ANALYSIS OF ALTERNATIVE FARE COLLECTION SYSTEMS

WBS 14 CAE11

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SUMMARY

This report presents the results of an evaluation of alternative fare collection systems for Metro Rail. The purpose is to assist the Metro Rail Project staff in the development of the rail transit fare collection system.

The study commenced with the definition of system objectives and development of the alternatives to meet these objectives. These alternatives were then analyzed and evaluated with respect to a series of evaluation criteria.

The objectives of the fare collection system were identified by the Metro Rail staff and their Systems Analysis consultant, Booz·Allen & Hamilton Inc. The objectives were: the need to ensure the proper payment of fare by Metro Rail passengers and the need to provide the maximum flexibility to set and adjust fares in the future. To achieve the objective of flexibility, it was determined that the system should be capable of accommodating a graduated fare structure, intermodal transferring, reduced fares (including possible restrictions on their use), single- and multi-trip fares, and peak/off-peak fare differentials.

Two generic types of fare collection systems were analyzed and evaluated. The automatic barrier system would utilize fare gates and machine-readable tickets to enforce fare payment by patrons. The other type of system, called barrier-free or self-service, would utilize random manual inspections of printed tickets in lieu of the fare gates.

Barrier fare collection is an accepted concept applied in varying forms throughout the world. The most recent applications to rail transit in North America are in San Francisco, Washington, D.C. and Atlanta. Barrier-free fare collection is new to the United States, although it is in widespread use in Europe. In North America, it has been successfully implemented on light rail systems in San Diego, Edmonton and Calgary, and was recently implemented on the bus system in Portland, Oregon.

The two system alternatives were evaluated according to the following criteria:

- System Flexibility;
- System Cost;
- Fare Enforcement;
- Administrative Requirements; and
- Passenger Convenience.

The results and conclusions, presented in Table S-1, show that a barrier-free system would have certain advantages over the barrier system in the areas of cost, passenger convenience and system integration:

- It would be far less costly to implement ($7.1 million vs. $18.2 million in capital expenditures)

- It would be somewhat less costly to operate, provided fare evasion levels are minimized ($4.3 to $5.2 million vs. $4.9 to $5.4 million)

- It would be more convenient for passengers to use (1 to 3 steps vs. 3 to 6 steps)

- It would be more reliable (one failure per 500 to 2,000 passenger trips vs. one per 200 to 800 trips)

TABLE S-1
EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES

Criterion	Conclusion	Automatic Barrier	Barrier-Free
System Flexibility	Both systems perform well.	. Can accommodate zone or distance-based fares. . Permits transferring between bus and rail fare structures. . Lack of media commonality can limit integration.	. Can accommodate zoned fares; difficult to implement distance-based fares. . Permits transferring between bus and rail fare structures. . Media commonality enhances integration of fares. . Can be unified with barrier-free on light rail system.
Cost	Barrier-free is superior; however, cost to courts unknown.	. \$18.2 million capital investment. . \$ 4.9 – 5.5 million annual operating cost. . \$ 7.3 – 7.8 million annualized equivalent cost.	. \$ 7.1 million capital investment. . \$ 4.4 – 5.2 million annual operating cost. . \$ 5.3 – 6.1 million annualized equivalent cost. . Cost incurred by courts in collection and prosecution of fines is unknown, but will be high; ability to recover costs must be further examined.

TABLE S-1
EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES
(Continued)

Criterion	Conclusion	Automatic Barrier	Barrier-Free
Fare Enforcement	Barrier is superior.	. All fares inspected. . Minimal jumping of fare gates expected. . Potential abuse of reduced fares. . Poor time control on transfers. . Ticket counterfeiting difficult.	. Small percentage of fares inspected. . Higher percentage of fare evasion anticipated. . Manual inspection controls abuse of reduced fares. . Good time control on transfers. . Ticket counterfeiting potential similar to bus system.
Administrative Requirements	Each system has its advantages.	. Requires encoding, distributing and recycling tickets, passes, and transfers specifically for Metro Rail use. . Requires bus driver to issue two types of transfers — bus and rail. . Places no burden on court system. . Can be designed to provide detailed ridership statistics. . Permits control of access to platform, in emergencies.	. Uses same passes, transfers as bus system. . Bus operator continues to dispense one type of transfer. . Adds to heavy burden on court systems. . Requires an extensive reporting system for evasion-related information. . Requires origin-destination surveys and passenger counts to collect ridership statistics.

