number of cars it needed to carry its passengers. When he gave the train its assigned destination the TLC would communicate with the crew dispatcher at Montgomery the consist of each approaching train. (It takes about 4 minutes for a train to move from Van Ness to Montgomery.) During this time the crew dispatcher would assign the crew for the train and the operator(s) would move out of the waiting room and move to the platform at Montgomery to meet the train.

Gaining control of both trunks at Van Ness has proved successful in a number of ways. Service is spread consistently to both trunks, thereby reducing the waiting time for most passengers. By improving the consistency of service, passenger complaints have been significantly reduced.

By working with all the cars, they are distributed in a regular fashion, and so the TLCs on the surface are provided with a more regular outbound flow of LRVs. This allows them to provide the 6-minute headway with a minimum number of switchbacks.

Finally, this system has reduced any large gaps on a particular line caused by a lengthy delay by spreading the available cars among the five lines. When the delay is cleared, the cars trapped behind it are redistributed to lines that may have received a reduced number of cars.

However, no system is without its problems. Although space does not allow an in-depth discussion, following are some of the problems Muni is working to solve:

- Developing new operator dispatching procedures, including deployment of adequate fallback relief, making reliefs, tracking operator trips, and identifying operators and cars.
- Managing changeover from headways to night schedules after 10 p.m.
- Stacking of outbound trains caused by breaking up large trains at Embarcadero to keep proper sequence.
- Proper distribution to lines when the Van Ness trainmaster has too few cars.

Even with these problems, it appears that the dynamic schedule will remain at Metro since it works to help Metro meet its ever-increasing demand.

REFERENCES

1. Peter Straus. Muni Metro: Issues and Strategies. Issue Paper No. 1, 1977.

2. Jack Fritscher (Ed.). Muni Metro Master Plan: System Description, 1979.

3. San Francisco Municipal Railway 5-Year Plan, 1980-85, April 1980.

Base Specifications for Major Subsystems on the San Diego Light Rail Transit Project

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This paper provides information on the development of the base specifications for four major subsystems on the San Diego light rail transit project. These subsystems include transit vehicles, traction power, and signal and fare collection equipment. The plans and specifications were prepared from the operations plan and project design criteria.

On the San Diego LRT project, the plans and specifications of four major subsystems were prepared from the project criteria and were based on the features indicated in the operations plan. These features included a specified circuit time (roundtrip including both turnaround times), provisions for joint operation with freight trains, minimization of operating and maintenance staff requirements, a specific track plan, an indicated fleet size, absolute block limits, and a derivation of installed traction power capacity. The plans and specifications were developed with the philosophy of simplicity, use of proven equipment, and minimization of custom design; however, essential requirements were specified. Where such requirements were not mandatory and supplier or contractor ingenuity could contribute, the plans and specifications were open.

TRANSIT VEHICLE

The specifications of the transit vehicle may be considered in four parts. First, the vehicle had to have certain features and capabilities; second, the order would be for the fleet size; third, to minimize or avoid unexpected operating costs and difficulties, the vehicle design had to provide for maintainability; and fourth, provisions were made for elderly and handicapped (E&H) passenger access.

With regard to the vehicle features and capabilities, suppliers were required to supply their standard production vehicle, which would have to satisfy the following objectives:

1. The vehicle must meet the requirements of the California Public Utilities Commission General Order 143[1], which deals comprehensively with LRT operations and includes a subsection on vehicle design. It provides minimum requirements for safety equipment, including brake control, door controls, and warning lights, and requires structural integrity for protection in the event of collision.
2. Performance was specified in terms of a 75-minute circuit time. Plan and profile data were given to prospective suppliers to determine computerized velocity-distance-time profiles. To qualify, suppliers were required to submit the data along with their computed energy consumption projections.
3. Peak-hour patronage at the maximum load point required a 15-minute headway to service 1500 passengers per hour. The Metropolitan Transit Development Board (MTDB) looked for a practical standee space, and, as a result, the standing load was generally considered as 2 passengers for each seated at the time. Two-car trains were expected to handle this load. It may be noted that actual San Diego experience indicates that a maximum practical load is 150 seated and standing passengers per car.

