San Francisco's Muni Metro, A Light-Rail Transit System

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This paper describes improvements that are being made in San Francisco's light-rail (streetcar) transit system, the Muni Metro. The new dual-level Market Street subway accommodates Muni on the upper level and the Bay Area Rapid Transit System on the lower level. The new articulated light-rail vehicles, designed to serve the needs of both San Francisco and Boston, are described. In order to provide facilities for storage and maintenance of these vehicles, a new rail center is being constructed. The design of this facility was a particular challenge because of constraints imposed by the small size of the urban site used. Virtually all surface tracks in the city are being replaced. Muni had hoped to develop special transit rights-of-way in conjunction with the rerailing projects but encountered a political snag in the process. The power supply system that provides Muni's electrical power is unique, and the facilities it uses are also being upgraded. Finally, several route extensions contemplated by Muni are described. The new Muni Metro system is scheduled to be in full operation in late 1979.

San Francisco has always been oriented to mass transportation. Before World War II the entire city was covered by a network of streetcar lines. As in many other cities in the late 1940s and early 1950s, many of the streetcar lines were converted to diesel bus or electric trolley coach. However, a basic rail network was retained for those lines that were heavily patronized. Most of these lines served the predominantly residential areas in the western half of the city and transported riders to the commercial and financial districts, which are located in the northeastern section.

Between 1946 and 1952, the San Francisco Municipal Railway (Muni) acquired 105 Presidents' Conference Committee (PCC) streetcars (cars first produced in 1935 that had performance characteristics far superior to all previous models). These were used on the five streetcar lines that originate in the residential districts and then come together on Market Street, the main artery of the downtown business district. The downtown area of the city is the main destination of most of the Muni riders on the average weekday. These five lines, shown in Figure 1, carry an average of 96 000 riders/d.

A significant event occurred during the 1950s that was to have a substantial impact on Muni in the later years. This was the investigation of the feasibility of a rapid transit network for the San Francisco Bay Area. What finally evolved was the system that we know today as the Bay Area Rapid Transit (BART) System. During BART's study phase it was recognized that the BART system would serve primarily as a commuter rail system and would serve only one transit corridor in San Francisco. A second subway route was shown as a future rapid transit line following the streetcars' existing main trunk line along Market Street and through the Twin Peaks Tunnel. The report stated that this route would initially be used by the Muni streetcars.

In 1962, the voters of San Francisco, Alameda, and Contra Costa counties (both sides of San Francisco Bay) approved the BART bond issue; San Francisco provided the largest affirmative vote. The bond issue provided for the construction of a two-level subway under Market Street in which Muni would occupy the upper level and BART the lower level. Two proposed arrangements are shown in Figure 2. The Muni level begins at the foot of Market Street and proceeds westward through four joint stations. Beyond the Civic Center Station, the BART subway departs from the Market Street alignment and continues southward to its terminal across the county line in Daly City.

The Muni subway continues under Market Street to the first Muni-only station, Van Ness Avenue. Beyond the Van Ness Avenue Station there is a critical point for the subway. This is the Duboce Portal where the cars on two lines, the J and N lines, emerge from the subway and then follow their surface trackage (see Figure 1). The Duboce Portal is arranged as a grade-separated junction with the inbound Duboce track passing under the outbound Market track and merging with the inbound Market track. This was possible because it is the highest elevation on the Market Street subway.

Next are the Church Street and Castro Street stations. The Castro Street Station is unique in that it is constructed on a slight curve and connects directly to the Twin Peaks Tunnel, which was constructed by Muni in 1917. The tunnel is a horseshoe-shaped double-track facility. It is of particular interest that, when the tunnel was being designed in 1914, it was anticipated that there might be a subway under Market Street at a future date. The tunnel grade was set so that, in the last 305 m (1000 ft) of the tunnel, the track rose on a ramp to the surface. It was a simple matter, 60 years later, to match the tunnel grade to the subway grade.

The final 3.6 km (2.25 miles) of the underground portion of the Muni Metro will be in the Twin Peaks Tunnel. In essence, three lines (the K, L, and M) will run underground for a distance of approximately 9.6 km (6 miles). These three lines will emerge from the tunnel at the West Portal Station and then continue on their individual routes over surface trackage.

