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.

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

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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.

In the early stages of the feasibility study, the MTDB's Board of Directors determined that light rail vehicle technology would be most appropriate for San Diego. With that determination, efforts began to focus on use of the self-service, barrier-free fare collection system. The planning principles adopted by the MTDB's Board of Directors in December 1976 called for a practical, low-cost guideway project. These adopted principles recognized the necessary practicality involved with designing a rail transit alternative suitable to San Diego's conditions. These principles stated that, for a guideway transit system to be feasible in San Diego, it must have a low capital cost, operate mostly at grade, operate a long distance, be capable of operating at a high speed, have a low operating cost burden, and minimize the potential for adverse environmental impacts.

With regard to the fare collection system, these principles converted into the following:

- Low-cost station facilities—the ability to construct relatively low-cost shelters with no escalators, elevators, turnstiles, or barriers.
- Minimal operating cost per unit of revenue collected—the ability to cut down on labor costs by eliminating conductors on board for fare collection and ticket and fare collection personnel at stations (to be replaced with a ticket inspection team).
- High-speed, multi-door boarding—the ability to minimize dwell times at stations by permitting use of all doors on a multi-car train for boarding.

The light rail transit project adopted by the MTDB's Board of Directors and subsequently implemented initiated revenue service on July 26, 1981. The line, called the San Diego Trolley, runs 16 miles between Centre City San Diego and the International Border at San Ysidro (Figure 1). There are a total of 18 station stops, with 11 located outside Centre City at an average spacing of around 1.25 miles. A top speed of 50 mph is reached in the non-Centre City portion of the line. On-street operations in Centre City are limited to 25 mph (or the posted traffic speed limit).

The key determinant to the feasibility of the light rail project was the potential for operating cost efficiencies to be obtained in the South Bay corridor. To realize these savings, labor costs had to be reduced while ridership was being maximized. Thus, the self-service fare collection system became a critical part of the feasibility determination, one that the MTDB's Board of Directors followed through into operations despite skepticism from the community[3,4] and from transit operators. Typical of the attitude of the transit community was the technical review from an area operator in San Diego that concluded with the following:

> Based on the amount of difficulty we presently experience and the hassles on the buses currently caused by fare collections, we must express our skepticism about the self-service fare system proposed in the MTDB plan. Self-service fare systems may be common in Europe; however, to our knowledge there are no systems operating in the United States. Granted such a system would facilitate the loading of passengers and would make possible lower cost stations, particularly in the downtown area; but there is also the very real possibility of losing a great deal of revenue due to persons paying the wrong fare or no fare at all.[14]

It is relevant to note that the MTDB's Board of Directors was not skeptical. Thanks to an intensive eight-city tour of European transit systems, the Board was convinced that the self-service fare collection system would work in San Diego.[11]

DESIGN CRITERIA

The light rail project was adopted by the MTDB's Board of Directors in late 1978. A key facet of the feasibility determination was the emphatic requirement to stay with the light rail operating philosophy. Thus, the critical step in going from planning to implementation was to develop design criteria that accurately and realistically carry out the philosophy. It was important, too, that the eventual criteria were adhered to all the way through to operations.

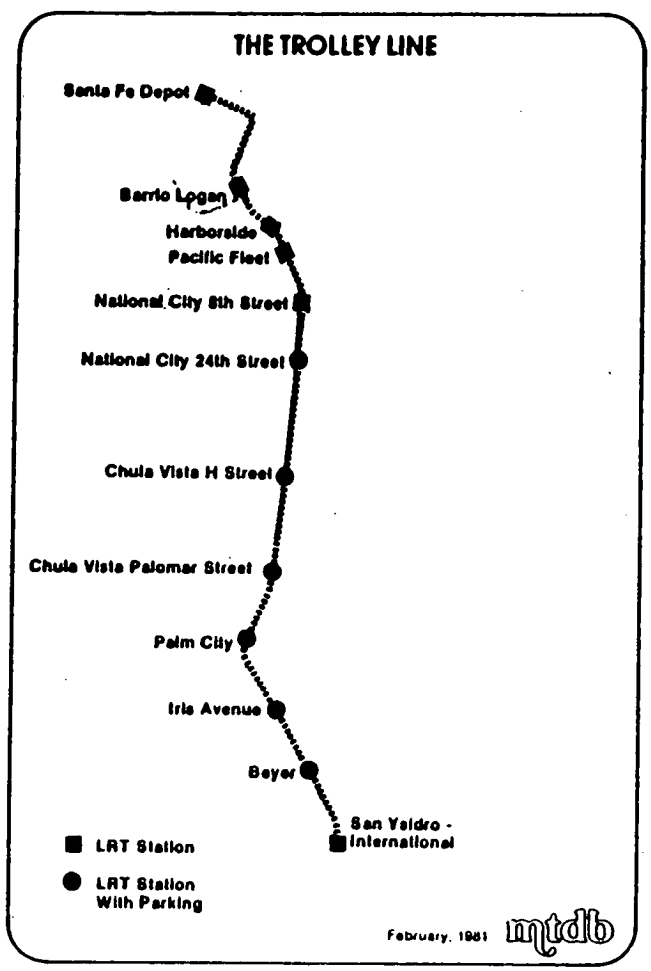
Bechtel, in a coordinated effort with Tom Parkinson, pulled together the initial technical study supporting the various operational facets of the self-service, barrier-free system.[1] Their work provided the basis for detailing the equipment needs as well as operational features of the system. In addition, this effort included cost analyses comparing the self-service system to a more standard rapid transit fare collection system with turnstiles and paid loading areas.