4. The question of air conditioning was studied quite extensively before deciding on natural ventilation for these cars, which would run in the San Diego coastal area. Suppliers were asked to describe how air conditioning would be provided and what its estimated energy consumption would be. The study indicated high costs in capital investment, maintenance, and energy consumption, all of which would result in an increase in the life-cycle cost of the system, with negligible benefits to the passengers, if the cars were equipped with air conditioning. Consequently, the traction power subsystem was not sized for air-conditioned cars.

5. The cars were required to be able to operate in multiple units. While initial operation required 2-car trains, system expansion contemplated 4-car trains. Trainlining was required for door operation, passenger signal, internal and external public address, propulsion and brake control, marker lights, and other train functions. A later requirement included trainlining the ticket canceler control (station setting and inspection freeze), but this was eliminated when on-board cancellation was removed from further consideration. The specifications required trainlining by contacts in a button head integral with self-centering couplers.

6. Because of the joint operation with the San Diego & Arizona Eastern (SD&AE) Railway traffic, all special trackwork and embedded track had to accommodate railroad cars and locomotives used in interchange service. Thus the vehicle specifications required the supplier to equip the vehicles with standard railroad wheel tread and flange. The specifications also required a resilient wheel-hub design to mitigate noise.

7. The specifications expressly required double-ended vehicles with doors and stairwells suitable for street-level loading at all stations.

8. The specifications were prepared early in December 1978. They required vehicle delivery beginning in Autumn 1980, i.e., a period of 18 to 24 months.

9. To avoid operating and maintenance problems, the supplier was required to substantiate proven experience in his proposed offer with regard to propulsion equipment, brakes, and doors.

10. The initial specifications required a 60-ft minimum turning radius. Later, the basis of the 60-ft limit was removed and a longer radius (82 ft) was permitted.

With regard to the fleet size, the operating plan indicated a circulation time of 75 minutes. In 15-minute headway service, this results in five 2-car trains. Thus, at maximum capacity, 10 cars are in the base or circulating fleet. In addition to this minimum base fleet, the operations plan required one 2-car train on standby and one 2-car train in scheduled maintenance, resulting in 14 vehicles.

With regard to maintainability, there were some practical difficulties in the specifications. A well-recognized and correct way to specify maintainability is to specify availability, which is a function of reliability and maintainability. The usefulness of this approach depends on the accumulation and proper monitoring of maintenance and reliability data during revenue service. The lack of such statistics made the monitoring question moot. For this small fleet, and the reliance on standard design, this approach could not be considered appropriate. It was realized that the significance of standard equipment means that the equipment is in satisfactory use somewhere. This leads to the specifications requiring the supplier to furnish an operator's certification that the design of the equipment offered has operated for 50 car-years with an operational availability of 90 percent based on a labor distribution of 0.1 man-hour or less per vehicle mile of revenue operation.

With regard to the provisions for E&H passenger access, MTDB had been working with a community committee representing E&H interests. As a result of its work, a number of features for E&H access that affected the vehicle were examined. The one feature new to LRT was a chair lift. One installed lift was specified per vehicle. With no definitive answer, the basic project criteria relating to standard design was violated in the special interest of the E&H community.

TRACTION POWER SUBSYSTEM

The traction power subsystem includes all equipment and materials, from points of receiving power from the local utility company to points of utilizing that power by light rail vehicles. In general, the subsystem includes traction power substations, catenary, and feeders.

The preparation of specifications depended on four principal items: (a) the LRT system operating strategy; (b) the type of light rail vehicles selected, particularly the vehicle propulsion requirements; (c) the local power company's requirements; and (d) track plan and profile. After establishing these items, the design criteria were used to prepare the basic traction power subsystem specifications. For the substations, the following key criteria were applied:

1. The traction power subsystem must be designed to provide normal operating performance when all substations are operating on-line. This means it must allow (a) trains to operate at 15-minute headways, (b) two 2-car trains to accelerate simultaneously under full performance at any passenger station in the double-track section, and (c) one 2-car train to accelerate under full performance at any location on the single-track sections. The traction power subsystem must withstand the loss of any one adjacent substation without interruption of transit service. Under this condition, a train in the vicinity of the off-line substation should be able to accelerate with its traction motors in series connection if normal performance is not possible.