TABLE S-1
EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES
(Continued)

Criterion	Conclusion	Automatic Barrier	Barrier-Free
Passenger Convenience	Barrier-free is superior.	. Requires three-six (3-6) steps to use. . Lower equipment reliability could inconvenience patrons more often; a failure will occur once every 200 to 800 passenger trips. . Risks no fine for making a mistake in using system.	. Requires one-three (1-3) steps to use. . Reliability could be higher; failure will occur every 500 to 2,000 trips. . Risks a fine for making a mistake; however, inspectors and courts can be given discretion in fining patrons.

- It would permit more complete integration between bus and rail (printed tickets vs. specially encoded tickets)

However, the magnitude of these advantages is not sufficiently compelling to warrant the selection of a fare collection system that has not been implemented on a U.S. rail rapid transit system. There is a significant level of risk associated with the barrier-free concept because of the lack of experience with a U.S. system on the scale of Metro Rail or in a city the size of Los Angeles. It is uncertain as to what extent the experiences in the smaller cities like San Diego, Edmonton and Calgary can apply to Los Angeles with its unique demographics.

The level of fare evasion anticipated on Metro Rail is an unknown that would considerably influence the cost of fare inspection for Metro Rail. A high number of evaders could tax the local court system, which would be expected to prosecute fare evaders and collect appropriate fines.

The barrier system would have the following advantages:

- It would ensure collection of virtually all rail revenues;
- It would not rely on the court system for fare enforcement or require special legislation prior to implementation;
- It would provide the flexibility RTD needs to set fares;
- It would permit control of patron access to platforms in emergencies;
- It could be designed to gather pertinent ridership data on a regular basis.

Because of the uncertainties associated with barrier-free fare collection and the advantages inherent in a barrier system, it is recommended that Metro Rail be designed to accommodate an automatic barrier system in the preliminary engineering phase. The relative design requirements of the two systems, make it possible to convert to a barrier-free system if future experience mitigates existing concerns. Switching from barrier-free to barrier after system start-up, however, would be both costly and inconvenient.

CHAPTER 1
INTRODUCTION

The alternatives analysis of fare collection systems for Metro Rail is one phase of the Metro Rail fare collection subsystems study. This chapter discusses the scope of the overall study and this particular element, and the objective of the fare collection system itself.

1.1 PURPOSE AND SCOPE OF THE STUDY

The purpose of the Fare Collection Subsystem Study is to assist the Metro Rail Project staff in developing the fare collection system.

This report presents the results of an analysis and evaluation of fare collection system alternatives. To perform this evaluation, the objectives of the fare collection system were first defined by the Metro Rail Project staff and the Systems Analysis consultant, Booz, Allen & Hamilton. System alternatives were then developed to meet both these objectives and certain operational requirements. Two basic types of fare collection systems were examined: a barrier system which utilizes fare gates to examine machine readable tickets; and a barrier-free or self-service system which utilizes random manual inspection in lieu of fare gates.

This analysis follows a review of fare collection methods on other rail transit systems. That review has been documented in an earlier task report, Fare Collection Technology Assessment, September 1982.

A summary of the alternatives analysis and recommendations will be incorporated into the Metro Rail Project's Milestone 8 Report for public review and comment. The RTD Board of Directors will then consider the staff recommendations and public comments in selecting the preferred fare collection system.

Once the fare collection method has been adopted by the Board, operational and design criteria will be developed to guide the Subsystems consultant in the preparation of preliminary designs, specifications and drawings.

Following the completion of the design documents, they will be reviewed to ensure their completeness and compliance with the criteria.

1.2 OBJECTIVE OF THE FARE COLLECTION SYSTEM

The primary objective of a fare collection system is to ensure that passengers pay the proper fare for their trips. To best meet the needs of the RTD, the Metro Rail fare collection system should also be flexible enough to allow the District Board to change fares as needed in future years.

Uncertainty about future financial needs makes it both difficult and inadvisable to define a specific fare structure so many years before Metro Rail is scheduled to start operation. Therefore, the fare collection system has been designed to provide the maximum flexibility to set and adjust fares in the future.

Recent experience at RTD and other transit systems has been indicative of the financial pressures that may lie ahead. With the decline in subsidy levels, transit systems are finding they need to cover a higher percentage of operating costs from the farebox. Many systems, however, have been hard pressed to generate additional revenue because the inflexibility of their fare collection systems limit the types of fares that can be implemented. To generate the ridership and revenue it will require, the District will need to be able to institute a fare structure that satisfactorily differentiates each transit market, establishing fares that are based on the relative cost or value of a particular service.