The operational criteria essentially revolved around a key consideration: the higher the percentage of prepaid users on the system, the lower the dependence on fare collection personnel and machines. Even so, there still was a need for single-ride fare collection capability.

The criteria finally adopted called for a self-service, barrier-free system with the following capabilities:

1. Machinery that would provide for six-value fare tariffs;
2. Accommodation of on-vehicle and off-vehicle ticket vendors and on-vehicle ticket cancelers and validators;

Figure 1. Trolley line: Santa Fe Depot - San Ysidro International.



3. Fare policies encouraging prepayment of fares at off-system locations; and
4. Development of effective legal means to form and carry out policy and procedures to deter evasion.[3]

After adoption of the design criteria, it was decided that the fare collection equipment should provide a single-ride ticket already validated. After further staff evaluation, the on-board ticket validation machine was discarded as a practical option. Instead, it was decided to have all validation occur off the vehicle to allow the most efficient passenger boarding possible. In combination with the location of the vending machines at the stations, the criteria were further modified to include that the machines be especially vandal-proof and ruggedly constructed.

DESCRIPTION OF THE FARE COLLECTION MACHINE

Bids on the fare collection devices were received in September 1979. The resultant low bid was obtained from Autelca of Gumligen, Switzerland. The resulting machine, called the BE-20 by Autelca, has the capability of providing a single-ride cash-fare ticket and validating a multi-ride ticket. The MTDB specifications required coin fares only but included the Susan B. Anthony dollar; no change is provided.

The two types of tickets considered are the single-ride ticket, which is dispensed on deposit of the required coin fare and indicates type of tariff, date, time of day, station number, and a security symbol, and the multi-ride ticket ("Ready 10"), which is validated with information similar to the single-ride ticket. Upon inserting the ticket into the proper slot, the machine prints the information and guillotines off one-tenth of the ten rides available. As many as 10 people could ride using the one Ready 10 by inserting the ticket for multiple validations (once for each individual riding). A two-ride ticket ("Ready 2") has also been developed and operates in the same way as the Ready 10.

In addition to being proof of payment, the ticket received from the machine is valid as a transfer to all connecting bus carriers in the metropolitan area. Bus transfers to the trolley are also accepted but sometimes require an upgrade. This transfer arrangement is part of an areawide agreement among all fixed-route public transit operators in the San Diego metropolitan area and encourages efficient transfer among all routes regardless of operator.

This areawide transfer agreement is also coordinated with a fare policy in which all operators participate. The fare policy is a variation of a flat fare structure and has set fares based on service function rather than zones. The level-of-service concept is based on average passenger trip length and covers three classes: (a) metro—higher speed, express and trolley routes; (b) urban—trunkline, arterial routes; and (c) local and feeder—local, neighborhood routes. The fare policy permits free transfer between routes of similar function, although a transfer from urban or local and feeder to metro requires an upgrade.

The resulting fare structure is as follows:

- Single-ride fare:
  - Metro (includes trolley) = $1.00
  - Urban = 0.80
  - Local and Feeder = 0.60
- Senior citizen and handicapped fares: 0.40
- Transfer upgrade (from urban and local feeder to metro): 0.20
- Transfer between metro bus and trolley: Free

For the trolley only there is a special 25 cent fare for the Centre City zone. The Ready 10 offers a discounted fare and sells for $7.50 (or 75 cents a ride). The Ready 2 is sold at full value, or $2.00.

Rounding out the fare policy is the area's monthly pass ("Ready Pass"). The pass is accepted by all operators and offers a discount for the regular rider (sells for $31 per month). It is usable on all systems and on all fixed-route services (i.e., no upgrade is necessary).

TICKET MACHINE PERFORMANCE

Machine performance, from both the public and maintenance viewpoint, has been very satisfactory. As with most other equipment being used, the basic machine has been in use at other properties for many years.

The 27 machines in service are vending 190 066 tickets and validating 34 637 multi-ride tickets in an average month. In December 1981, there were 180 reports of machine malfunction, of which 25 percent were false reports (the machines were working properly when inspected). Through maintenance procedure changes, the failure rate has been decreased 50 percent over that experienced in the first month of operations. Further improvements are expected.

About 20 percent of the service calls are due to a jammed validator. In some cases validators are being intentionally jammed (vandalism) and in others it is due to the condition of the multi-ride ticket stock. The stock will be changed when tickets are reordered to eliminate this problem. Vandalism and machine tampering have not been major problems.