2. The incoming primary feeder from the local power company to each traction power substation must be limited to a single circuit. This approach simplifies the substation design and thus reduces its cost. A reduction in utility service charges was obtained by requiring that the incoming primary feeder be a non-dedicated line. However, the same primary feed may not service two adjacent substations because the transit system must retain operating capability if any one substation goes off-line.

3. The design of the traction power subsystem must minimize and mitigate the effects of stray currents.

4. The traction power subsystem must be entirely self-protecting and self-supervised, with no remote controls. External trouble annunciation is provided by an outside dome light visible to the train operator at each substation.

5. The substations must be designed to use proven equipment. Each substation must be transportable so that it can be readily relocated, if required. The substations must be factory-tested and when delivered must be ready for connection to the utility interface points.

The next design task was to size and locate substations by use of a series of computer programs. Prior to the computer analysis, a study was made to determine the materials for the catenary conductors for contact and messenger. Because the LRT line is in a sea air environment and also in one that is subject to industrial chemical pollution, the use of any material subject to corrosion was eliminated. Thus the choice for the messenger was reduced to hard-drawn copper. Because the messenger is the principal feeder circuit, the use of copper favors wider substation spacing. However, there is a limitation on how far the substations can be spaced because their spacing has significant effects on negative voltage rise in the track and overhead conductor temperature rise.

Setting economics aside, the best choice for the contact wire appeared to be bronze because (a) it has a greater life duration than that of hard-drawn copper and (b) it has a more definite yield point than copper and thus

mitigates the problem of creep or stretch. But the cost of bronze contact wire is about three times that of hard-drawn copper. Because the temperature range in San Diego is not too great and the amount of contact wire wear is not a real problem in LRT service, the specifications permitted the use of hard-drawn copper contact wire.

The candidate vehicles had an operating voltage range from 420 volts to 720 volts DC. As a result, 650 volts were selected as the 100 percent full-load voltage for the traction power subsystem, as opposed to 600 volts on other systems of this type. Such a selection was of a significant advantage because it allowed a higher line voltage drop, which allows substation spacing further apart than the usual 600-volt rating. To minimize voltage drop and the effect of conductor over-temperature, the overhead conductors for both directions in double-track sections were cross-connected.

One of the most important inputs to the specifications as a result of the computer analysis was the substation duty cycle indicated in Figure 1. The inclusion of this load cycle in the specifications was very important to ensure that the substations, particularly the transformer-rectifier units, would be properly sized for the intended operation in San Diego. The load cycle normally used for substations is not directly applicable to the San Diego LRT operation because it is based on a predictable overload that the system may experience at predictable times and locations. For the San Diego case, the base and peak periods are the same, and it lasts 12 hours every day. However, because the San Diego system is on a non-exclusive right-of-way, irregular stops are frequently necessary, and thus the locations for train acceleration are not preset as one might desire. Consequently, the design of equipment conforming to this special load cycle and that normally used for transit substations would ensure that the substations would operate satisfactorily.

Several features were incorporated in the design of the traction power subsystem to mitigate stray currents. Some of these features, which are generally accepted in the industry in North America, are (a) an ungrounded DC system, (b) relatively short distances between substations, and (c) the use of negative drainage equipment.

The catenary or overhead subsystem that supplies power to light rail vehicles consists of two distinct designs. The first is a single overhead suspension (Figure 2) where the contact wire is suspended by cross-span wires. Because of the relatively low conductance and amperage of the contact wires, underground feeders were installed parallel to the trackway. This design is utilized in Centre City.

The second type of design consists of a catenary subsystem where a contact wire is suspended from two messenger wires (Figure 3). The tension of the contact wire and messenger wires is maintained constant over a wide temperature range through use of a balance weight system. This latter design is applied along the SD&AE mainline. The base specifications included the following provisions:

1. In Centre City, the catenary subsystem was required to harmonize with the extensive urban design work that had recently been completed on C Street. Consequently, parallel feeders were installed underground, and square tubular poles were selected to support the cross-span wires. The Centre City section was sufficiently defined to ensure that urban design constraints were satisfied.
2. Double insulation as required by California Public Utilities Commission General Order 95[2] (CPUC G.O. 95) was specified between all live parts of the catenary subsystem and ground for both the SD&AE mainline and Centre City sections.
3. Between the ambient temperature limit of 25°F and 130°F, the contact wire must be at or above the minimum heights specified by CPUC G.O. 95. In Centre City, 19 ft is the minimum height above top-of-rail. Along the SD&AE mainline, the minimum clearance is 22 ft above top-of-rail. The 22-ft clearance was difficult to maintain over such a wide temperature range. Thus, on the SD&AE mainline, the messenger and contact wire tensions are maintained constant over this temperature range with balance weights.
4. To obtain an economical pole design for the SD&AE mainline, the contractor was given three options: (a) prestressed concrete (selected by the contractor), (b) tapered tubular steel, or (c) wide-flange structural members.
5. Side clearances were specified to conform to CPUC G.O. 26D[3] where freight and LRV traffic operates jointly and to CPUC G.O. 143 where no freight would operate.

Two different overhead wire configurations that have approximately equal conductivity were specified: (a) one 750-kcmil copper messenger supporting one 4/0 grooved copper contact wire and (b) two 185-mm^2 (approximately 730 kcmil) supporting one 120-mm^2 (approximately 4/0)

Figure 1. Traction power substation duty cycle.

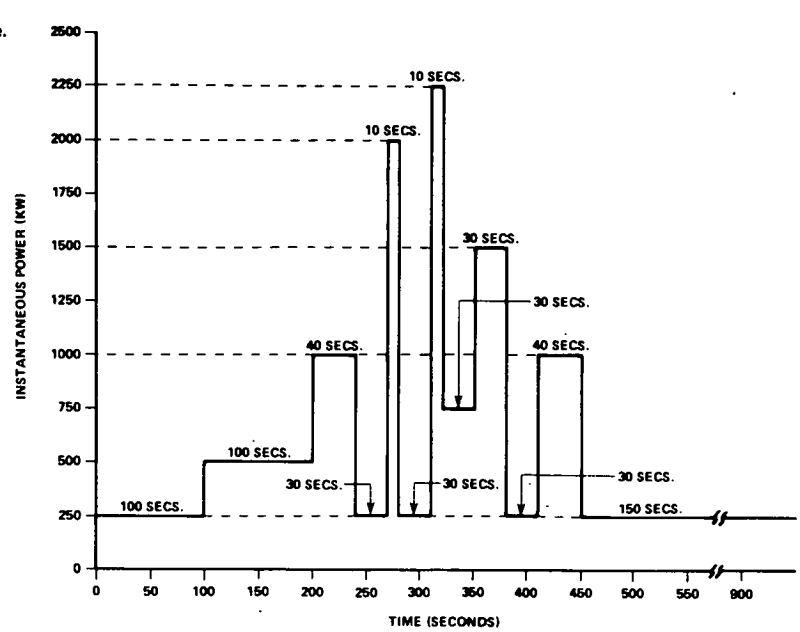


Figure 2. Single overhead suspension.

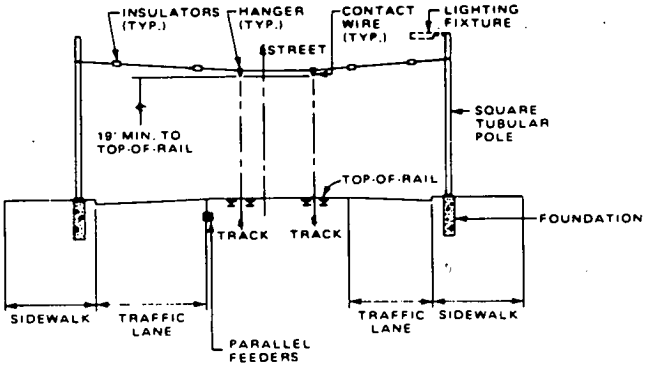
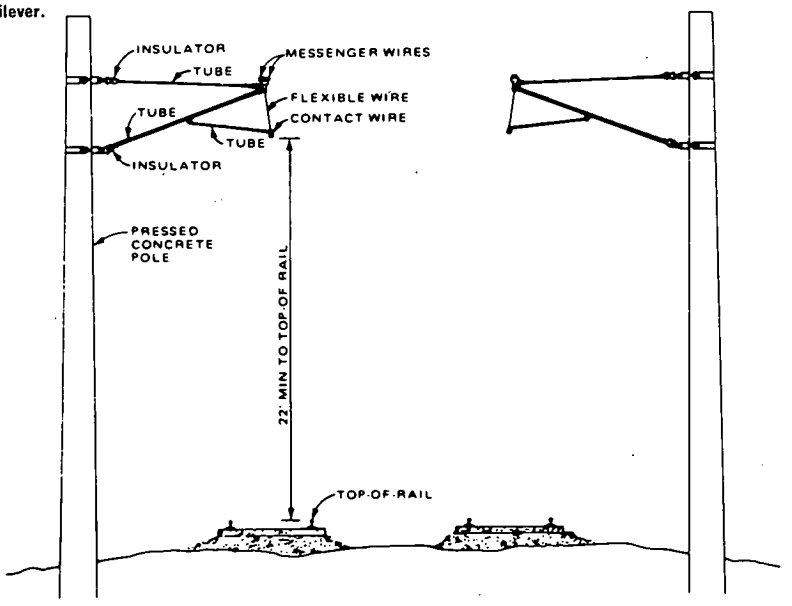