Rail transit fare collection systems can accommodate intricate fare structures, provided they are designed with the necessary capability. The capability of the fare collection system will influence fare policy decisions made by the RTD Board for the economic life of the equipment.

To achieve the objective of providing maximum flexibility in setting fares, the following requirements were identified for the Metro Rail fare collection system:

- A graduated-fare structure would be possible on Metro Rail;
- Metro Rail could be fully integrated with the bus and future light rail systems, with transferring possible among modes;

- Special fares, including elderly/handicapped, and student fares could be accommodated;
- Single-trip fares, monthly (or bi-weekly) passes and/or multi-trip tickets could be instituted on Metro Rail;
- A peak/off-peak pricing strategy could be implemented; and
- Reduced fare tickets and passes could be restricted from use at certain times of day.

These criteria form the basis of developing the fare collection system alternatives described in the following chapter.

* * * * *

This chapter has discussed the scope of the fare collection study and the objective of the fare collection system itself. With fare-setting flexibility defined as being of primary importance, fare criteria have been established to guide development of the system alternatives.

The following chapter describes the system alternatives in detail.

CHAPTER 2
DESCRIPTION OF ALTERNATIVES

The alternatives analysis focuses on two very different concepts: barrier or barrier-free fare collection. For each concept, a system alternative was developed (See Appendix A) and sized (See Appendices B and C) for Metro Rail. Each alternative was developed in accordance with the previously stated objective of providing RTD with a high degree of flexibility to set and adjust fares.

The system alternatives also meet certain operational requirements established for Metro Rail. These include the ability to operate without station attendants, the ability to accommodate the handicapped, and provisions for safe operation and the avoidance of hazardous conditions.

There are several options to specific components of each system alternative that are evaluated in this analysis. Once the preferred fare collection concept has been selected, further analysis will be undertaken to refine the alternatives, through examination of these options.

This chapter describes each concept and the associated system alternative for Metro Rail.

2.1 AUTOMATIC BARRIER SYSTEM

The automatic barrier fare collection system utilizes a control line of ticket-reading fare gates to ensure that each patron has paid a proper fare for the trip. All patrons must insert a valid machine-readable ticket or pass into a fare gate both to enter and to exit the rail system. If the ticket or pass is not the correct fare for the trip, the fare gate will remain locked and will instruct the patron on the proper recourse. This may involve the use of an "add-fare" machine to pay additional fare. In other instances, the patron may be directed to a passenger-assistance phone which will connect him or her to a central control operator for assistance. The basic concept is illustrated in Figure 2-1.