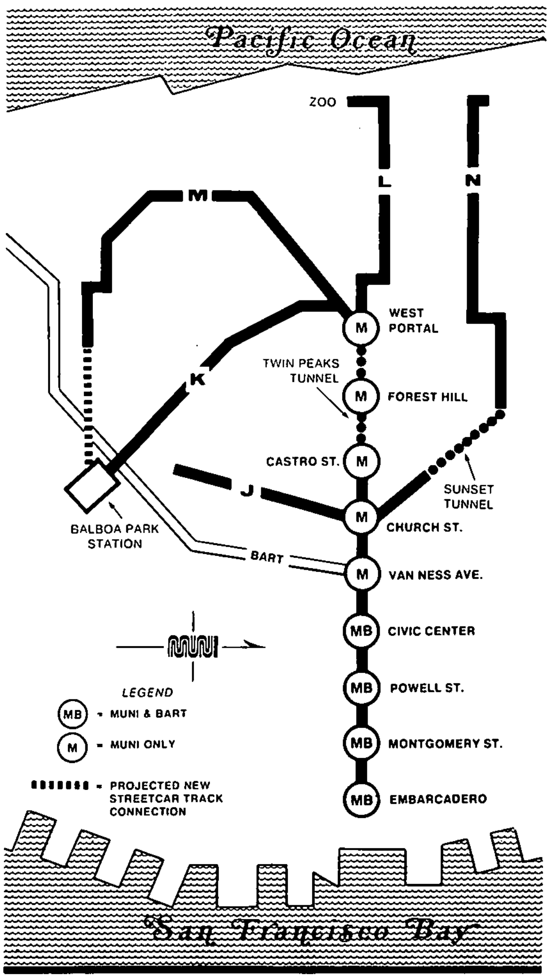
In the underground portion of the Muni Metro, the cars will operate through three different sections. From Embarcadero to Van Ness, two bored tunnels are used. From Van Ness to Castro, a reinforced concrete double-box section, constructed by the cut-and-cover method, is used. The final section is the Twin Peaks Tunnel, which is a twin-track horseshoe-shaped facility.

All sections of the subway under Market Street were constructed for Muni by BART. The stations and the tubes are constructed to BART dimensions and are capable of handling BART rolling stock. A total of eight stations will have been constructed by BART. A ninth station, Forest Hill, was constructed in 1917 when the Twin Peaks Tunnel was completed. This antiquated station will be completely replaced by Muni under a grant from the Urban Mass Transportation Administration (UMTA).

Muni and BART have executed a maintenance agreement that establishes their respective responsibilities and costs. Essentially, Muni and BART will each be responsible for their respective levels and areas of the subway and will share costs in such jointly used areas as the free areas of the mezzanines and the escalators from street level.

BART provided a complete subway, including trackage and architecturally finished stations. Muni's responsibility was to install all systems to make the subway operational. This responsibility included electrification, the subway signal control system (100 Hz), fare collection, an antenna system for communications, a public address system in stations, closed-circuit television for surveillance, and centralized train control.

Figure 1. The five lines of San Francisco Muni.



MUNI METRO CARS

The light-rail vehicle (LRV) that will replace Muni's PCC streetcars has been specifically designed to suit the unique conditions of the San Francisco terrain while using modern technological developments in transit equipment. The Philadelphia firm of Louis T. Klauder and Associates was retained by Muni to develop the specifications for a vehicle that would replace the PCC cars on all surface lines and also operate in the BART-constructed Muni subway. To get maximum use of the new subway and its nine subway stations, Klauder recommended that the vehicle be equipped with special doors and high-low steps to allow platform entry and exit in the subway as well as street-level entry and exit in city streets.

UMTA, which funded the joint purchase of vehicles for Boston and San Francisco, stipulated that the LRV should be standardized to the maximum extent possible. The length and width of the vehicle were limited by Boston subway clearances to 21.6 m (71 ft) and 2.64 m (8.67 ft) respectively. Sharp 12.8-m (42-ft) radius curves necessitated an articulated vehicle with three trucks. The articulation also made possible a longer vehicle that could carry more passengers per operator than the PCC cars. The salary of the operator is a significant portion of the cost of transit per passenger kilometer.