Figure 3. SD&AE catenary-cantilever.



grooved copper contact wire (selected by the contractor).

Once the configuration, weight, and cross section of the messenger and contact wires were determined, the maximum spacing between support structures and system height was determined, resulting in a maximum span length of 200 ft.

Two types of catenary support structures, cantilever and headspin, were specified for the SD&AE mainline. The primary structure, preferred for esthetic reasons and cost savings, is the cantilever structure. The cantilever arm assembly can be installed on poles located either to the side of a track or midway between tracks to allow one pole to support the catenary for both tracks. The inability to meet side clearances in track sections with existing highway structures or existing transmission towers did not permit center-pole cantilevers to be installed in all double-track sections.

The common characteristics of both structures is the inherent relief of tension in the event of broken messenger or contact wires. The cantilever assembly is hinged at the pole so that tension is relieved in the event of a broken wire through rotation of the cantilever assembly about the pole. In the case of headspans, tension is relieved by the deflection of the cross-span wires in the event of a broken contact wire and by free movement of the messenger wires on their pulley supports in the event of a broken messenger wire.

The movement of contact wire and messenger wires relative to their support structures is essential to a constant tension system. Balance weight assemblies are installed at 4000-ft maximum intervals known as tension length. The messengers and contact wires are secured at the midpoint of each tension length. Each balance weight assembly consists of a pulley with a number of concrete or iron weights to keep the sag and tension of the wires constant. Spans of adjacent tension lengths were overlapped at each end of each tension length. The overlap spans were arranged to permit the pantograph to pass smoothly from one tension length to the next.

SIGNAL SUBSYSTEM

The signal subsystem specifications were developed in three distinct areas. These areas covered (a) the protection of trains, (b) the protection of motor vehicles at railroad grade crossings, and (c) the control of traffic signals in downtown San Diego. The specifications for the train protection subsystem were a direct outgrowth of the operations plan, which called for absolute block signaling (i.e., no following train moves within a given signal block). Several specific design features, incorporated into the absolute block subsystem to meet special requirements for the San Diego LRT project, were as follows:

1. Because of movements of both transit and freight trains, the subsystem would have to meet all applicable safety requirements of both the California Public Utilities Commission and the Federal Railroad Administration.
2. Signaling would be accomplished by wayside color light indicators and manual operator response so as to eliminate the need for any on-board signal equipment on either transit cars or freight trains.
3. Switches at the ends of double-track sections would be powered by switch and lock movements.
4. All mainline switches to freight leads and spur tracks would be protected by electric locks. All locks may be unlocked by mainline train presence at the switch. In addition, some locks at freight leads or long spur tracks may be unlocked by absence of mainline traffic within the respective block control zone. This latter feature allows an operating freight to clear the mainline for transit moves should such action become necessary.
5. Central control of trains would be by radio only. With only five trains on the system at any one time, a radio dispatcher can readily control operations under any system conditions.

Signals in the block subsystem are established at freight train braking distances. Track circuits for the block subsystem are a combination of 60 and 100 Hz. The 100-Hz circuits are used where the tracks are located below several 138-kV transmission lines and may be subject to induced electrical interference.

An interesting feature of the signal subsystem is the need at ends of the line to discriminate between freight and transit trains where their respective trackage diverges. To avoid having any on-board ID equipment and for simplicity, the specifications called for a contact switch mounted on the overhead contact wire. Operation of the switch coupled with approach block occupancy calls for the transit route. Occupancy with no switch operation requests the freight route.