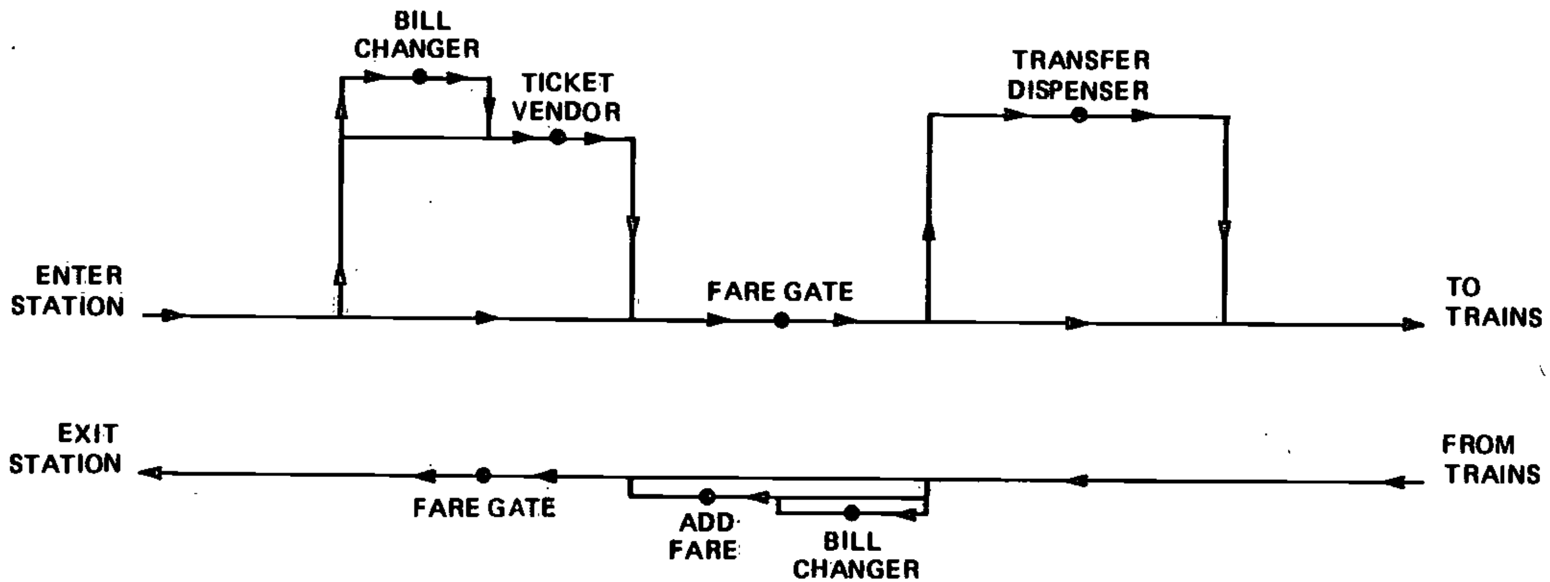
2.1.1 Passenger Procedures

Procedures for use of the Metro Rail barrier fare collection system are illustrated in Figure 2-2.

Passengers making a single-trip on Metro Rail would purchase a ticket from a ticket vendor at the start of their rail journey. The ticket would be encoded with pertinent information for entry and exit through the fare gates.

Passengers transferring from a bus would first obtain from the bus operator a machine-readable bus-to-rail transfer card. When purchasing a Metro Rail ticket, the patron would insert the transfer card into the vendor to receive appropriate credit for the fare paid on the bus.

FIGURE 2-1
BARRIER SYSTEM PASSENGER FLOW CHART



Note: *Fare System illustration reflects relative magnitude of patrons utilizing each equipment component.*

FIGURE 2-2
AUTOMATIC BARRIER SYSTEM PASSENGER PROCEDURES

	Sales Outlet	Bus	Entry Station: Ticket Vendor (1)	Entry Station: Entry Fare Gate	Entry Station: Rail/Bus Transfer Dispenser	Exit Station: Add-Fare (1)	Exit Station: Exit Fare Gate	Bus (2)
Pass or Multi-Trip	Purchase Pass or Ticket →	Show Pass or Ticket →		Insert Pass or Ticket →		Upgrade Ticket, If Necessary →	Insert Pass or Ticket →	Show Pass or Ticket
Bus/Rail Transfer		Pay Fare Obtain Transfer →	Insert Transfer, Purchase Ticket →	Insert Ticket →	Purchase Transfer, If Desired →	Upgrade Ticket, If Necessary →	Insert Ticket →	Show Transfer
Rail Single-Trip			Purchase Ticket →	Insert Ticket →	Purchase Transfer, If Desired →	Upgrade Ticket, If Necessary →	Insert Ticket →	Show Transfer

(1) Change dollar bills at Bill Changer.
(2) Rail/bus transfer option.

Patrons with single-trip tickets who wish to transfer from rail to bus would purchase a separate rail-to-bus transfer from a dispenser located within the paid area of the station.

Patrons using monthly (or bi-weekly) passes would be entitled to an unlimited number of rides prior to the printed expiration date. The pass could be restricted to use only between the zones specified on the pass. Passes would be sold at sales outlets as at present.

If a multi-trip ticket is instituted in place of the unlimited ride pass, procedures for its use would be similar to those for the pass. The only difference would be that the multi-trip tickets would have a finite value. Each time it is used, the appropriate fare would be deducted from the remaining ticket value. As is the case in Washington, the multi-trip rail ticket could be used as a pass on the bus; in that case it would, however, require an expiration date. The full potential for multi-trip tickets will be realized if, in the future, optional ticket read/write encoding devices are installed on each bus. These devices are currently undergoing a test in revenue service on express buses in San Diego.

Reduced single-trip fares would not be accommodated by the barrier system. These fare elements were eliminated due to the potential for substantial abuse and the added equipment and administrative complexity that would be necessary. Reduced fares with the barrier system would be accommodated exclusively by passes or multi-trip tickets sold at RTD sales outlets. This policy would be similar to that at BART (San Francisco), WMATA (Washington, D.C.) and PATCO (Philadelphia).