Prior to 1972, the UMTA Office of Research, Development, and Demonstration had sponsored a number of demonstration programs to advance rail technology and apply the advances from other fields to transit vehicles. However, there appeared to be small likelihood that these advances would be applied to production vehicles because of the reluctance of transit operators to purchase new and largely untried systems at costs that would not be competitive with the proven systems that formed the basis of most vehicle purchases.

The design of an advanced soild-state propulsion control system was one of a number of advances that had been underwritten by UMTA. The UMTA state-of-the-art car was equipped with such a control, called a chopper, and was demonstrated on a tour of major rapid transit systems in the United States.

In order to introduce a chopper control into the fleet of an operating transit system without undue financial burden on the system, UMTA established certain ground rules for the bidding on the 230-car order for Boston (150 cars) and San Francisco (80 cars); the order was later increased to 175 cars for Boston and 100 for San Francisco. There were to be two propulsion control options—a conventional cam control and an electronic chopper control. Also, if the total bid for vehicles with electronic chopper control was less than $71 million, the award would be made on the basis of that system regardless of the bid for vehicles with a cam control. Since the Boeing Vertol bid for vehicles with an electronic chopper control was $67 million, the award was based on a vehicle with a chopper control.

The chopper was designed to operate over a variable frequency range from zero (no motion) to 400 Hz at about 27 km/h (17 mph). At speeds above 27 km/h, the current is not chopped. It was discovered during testing that as the chopper swept through 100 Hz it caused electrical interference with the 100-Hz cab-signal control system. After a number of schemes had failed to completely eliminate potential interference, it was decided that the chopper's range would have to be altered so that it did not operate at frequencies below 150 Hz.

The manufacturer of the propulsion system, Garrett Corporation, developed and evaluated eight designs and finally settled on a field-weakening concept that allowed the entire redesign to be concentrated on one circuit card.

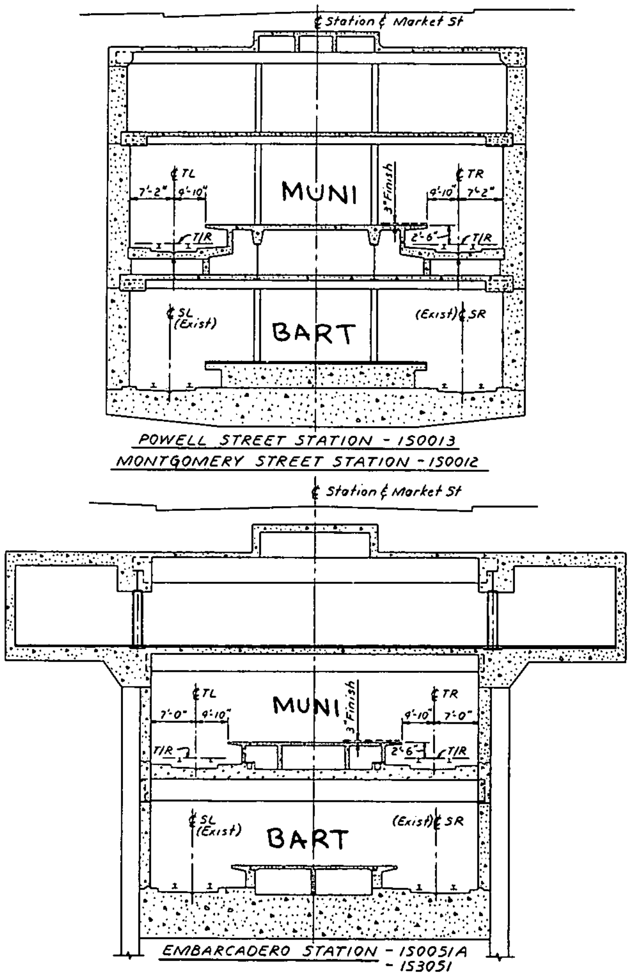
The vehicle developed, known as the U.S. standard light-rail vehicle, is a completely new vehicle and represents an enormous advance over the PCC car, which was the standard for the last 40 or so years. During the severe winter of 1976, the LRVs demonstrated a cold-weather capability superior to that of the PCC cars. In sub-zero weather the Boston riders enjoyed car interiors that maintained an even temperature of 21°C (70°F). Resilient wheels and an air suspension system provided a vastly superior ride.