The project criteria required that all at-grade crossings of the SD&AE mainline be fully protected. The specifications accordingly required a full complement of automatic gates and flashing lights at each of the 28 crossings. In addiltion, at those locations with traffic-signaled intersections adjacent to the crossings, a preemption interface was provided to the traffic signal controllers to avoid giving motor vehicles conflicting signals.

Of interest in the crossing subsystem was the desire to be cost-effective by retaining several existing crossing protections. Problems that arose during start-up demonstrated that this older equipment was not capable of handling the number of cycles caused by a transit-type headway. Failures occurred primarily in gate mechanisms and power supplies, and most of these were replaced.

A relatively new feature for LRT operations was specified in downtown San Diego, where vehicles operate on the city streets. This was a subsystem of timed preemption of traffic signals to allow trains to proceed from station to station without stop. This subsystem was considered necessary if trains were to meet the run-times required by the operations plan. In addition, C Street, a one-way street for motor vehicle operation, had turns across the tracks prohibited.

Operation of the preemption subsystem on 12th Avenue was as expected; operation on C Street was not. The problem here was interference between preemption and the city's progressive signal phasing. The city and MTDB have arranged a trial arrangement to (a) not preempt and (b) to place all signals on the street into a common all green-all red timing sequence. Due to station spacing, trains move from station to station under signal control, with direction of move eliminated as a disrupting factor. Thus, the arrangement operates with a mixture of timed preemption on 12th Avenue and standard signal phasing control on C Street, and this appears reasonably effective.

FARE COLLECTION SUBSYSTEM

The specifications of the fare collection equipment were developed somewhat more subtly than the specifications for the three subsystems just discussed. In addition to the project criteria, the development of the specifications had to consider the fare concept. Five factors were considered:

1. The cost of fare collection must be a small fraction of the fare collected.
2. The subsystem must be suitable for regional bus transfers, including compatibility with present collection methods.
3. The subsystem must be able to cope with changes in the tariff, including changes in the value of tariffs.
4. A very important requirement was that the subsystem must not constrain vehicle loading to designated entrances or restrain station passenger circulation by virtue of paid and free areas.
5. The associated equipment must have been in proven revenue service and dependable.

Other issues, especially security, are inherent requirements of any conceptual choice. The issue of security involves protection of money handling and the prevention of passenger fare evasion. Once it is realized that absolute security is not possible, a design can be made for the most secure scheme without requiring a large staff and extraordinary facilities.

The ensuing study showed that the total cost of a barrier-free ticket system would be less than that of a farebox scheme. The ticket scheme is compatible with the regional bus systems, and it is flexible with regard to tariff changes. In addition, the ticket subsystem, especially inclusive of multi-ride tickets and monthly passes, enables fast boardings through all doors. No restraints are placed on the station design. In addition, the expected rate of fare evasion would be on the same order as the evasion rate for farebox and transfer-type systems. Having selected a barrier-free fare subsystem, provisions were made for ticket inspection by roving conductors who inspect tickets rather than lift them. MTDB proceeded to obtain powers of arrest to enforce penalties in the event an inspector locates an evader.

Two principal types of machines were specified—a vending machine and a canceler. The vending machine is coin-operated to vend tickets automatically in accordance with the passenger's selection of destination and fare class. The canceler is an automatic validator of a multi-ride ticket. In these specifications, the vending machine and canceler are placed in the same standing unit.

At the time bids were invited, the MTDB had not determined the applicable tariff. The specifications required a six-valued tariff—i.e., the product of fares and class of fares would be six. Later, MTDB decided on two zones and three classes, one of which merely upgrades a bus transfer. This tariff was readily introduced after the machines were built.

A key feature of the vending machine is coin processing. The specifications required the use of U.S. coins only; these included nickels, dimes, quarters, half-dollars, and the Susan B. Anthony dollars. In order to keep the base equipment simple, no change-making ability was required.

The specifications required the vendor to print and validate (i.e., cancel) tickets on the vend transaction. The imprint shows the time and location of the vend and the amount paid. Security is provided by a special imprint, a small saddle tank locomotive in this case, and by the use of specially imprinted paper stock. This is the essential minimum information required for on-board inspection. The ticket printer also prints the bookkeeping data generated from the microprocessor and required for accounts of the transactions of the machine.

