at Heller Parkway, Davenport Avenue, and Norfolk Street have the lowest use.

On a weekday, the total southbound traffic is greater than the total northbound traffic. This is caused in part by Newark downtown-bound riders who take a bus in the morning as far as a connecting subway stop and transfer to the subway for the rest of the trip, even though the bus route continues into the downtown. The subway has a travel time advantage over the bus. However, on the return trip, passengers board the bus downtown in order to get a seat, thus sacrificing the travel time benefit of going part of the way by subway. Another reason for the difference in the directional flows is the 15-cent reduced fare available for trips between Penn Station and the Warren Street station. The reduced fare is applied at all times in the southbound direction but is not in effect in the northbound direction between 4:00 p.m. and 6:00 p.m. on weekdays.

The numbers shown on Figure 2 are estimates of station and subway use during specific time periods. Individual values should not be taken literally but only as an indication of relative travel activity. This is particularly relevant where low values and zeros appear; they indicate only that these origin-destination pairs have very little activity during the day.

## MAINTENANCE OF SERVICE ALTERNATIVES

According to available ridership information, 96.4 percent of daily traffic is carried between 6:00 a.m. and 7:00 p.m. If the subway were shut down from 7:00 p.m. to its usual closing time of 12:47 a.m. and from its usual start of service at 4:38 a.m. until 6:00 a.m., less than 4 percent of the ridership, about 455 patrons, would be affected. This would provide an 11-hour construction shift during the night. Substitute bus service could be provided during the shutdown period.

Construction activity should not interrupt weekday peak-period service (6:00 to 9:00 a.m., 4:00 to 7:00 p.m.). The subway operates during these periods at 2- to 4-minute headways and carries over 55 percent of the total daily traffic (around 6950 passengers). The morning peak traffic flow is generally from the stations at the northern half of the line, such as Franklin Avenue, Bloomfield Avenue, and Park Avenue, south into the CBD stations of Penn Station, Broad Street, and Washington Street. There is also a substantial northbound flow from Penn Station to the Broad Street and Washington Street stations. The high ridership level and slow bus operating speeds due to peak-hour traffic would make adequate substitute bus service difficult to provide. Approximately 30 buses and drivers would be required to carry the passengers. That number of buses may not be available during peak periods. Also, on some streets, that many buses may cause local capacity problems.

Midday (9:00 a.m. to 4:00 p.m.) ridership on the subway accounts for 41 percent of the total traffic (around 5180 passengers). The subway runs at 5- to 6-minute headways during this 7-hour period. This is a fairly busy period for the subway and would not be a desirable time to suspend service. Minor delays, single-track operations for short sections of track, or occasional shutdowns might be tolerable if certain work or deliveries of material or equipment cannot be handled at night or on weekends. However, full service would have to be restored by the beginning of the evening peak period. If midday service is suspended, substitute bus service at 5-minute headways would be required.

Saturday subway service is provided at 7- to 10-minute headways for most of the day, while Sunday service has 15-to 20-minute headways. Early morning and late evening service is provided at 30-minute headways. Because Saturday and Sunday ridership could be easily accommodated by buses, the subway could be shut down on weekends to provide an uninterrupted work-time slot of over 52 hours.

If the subway could shut down on weekends and in the early mornings and evenings on weekdays, an uninterrupted time slot of 59 hours would be available for construction work (7:00 p.m. Friday to 6:00 a.m. Monday) in addition to 4 weeknight shifts (Monday to Thursday) of 10 to 11 hours each.

In addition to these recommended construction periods, the following alternatives were examined and rejected:

- Total shutdown of service for the duration of construction. While this alternative would have benefits in terms of construction time and cost, approximately 30 buses and drivers would be needed to provide peak-period service to the subway patrons. It would be extremely difficult and costly for the operator to make this many vehicles and drivers available during the peak periods for any length of time.
- Shut down parts of system (one track at a time) as needed for construction; run single-track service. Single-track operations would not be practical; PCC cars used on the Newark City Subway have doors on one side only and could not easily serve passengers in several of the stations. Peak-period service, with headways as close as 2 minutes, would be nearly impossible to maintain because vehicles would have difficulty making more than one peak-period round trip. Construction would also be slowed by the "live" track adjacent to the work area.
- Shut down sections of the system (two tracks at a time); provide shuttle bus service. The Newark City Subway is a closed one-way loop; vehicles cannot operate efficiently in reverse and therefore must be able to make the complete loop between Penn Station and Franklin Avenue. Transit service cannot be maintained if sections of the track are taken out of service.

Suspending only weekend and early morning and evening weekday service minimizes the negative impact to the ridership, allows the operator to use excess buses and drivers available in the off-peak periods for substitute service, and allows the construction crews a useful period of time.

## SUBSTITUTE BUS ROUTE

Transit service can be maintained during the period when the subway service is suspended by providing alternative bus service along a route parallel to the existing subway route. This is the same route used for emergency service in the past by Transport of New Jersey. It includes all 11 subway stops.