In addition to the extensive tests on the Boeing Vertol test track starting in fall 1974, the vehicle was tested for 11 weeks in Boston in 1975. In fall 1975, three vehicles were sent to the U.S. Department of Transportation test track in Pueblo, Colorado. Over a period of about 6 months, the vehicles were tested singly and in two-car trains. Subsequently, other vehicles were tested in Boston in simulated revenue service.

The San Francisco LRVs will have 68 seats. To expedite turnaround at terminals, the six side and front destination signs will be automatically controlled from the operator's console.

San Francisco has five transit lines. Three lines converge, enter Twin Peaks Tunnel at its West Portal, and continue underground to the downtown terminal at Embarcadero Station. The other two lines converge and enter the subway at its approximate midpoint. LRVs that operate as single units on city streets will couple as

Figure 2. Station cross sections for the two-level subway.



they enter the subway. Two- and three-car trains will uncouple as they leave the subway and return to street service. Four-car train operation is possible. The specifications for the LRV call for it to have the capability of automatic coupling and uncoupling with a full load of passengers. Coupling and uncoupling are entirely controlled by the operator of the following vehicle. Coupling is used during peak hours to maximize the subway's available capacity. Single-unit operation would reduce capacity because of the distance the signal system blocks require between units.

When units are coupled, the operator of the lead car operates the whole train. All functions are operated from the lead car except the doors. The cab consoles on the following cars are locked out of service. Each operator operates the doors on his or her car. A light on the lead car's console signals when the doors on all cars in the train are closed. The coupling procedure at the portals will require precision operation in respect to schedules. Interference by automotive traffic or other sources during surface operation could have a substantial impact on schedules.

The San Francisco LRVs will accelerate at 1.34 m/s^2 (3 mph/s) to base speed with a 100-passenger load. The 157-kW (210-hp) monomotors on the end trucks are independently force ventilated. Braking is normally accomplished by a blend of dynamic and friction brakes, but disc brakes are capable of providing full-service braking. In addition, track brakes are capable of providing emergency braking in case of a prime power failure.

Power is collected at the trolley wire by means of a pantograph that uses contacts designed to negotiate the gaps in the wire at trolleybus crossings.

The vehicles' radios are equipped for the transmission of digital data, such as the vehicle's serial number, in addition to normal voice transmission.

SURFACE SYSTEM

All surface trackage—approximately 32 route km (20 route miles) of double track—is being replaced, including that in the Twin Peaks Tunnel. This trackage has an average age of 50 years. Rerailing consists of replacing the rails, ties, accessories, and ballast. If the tracks are in city streets, the street is also being repaved (this affects most of the routes). In some locations, open trackage is located on private right-of-way or in the median strips of wide boulevards.

It is very difficult to maintain streetcar service while the tracks are being rerailed. It is accomplished by using portable crossovers and single tracking in both directions over a stretch of track while work is proceeding on the adjacent track. The single-tracking length varies, but it usually is kept under 300 m (1000 ft) in order not to affect service. A temporary signal system is arranged to control movements. It is operated manually during construction hours and automatically at all other hours.

In order to reduce the impact of excavation on the neighborhood, we have under way a program in cooperation with the Department of Public Works (DPW) whereby any sewer work that needs to be done is included in the rerailing contract. The DPW has also been very cooperative in work on projects that aid transit, such as installation of preempting signals, lane markings, narrowing of sidewalks, and expediting permits for street work.