The coin vault has a 4-liter volume. The specifications required a secure arrangement so that the contents

could be held in a vault until released in the counting room. An improvement proposed by the supplier and accepted by MTDB calls for locating the vault in the pedestal; this means that there is no reason for accessing the machine to change the coin vault.

The canceler operates on separately purchased multi-ride tickets only. Multi-ride tickets are canceled by guillotine, with validation data stamped on the ticket with each guillotine cut.

Because the consequences of a vendor failure are serious, the specifications required that the machine flag itself out of service if it ran out of paper, had a jammed coin accepter, or otherwise could not process a vend. In addition, provisions are made for remote flagging over leased telephone lines to a central office. This feature allows immediate dispatching of service in the event a vendor is out of service.

SUMMARY

The plans and specifications of the four major subsystems were derived from the operations plan and project design criteria. The specifications for the vehicle were developed first because it was on the critical path of the project, and the design of the other subsystems depended on it. This was followed by the specifications for the traction power subsystem and simultaneously by the signal and fare collection specifications. The plans and specifications prepared for this project attracted competitive bidding and are considered to have successfully fulfilled the intent of the LRT operations plan and project design criteria.

REFERENCES

1. General Order 143, Rules for Design, Construction and Operation of Light Rail Transit Systems including Streetcar Operations. California Public Utilities Commission.

2. General Order 95, Rules for Overhead Electric Line Construction. California Public Utilities Commission.

3. General Order 26D, Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structures, Parallel Tracks, Crossing of Public Roads, Highways and Streets. California Public Utilities Commission.

Self-Service Barrier-Free Fare Collection: An Early Look at San Diego's Experience

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With the opening of revenue service on July 26, 1981, the San Diego light rail transit system also inaugurated a self-service barrier-free fare collection system. Experience to date indicates that the fare collection system not only is achieving the objectives set forth but also is having other residual benefits. There are 18 stations and 27 ticket vending machines along the 16-mile line. These vending machines produce a validated ticket upon insertion of the correct fare, and they can also validate a 10-ride ticket. Valid tickets, bus transfers, or monthly passes must be in the possession of each rider (i.e., valid proof of payment). Thus far, fare evasion has been found to be far less than 1 percent of the daily riders. Patrons generally have positive feelings about the fare collection system. Capital costs were low and primarily a function of the type and complexity of the vending machines. Likewise, the operational benefits include low labor intensity (ticket inspectors are required for policing proof of payment) and efficient boarding and unloading of passengers using all doors on one side of the train (e.g., eight for a two-car train). An important result of the ticket inspection team is the public relations benefit gained. The ticket inspectors have become ambassadors of a sort. The nature of the system means there are no conductors and no station attendants; also, the train operator does not participate in any patron functions. Therefore, the ticket inspectors become the only employee of the operation that the public comes in contact with. A firm yet positive attitude was stressed during their training program, and this has seemingly paid off with resulting positive attitudes from patrons. The early results of self-service barrier-free fare collection in San Diego demonstrate its cost-effectiveness.

Self-service, barrier-free fare collection systems have recently been implemented in Edmonton and Calgary, Canada, and in San Diego, California. Portland, Oregon, is also preparing for a major effort to implement such a system for the entire bus network.

Attention to self-service fare collection has heightened over the past few years through various research efforts.[5-10] However, implementation has been stalled for a variety of reasons, but primarily due to a skepticism that such a system would work. According to recent research, the self-service concept represents such a significant departure from current U.S. transit systems' fare collection procedures that a series of demonstrations are recommended.[7]

With the recent start-up of light rail transit in San Diego, the self-service, barrier-free fare collection system was also inaugurated. The system was particularly patterned after European examples without benefit of demonstration results. An early look at San Diego's experience confirms the benefits cited by the research.

BACKGROUND

As part of the guideway feasibility studies conducted by the San Diego Metropolitan Transit Development Board (MTDB), a key concern of the impact and economic analyses centered around the type of fare collection system to be used.[1,2] The fare collection system can have significant bearing on the capital costs (e.g., turnstiles, fare machines, "paid" areas), operating costs (e.g., conductors, revenue collection personnel, maintenance of machines, ticket booth personnel), and, in San Diego's case, the operating plan.