The current round-trip time for the subway is 26 minutes. Round-trip running time for a bus along the alternative route has been timed at 50 minutes, with adjustments made for dwell times and traffic signals. Allowing for layover and unanticipated delays, it is assumed that 1 bus and driver could make 1 round trip per hour. Therefore, 1 round trip per hour requires 1 bus and 1 driver for that hour (1 bus-hour). For the proposed route, 1 round trip requires 9.4 bus-miles, meaning the bus must travel 9.4 miles (15.1 km) to make 1 round trip. The bus route distance is nearly the same as that of the subway. Bus-miles are used to estimate fuel and maintenance costs.

## LEVEL OF SERVICE ALTERNATIVES

Four alternative service levels were examined. They vary

only in the frequency or level of service at various times of the day.

Alternative 1 would provide service at a level sufficient to meet anticipated demand (although the maximum headway would be 1 hour). The demand for the service was derived from the trip tables developed previously. Some minor adjustments were made to account for NJ Transit's proposed changes in bus routes serving the subway. Some routes are being eliminated or consolidated. Other routes are being altered and extended to act as feeder services to the subway. In addition, because the travel time of the alternative bus route is about twice that of the subway, some trips can be made faster by using an existing or proposed regular bus service or by walking.

The level of demand to be served by the buses was determined from the hourly peak-direction, maximum line volume (generally between the Broad Street and Washington Street stations). By providing capacity for this level of demand, adequate capacity would be provided along the entire route.

Alternative 1 would require the fewest buses and drivers of the four alternatives; it would, however, result in long headways and a reduced level of transit service for the riders, compared with the existing subway service.

Alternative 2 would use approximately the same number of drivers as the subway now uses during the various time periods, according to information supplied by the operator. By using the same number of drivers as the subway, the operator can use the same driver schedule. The operator avoids the expense of overtime and extra drivers. (The subway drivers are also able to drive buses.) Since the bus route travel time is twice that of the subway, the resulting level of service is roughly half that provided by the subway. Thus, headways would be longer than the existing subway but generally less than Alternative 1.

Alternative 3 would match the headway or frequency of service currently provided by the subway. Although patrons would receive basically the same level of service as on the subway, and better service than they would receive under Alternatives 1 and 2, the operator would need almost twice the number of drivers normally required, since the round-trip time on the substitute bus route is twice as long as the subway. The operator may be required to pay these extra drivers at an overtime rate.

Alternative 4 presents a compromise between providing a high level of service to the patrons (Alternative 3) and keeping operating costs reasonably low (Alternative 2).

## EVALUATION OF SERVICE LEVEL ALTERNATIVES

Table 1 shows the total bus-hours and bus-miles for each of the four alternatives. It is based on estimates of the total number of weekdays, Saturdays, and Sundays the subway would be shut down for construction and on the bus-hour and bus-mile requirements for each of the alternatives.

Of the four alternatives, Alternative 1 requires the fewest drivers and least equipment and produces the fewest bus-hours and bus-miles; however, it provides the poorest level of service. Alternative 2 allows the operator to maintain the drivers' schedule, although in some instances the level of service is poor. Alternative 3 provides the best service to the patrons; however, it requires the most bus-hours and bus-miles and the most bus drivers and equipment. Alternative 4 presents a reasonable level of service for the patrons while keeping the operating costs relatively low. The recommended level of service for the substitute bus service, therefore, was Alternative 4 (Table 2).

## COMPARISON OF LIGHT RAIL AND BUS SERVICE

One of this study's first findings was that the Newark City Subway would have to remain in service during peak periods while the rehabilitation work is performed. Transporting the current volume of people requires peak-period service at headways as frequent as 2 minutes. In each 3-hour morning (6:00 to 9:00 a.m.) and evening (4:00 to 7:00 p.m.) peak period, 61 vehicle trips are provided in each direction by the subway. Based on the ERPCC car's seated capacity of 55 and total capacity (seats plus standing room at 2.7 square ft per person) of 88, 3355 seats and 5368 places are provided during each peak period. Sixteen PCC cars are required to service the peak. To match this capacity with buses (assuming advanced design buses with 48 seats and 27 standees), 70 peak-period trips would be needed to match existing seating capacity and 72 peak-period trips would be required to match total capacity, at increases of 14.8 percent and 18.0 percent, respectively. Twenty-four buses would be required to handle the same ridership accommodated by 16 streetcars. To match the 2-minute peak-period headway currently provided by the subway, 30 buses (an 87.5-percent increase) would be needed. Unlike the subway cars, which can make 2 peak-period round trips per hour, the bus (running on the street) can make only 1 trip per hour.

Operational cost savings achieved by the LRT system over a roughly equivalent bus service are obvious. Because bus running time per trip is twice that of the subway, there would be some erosion of patronage by noncaptive riders, which might create a larger deficit. The impact on traffic in downtown Newark created by an additional 30 buses is likely to be severe and might also increase running time.