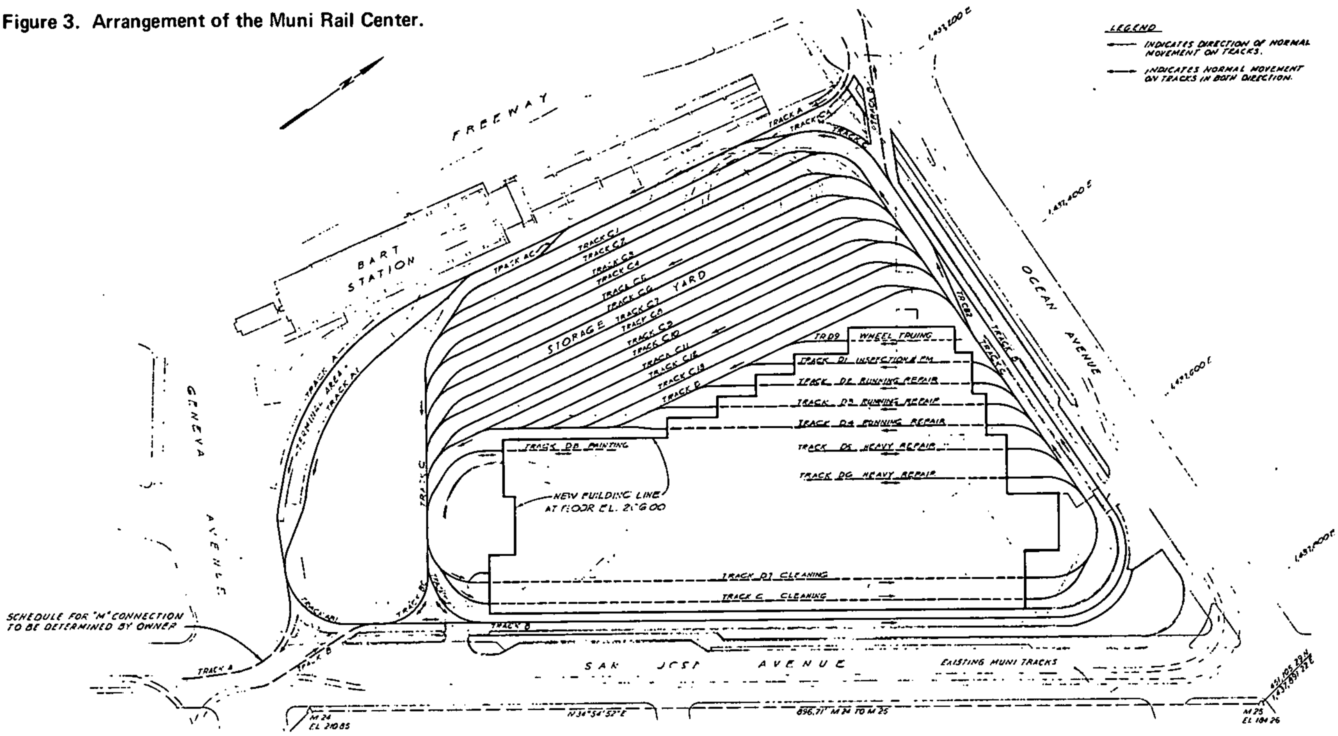
Where the tracks are located in the center of the street, the streetcars operate in mixed traffic. In order to enhance the operating environment for the new LRVs, which will require precision timing to remain on schedule for subway operation, we developed a right-of-way treatment for these locations. The tracks were raised 7.5 cm (3 in) above the adjoining traffic lanes. Contrasting exposed aggregate pavement was placed in the track area to define the transit right-of-way, and it was given a sloping edge. Legislative action was undertaken by the Board of Supervisors (equivalent to a city council) to amend the local traffic code to prohibit other vehicles from driving on a raised streetcar right-of-way except in an emergency or to pass a double-parked or disabled vehicle.

Our original plan was to use this right-of-way treatment wherever feasible on the surface routes. The first installation covered 10 blocks on the N Line. After completion of the first project, considerable controversy arose, both from the neighborhoods and from the drivers of other vehicles. Claims of interference with established traffic patterns and with ability to enter and leave driveways were voiced. The Board of Supervisors, while it acknowledged the transit benefits, yielded to political pressure from neighborhood groups and refused to permit Muni to continue this right-of-way treatment on the N Line or any other line.

Many transit planners have strongly advocated this treatment and, where wider streets than those in San Francisco are available, there is great merit in pursuing this idea. It is common practice in Europe. Unfortunately, the narrowness of most San Francisco streets makes it difficult to implement here.

Vehicles that are waiting on tracks to make left turns often cause delays. These delays accumulate as the car travels from its outer terminals toward the subway. In

Figure 3. Arrangement of the Muni Rail Center.



order to minimize interference by automotive vehicles with Muni Metro operations, the Board of Supervisors enacted no-left-turn legislation.

STORAGE AND MAINTENANCE

The new Muni Metro Rail Center is now under construction. This will be the storage and maintenance facility for the 100 new LRVs. It is located across the street from the Geneva Car Barn (constructed in 1902), where the fleet of PCC streetcars is stored. This location was selected because all trackage to the location had previously been installed.