TICKET INSPECTION

The self-service fare collection system used in San Diego is not an "honor system" but relies on each passenger having proof of payment. This proof can take the form of validated single-ride tickets, Ready 10s, Ready 2s, bus transfers, or Ready Passes. For enforcement, ticket inspectors conduct random checks throughout the system.

The ticket inspection team consists of six individuals plus a supervisor. They are uniformed and are equipped with two-way radios. Radio communication is necessary to keep in contact with the control center and security.

The training of the ticket inspectors (TIs) is especially important because these people are essentially the only representative of the operation with which the patron comes in contact. Therefore, the TIs must be firm for fare inspection purposes, but they also must have positive personalities in order to handle potentially difficult situations. Further, they must be able to help patrons who are in trouble with some facet of the operation or who need information on how to use it or how to transfer.

The TI training program takes 2 weeks and includes a mix of security instruction with ticket inspection procedures. The training was conducted under contract with a local private security firm schooled in police officer training and emphasized the community public relations aspects of the inspection services.

In preparation for the start of service, MTDB had some knowledge of ticket inspection procedures gained from the European trip and discussions with Edmonton (which started a self-service program in 1980) and consultant assistance from the Zurich transit system. Even so, development of the operating procedures had to be specific to San Diego and essentially was a "ground floor" effort. The type of vending machines, transfer arrangements, and operating plan of the trolley are all critical and unique conditions that required focused attention in order for the procedures to have application. In other words, one cannot just duplicate operating procedures from another system. The overall philosophy of ticket inspection must be established, and this can have different policy backing from one area to another.

After several months of development, a standard operating manual for the TIs was formally issued.[12] No grace period was established for patrons when service was initiated in July 1981. Rather, the TIs were instructed to start out using the standard procedures. In this manner, the TI was relieved from having any discretion as to what consti-

tuted a legitimate excuse for not paying a fare. However, there is an administrative procedure for dismissing citations, and this is used in certain deserving cases.

Observations, confirmed by letters and informal correspondence, indicate that the TIs have become an effective and popular representative of the transit system. Their job entails far more public relations and information help than writing citations, and this function is proving to be a positive and interesting part of the patron's ride. Also of significant help, due to the international market associated with the line, is the requirement that all of the TIs be bilingual.

Needless to say, there must be a penalty associated with fare evasion. In 1980, the state legislature passed laws that permitted MTDB to contract for security services and established a fine for fare evasion up to $500. In March 1981 the MTDB's Board of Directors adopted a fare ordinance that established bail at $20 for first-time evaders. On a second offense the individual would face a fine of $50, and a similar fine plus a mandatory court appearance on a third offense. State law provides that MTDB receive 85 percent of the fine revenue received from fare-evasion cases.

To ensure enforcement support from the courts, meetings were held with key judges before service was initiated. Ticket inspection procedures were reviewed and in some areas changed based on the judges' advice. As a result, a good partnership has been achieved.

After the first 6 months of operation, results of the self-service fare collection system are positive: 2 001 000 riders, 829 000 riders checked, 2231 cited for evasion. The inspection rate has averaged just about 41 percent of all riders. Thus, this experience shows an evasion rate of 0.27. This rate has remained constant, even though the TI team has been working with six members rather than seven for the last several months.

An internal audit of the ticket inspection procedures and the TIs' performance was conducted after service was in operation for a month.[13] In general, the results confirmed the adequacy of the procedures but helped assist in making various changes to tighten up. All things considered, the self-service system has been achieving the primary objectives that had been established.

INFORMATION PROGRAM

One aspect of the self-service system where the San Diego effort has appeared deficient concerns the in-place information system. The inherent nature of this fare collection system requires the patron to obtain information by reading or observing signs. Since there are no conductors and no station attendants, the signs at a station become critical information components. Not only must the information be readable and accurate, but the graphics must be reasonably appealing in order to catch the attention of patrons and lead them through the various components of buying a ticket and waiting for a train.

The initial signing was, at best, minimal. Perhaps this was a wise strategy from a cost standpoint, in that the new signing program has been developed based on actual surveys of riders and thus should be more responsive to actual, observed needs.

In providing information under a self-service situation, the TIs are normally the only system employee that a patron comes in contact with. It is significant to note that they themselves provide an important information function and are instructed to be as helpful as possible with patrons. This role for the TIs has provided unexpected benefits: They are a sort of roving ambassador for the trolley. In addition to giving out information, either orally or some of the pamphlets, they also try to make the ride a positive, enjoyable experience by being friendly and engaging without detracting from their inspection function. For example, they carry punch-out fold-up trolleys that they give to children riding the trains.

CONCLUSIONS

1. In San Diego's case, the self-service barrier-free fare collection system has achieved positive results:
   - The labor intensity for fare collection is low.
   - The fare evasion rate is low.
   - Boarding and unboarding times are minimized.
2. The self-service fare collection system does not risk abuse when
   - The fare is reasonable compared with the quality of service.
   - The penalty is sufficiently high to encourage payment.
   - Enforcement is readily visible.
3. A complementary signing and information system is required for the self-service system to work effectively.
4. The ticket inspection team can offer a positive face to the transit system and provide a roving ambassador function in addition to inspection functions.

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