## CONCLUSION

The Newark City Subway represents a form of light rail transit that offers better service to a large population than would be possible by bus. On the basis of operating and labor costs, it also appears to be more economical. Although this study did not examine the total economic picture of the system, it would be useful to determine if the full cost of operating the system, including debt amortization for rehabilitation and maintenance, was cheaper than bus. It appears that LRT is more economical in this corridor, but there is no conclusive evidence.

If only the costs of the operator are considered, which are mostly attributable to labor, LRT offers undisputed savings over bus. With the scheduled phase-out of federal transit operating subsidies, it makes sense for transit operators to invest in rehabilitation of existing LRT sys-

Table 1. Alternative levels of substitute bus service: bus-hours and bus-miles.

| Alternative | Per Weekday | | Per Saturday | | Per Sunday | |
|---|---|---|---|---|---|---|
| | Bus-Hours | Bus-Miles | Bus-Hours | Bus-Miles | Bus-Hours | Bus-Miles |
| 1. Meet demand | 9 | 85 | 45 | 425 | 23 | 216 |
| 2. Maintain drivers' schedule | 18 | 169 | 67 | 630 | 33 | 310 |
| 3. Match headways | 29 | 273 | 113 | 1 062 | 73 | 686 |
| 4. Recommended | 22 | 207 | 73 | 686 | 52 | 489 |

Table 2. Maintenance of transit service: Alternative 4; recommended service level.

| Hour Round Trips Ending | Weekdays | | Saturdays | | Sundays | |
|---|---|---|---|---|---|---|
| | Headway Per Hour | Round Trips (minutes) | Headway Per Hour | Round Trips (minutes) | Headway Per Hour | Round Trips (minutes) |
| 5 a.m. | 2 | 30 | 1 | 60 | - | - |
| 6 | 3 | 20 | 3 | 20 | 1 | 60 |
| 7 | a | a | 3 | 20 | 2 | 30 |
| 8 | a | a | 3 | 20 | 2 | 30 |
| 9 | a | a | 4 | 15 | 2 | 30 |
| 10 | a | a | 4 | 15 | 3 | 20 |
| 11 | a | a | 4 | 15 | 3 | 20 |
| 12 p.m. | a | a | 4 | 15 | 3 | 20 |
| 1 | a | a | 4 | 15 | 3 | 20 |
| 2 | a | a | 4 | 15 | 3 | 20 |
| 3 | a | a | 5 | 12 | 3 | 20 |
| 4 | a | a | 5 | 12 | 2 | 20 |
| 5 | a | a | 5 | 12 | 3 | 20 |
| 6 | a | a | 5 | 12 | 3 | 20 |
| 7 | a | a | 4 | 15 | 3 | 20 |
| 8 | 4 | 15 | 3 | 20 | 3 | 20 |
| 9 | 3 | 20 | 3 | 20 | 3 | 20 |
| 10 | 3 | 20 | 3 | 20 | 3 | 20 |
| 11 | 3 | 20 | 2 | 30 | 2 | 30 |
| 12 a.m. | 2 | 30 | 2 | 30 | 2 | 30 |
| 1 | 2 | 30 | 2 | 30 | 2 | 30 |
| Total bus-hours: | 22 | | 73 | | 52 | |
| Total bus-miles: | 207 | | 686 | | 489 | |

[a]Normal weekday subway service, no buses required.

tems and new high-capacity lines for which UMTA capital grant assistance is still available.

The Newark City Subway was developed in an era when streetcars were being forced off the streets as the auto became dominant. In several other cities, including Cincinnati and Rochester, similar streetcar subways were constructed and abandoned but still exist as untapped resources. Today, the continued survival of the Newark City Subway is assured, and it will play an increasing role in providing mobility to its patrons and reducing congestion in downtown Newark. It is hoped that this paper will inspire planners in other cities to reexamine abandoned streetcar rights-of-way and perceive in them an effective and economical means of creating high-capacity transit corridors for the future.

REFERENCES

1. Stephen P. Carlson and Fred W. Schneider. PCC—The Car That Fought Back. Interurban Press, Glendale, California, 1980.
2. Chase, Rosen and Wallace, Inc. Inventory Report Newark—Elizabeth Local Bus Study. New Jersey Department of Transportation, December 1979.
3. William D. Middleton. The Time of the Trolley. Kalmbach Publishing Co., Milwaukee, 1967.
4. Parsons Brinckerhoff Quade & Douglas, Inc. The Newark City Subway Rehabilitation, Phase I, Project Definition Report No. 7, Operations—Maintenance of Passenger Service During Construction. New Jersey Transit Corporation, October 1981.
5. Tri-State Regional Planning Commission. Weekday Bus Usage in the Tri-State Region. Technical Report 106, June 1980.

# Light Rail and Development: Constraints and Conditions

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**This paper discusses work carried out for the Urban Mass Transportation Administration (UMTA) on the economic impacts of the Buffalo Light Rail Rapid Transit System (LRRT). The system is the culmination of two decades of corridor planning that saw appreciable changes in planning criteria and justification of system benefits.**