Land in San Francisco is extremely precious; almost 700 000 people are squeezed into less than 117 km^2 (45 miles^2). There was no site that would meet all the requirements of the LRV fleet. It was therefore decided to use the 2.6-hm^2 (6.5-acre) parcel on which an existing bus division and old streetcar repair shops were located.

It was necessary to provide maintenance and storage facilities for 100 LRVs, a terminal for two lines adjacent to the BART Balboa Park Station, and a future Muni office building on this 2.6-hm^2 parcel. The task was assigned to the International Engineering Company of San Francisco, which worked in association with the architectural firm of Hellmuth, Obata, and Kassabaum. Various arrangements were studied; the solution finally approved is shown in Figure 3. One key feature of the arrangement is that it provides for movement predominantly in one direction, counterclockwise. Only two movements, exiting from the heavy repair area and exiting from the paint shop, require backing up.

A revenue-service loop completely encircles the site. The K and M lines will both terminate at a platform adjacent to the BART station. When BART was designing this station, Muni requested an access point for direct transfer. This was provided in the form of an opening in the station wall that is closed by a sliding grille. This transfer arrangement will be very beneficial to the 20 000 students at San Francisco State University, which is predominantly a commuter campus. Students from throughout the BART service area in the three counties on both sides of San Francisco Bay can travel on BART to this station and transfer to Muni. (Patrons who use Muni lines that feed the BART stations receive a 50 percent fare discount.) The M Line passes directly by the eastern edge of the campus. Another large traffic generator for Muni on the M Line will be the huge Parkmerced apartment complex that is immediately south of the campus.

The cars entering or leaving revenue service do so from the revenue-service loop. Cars of the J, L, or N lines pull out of the storage tracks, travel onto the service loop, enter Ocean Avenue, and then proceed to their terminals. Cars of the K and M lines continue around the loop to the terminal adjacent to the BART station, where they stand ready for revenue service. Cars returning from service pull in on the revenue loop and then are turned out to the ladder track.

After entering the rail center, cars proceed to one of the two service lines inside the building where there are stations for fare removal, sanding, washing, and cleaning. There is a car wash on only one service track since it is proposed that cars will be washed on alternate days. After they have been serviced, the cars emerge from the service line and either proceed to one of the running repair tracks or move onto the storage tracks.

There are four running repair tracks and associated pits and maintenance equipment. Diagnostic equipment and operations simulation test gear are used on these tracks. The last bay in the building contains the wheel-trueing machine; it can also be used as pit space. The heavy maintenance repair facilities consist of two tracks capable of handling four cars. Two cars are handled over pits and two car positions permit the raising of the car, by means of hydraulic jacking systems at lifting points, for truck removal. Truck repair areas are adjacent to this location. In addition, a truck drop table is provided on one of the running repair pits for unit replacement.

A complete machine shop for mechanical and electrical work is provided, as are a completely equipped electronic shop and paint shop, which is close by the body repair shop in order to give the crews in these two operations the necessary close liaison. The storage yard consists of 14 parallel tracks and is to be paved throughout. An extensive drainage system is included. The electrical overhead system is supported by steel poles.

One unique feature is that the yard was laid out in such a way that, when a market develops for the use of air rights, this will be feasible. The tracks were laid out in pairs, which will permit the installation of column footings for whatever structure might be built above. This would be an excellent source of revenue for Muni, and the structure would provide a "free" roof over the yard.

POWER SUPPLY

Of course, in order to operate the new Muni Metro there must be an adequate power-supply system. Because of San Francisco's commitment to electrical propulsion, an extensive electrical supply system exists, although it is ancient. The existing distribution and trolley overhead system is a combination of the original Muni system and that inherited from a private company that also operated in San Francisco and was acquired in 1944; most of the system was old then.

San Francisco made the decision to use electrical propulsion methods for many of its transit vehicles for two main reasons. One was the availability of low-cost hydroelectric energy from the Hetch Hetchy Water and Power System, a city agency under the jurisdiction of the city's Public Utilities Commission. Hetch Hetchy's Transit Power Division is responsible for supplying electrical energy to Muni's electrical vehicles.

The Hetch Hetchy project is located just north of Yosemite National Park in the Sierra Nevada Mountains and is the main source of water supply for San Francisco and many cities in the south Bay Area. Hydroelectric power facilities were developed in conjunction with the water supply system. There are three powerhouses with a total generating capacity of 300 MW. In a normal year, only 30 percent of the output of these plants is used for all of San Francisco's municipal needs, including Muni. Under these circumstances, Muni has an assured, low-cost supply of power. Hetch Hetchy supplies electrical energy to Muni at rates 45 percent lower than those charged by the local investor-owned utility that serves San Francisco.

The second reason for the commitment to electrical propulsion was that it is a quiet and pollution-free method. Furthermore, all the energy used is hydroelectric and aids in conserving our nation's resources. Muni operates 345 electric trolley coaches in addition to the streetcars, which will be replaced by LRVs.

The entire electrical distribution system and its network of substations is being replaced. All feeder cables are being placed underground, and the substations are being changed from old rotary converters to modern solid-state rectifier units to supply the required 600-V direct current. The number of substations is being increased from 19 to 25. It is to be noted that the distribution network supplies power to Muni and the many electric trolley coach lines.

All the electrical system improvements are being provided under a $50 million program, the major portion of which is covered by an UMTA grant. The program includes, in addition to those elements previously described, the electrification of the new subway. This consists of the installation of substation equipment, feeder cables, and trolley-wire overhead.

The entire trolley-wire overhead for surface operations is being converted to permit use of both the pantograph of the LRV and the trolley shoe of the present streetcars. This is necessary because there will be a period during which a mix of PCC streetcars and LRVs will be operating. We plan to convert one line at a time after the delivery of the LRVs has begun. Full Muni Metro service will be in operation after the conversion of the five lines.

PROPOSED EXTENSIONS

There are several planned extensions to the Muni Metro system. One is the extension of the M Line from its present terminal at Plymouth and Broad streets 1.44 km (0.9 mile) to the Muni terminal at the BART Balboa Park Station. As noted above, this would permit cars of the M Line to enter revenue service at the new terminal after leaving the rail center. Another extension is that of the K Line from its present terminal at the Phelan Loop to the same Muni terminal at the BART Balboa Park Station. Cars of the K Line will then also be able to enter revenue service immediately after leaving the rail center.

Under the current arrangement, all cars of the N and J lines must follow long deadhead routes from the storage facility to their terminals. N cars, especially, travel a long distance before beginning revenue service. When the Muni Metro service commences, these cars will have to travel all the way to the Embarcadero Station and then proceed to their outer terminals to begin revenue service. It is therefore proposed to construct a 3.4-km (2.1-mile) surface track connection from the rail center to the present J-Line terminal at 30th and Church streets. The new trackage would become an extension of the J Line and be used for revenue service. J-Line cars would then also be able to immediately enter revenue service. N-Line cars would use the new trackage and the J-Line tracks to proceed to their outer terminal. This would be a considerably shorter run than the long, circuitous route described previously.

The new trackage would provide total system flexibility since all routes would be interconnected. An ancillary benefit of this surface track connection would be its availability as an alternate route in the event of some catastrophe (such as a cave-in) in the 60-year-old Twin Peaks Tunnel. At present, loss of this tunnel would put all lines out of service. The proposed track connection would permit some operation of a truncated system.

The final extension proposed is short but very important. It would extend the Muni-level tracks east of the Embarcadero station to a loop track at the end of Market Street. At the present, Muni will use a double crossover west of the Embarcadero Station, a stub terminal arrangement. Muni asked for a turnaround, but BART stated that it could only afford the crossover. The new facility would be entirely underground.

The minimum headway possible with the double crossover is 2½ min during the peak hours. In order to reach the maximum subway capacity, a minimum headway of 1½ min must be achieved. After the loop-track facility has been completed, the double crossover will be available on standby for emergency use in the event that the loop track should become inoperative.

GENERAL

There were several key decisions that contributed immeasurably to the success of our program, including the purchase of common items that would be needed throughout the program. We were able to take advantage of the savings entailed in quantity purchases and eliminated delays in procurement by contractors working on the various construction and installation contracts. Bids were solicited for the following items, which were then stored in city facilities and provided to contractors as city-furnished materials or equipment:

1. Girder and tee rails and accessories—3.6 Gg (8000 tons),
2. Timber ties—57 000,
3. Feeder cables—427 km (1 400 000 ft), and
4. Rectifier units for 25 substations.

The first LRVs for Muni are currently scheduled to be delivered to San Francisco beginning in June 1978 at a delivery rate of approximately 10 units/month. Muni Metro service will be inaugurated in late 1978 and complete service is anticipated by summer 1979.

Edmonton's Northeast Light-Rail Rapid Transit Line

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Edmonton's light-rail transit (LRT) line has a total length of 7.2 km, 1.6 km of which is in subway. The line goes from the central business district (CBD) to the northeast sector of the city and uses the Canadian National Railways right-of-way. The project was approved at $65 million and is currently below estimates as well as ahead of schedule. The LRT line is the result of a balanced transportation plan that was finally adopted in 1974 to serve a city of nearly 500 000. The subway portion has two underground stations with full mezzanine floors. The mezzanine floors are part of an overall pedestrian system and connect with the basements of adjacent buildings. The subway was built to accommodate the largest standard subway car. The equipment specifications for the 14 articulated cars were based on performance and proven reliability. The construction methods used caused a minimum of interference in the CBD. Since relatively small portions were let successively, local contractors were able to use proven techniques to handle the work on a fixed-price basis. Despite the severe inflation of 1975 and 1976, costs were kept within reasonable limits. The proposed service will provide 5-min headways in the peak hour, giving a capacity of 5000 passengers/h. At midday the headway will be 10 min. The LRT line will be fully integrated with the bus transit system, and timed transfers will be provided between bus and rail. The LRT line in Edmonton makes use of available opportunities and provides the least expensive solution to the transportation problems of the northeast sector and its rapid residential development.

In September 1974 the city of Edmonton turned the first sod on a 7.2-km light-rail transit (LRT) line to serve the northeast sector of the city; inauguration of the service was scheduled for spring 1978. Extensions to this line and the construction of other lines are in the planning stages.

The LRT line under construction consists of a 1.6-km length of subway in the central business district (CBD) that has two underground stations and a 5.6-km surface section, which is contained within a Canadian National Railways (CNR) right-of-way, that has three surface stations. The line will use 14 articulated cars and will provide a peak single-direction capacity of 5000 passengers/h. The LRT line will be fully integrated with the Edmonton Transit surface bus system, which currently operates 590 buses that carry 57.1 million passengers annually, using the timed-transfer concept. The capital cost of this project is estimated at $65 million; at the present time approximately 99 percent of this project has been contracted, committed, or completed.

PLANNING

Edmonton has grown rapidly since World War II from a population of 160 000 in 1951 to 451 000 in 1976. The CBD has seen intensive high-rise development, while at the same time extensive residential development has occurred on the periphery. Older developed communities throughout the city are normally well maintained or redeveloped by private enterprise. City planning has a very active role in Edmonton and is constantly involved in forecasting studies, preparation and assessment of plans (at district and subdivision levels), and administration of zoning and development controls. The city's departmental organization provides that all municipal functions, such as engineering, utilities (the city owns its own electricity, telephone, and water utilities), traffic, and parks, work closely with the City Planning Department.

These developments in Edmonton have had a major impact on the transportation facilities and systems. Several major transportation studies have been conducted since 1960 and have recommended solutions ranging from a freeway network to a full rail rapid transit system, but these plans could not be implemented because of a lack of funds and difficulties in establishing rights-of-way. These studies and the general situation were reviewed in 1968, and a revised, more balanced approach was recommended that put greater emphasis on developing the arterial roadway system and improving the transit system to handle more of the peak loadings. Certain LRT routes were recommended for detailed investigation in corridors where there appeared to be available separate rights-of-way.

As a consequence of this review and subsequent public hearings in November 1972, a general transportation plan was finally adopted by the City Council on July 15, 1974. In the analysis of solutions for the transportation problems of the northeast sector, several alternatives were considered. Because it is limited by the river and the railway line, the existing road network was operating at capacity in the morning and evening peak hours. While the situation existing in 1974 was just tolerable, the new areas being developed in the northeast would overload the roadway system. The options considered were therefore the following.

1. A northeast freeway option: The transit compo-