2.1.1 Equipment

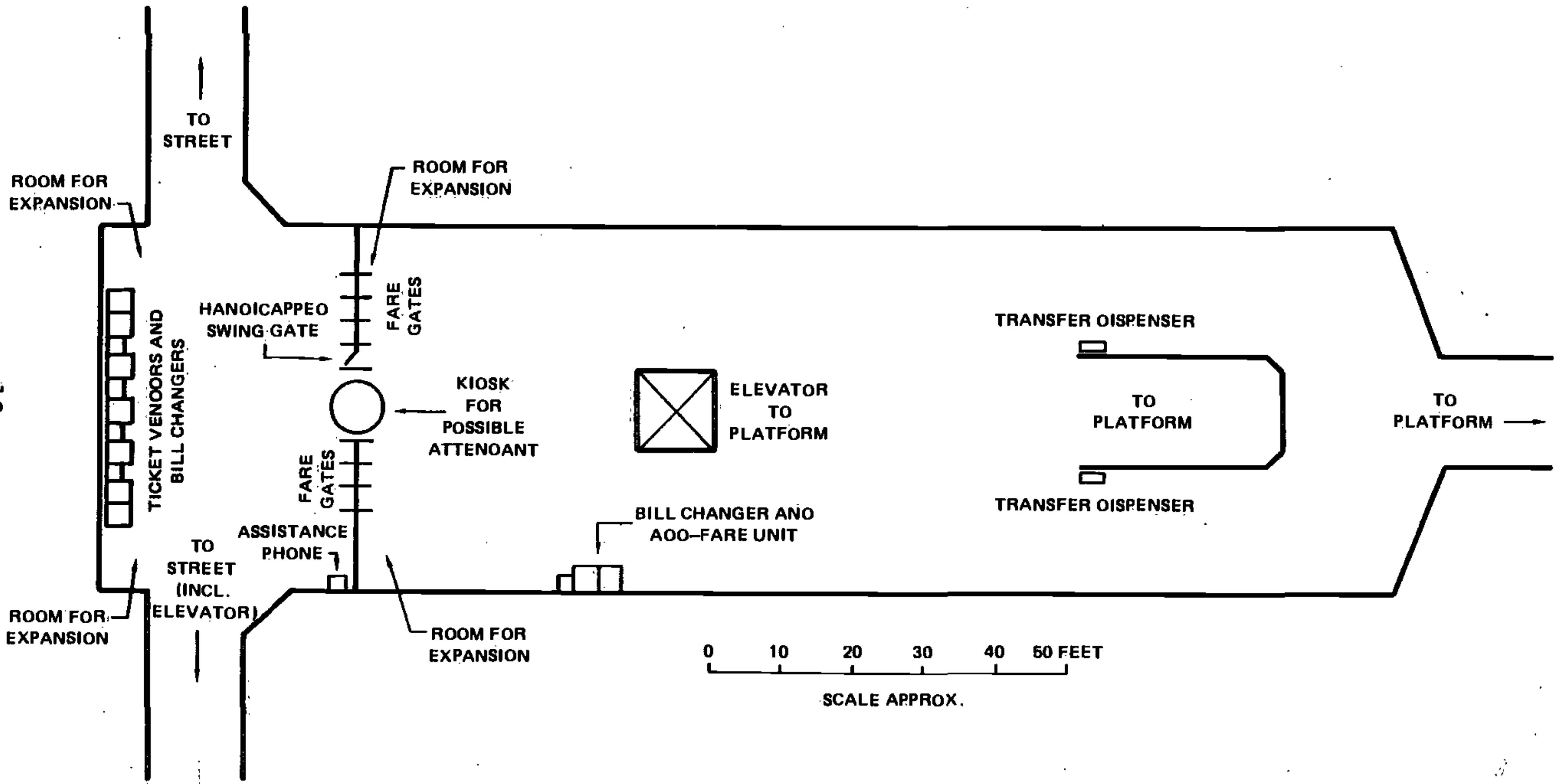
Implementation of an automatic barrier system requires the installation of sophisticated equipment in each station for Metro Rail. This would include:

- Fare Gates - that can read and write encoding on machine-readable tickets, on both entry and exit.
- Ticket Vendors - that can issue machine readable tickets to each destination zone and accept bus-issued transfer tickets for proper credit.
- Add-Fare Machines - that can upgrade a ticket or pass, if it is not already valid for exit, upon proper payment of fare.
- Handicapped Gate - that can read and write encoding on machine-readable tickets, similar to the fare gates, but is specially designed to permit access by patrons in wheelchairs.
- Transfer Dispensers - that can issue printed paper coupons for rail-to-bus transfer.
- Bill Changers - that can provide coin for use in the ticket vendors and add-fare units.
- Passenger-Assistance Phones - that would permit a patron having difficulty to communicate with a central control operator.

A typical station layout is illustrated in Figure 2-3.

Also required for each station would be revenue handling carts, with which to transport revenue and ticket stock between vendors, etc. and a station secure room, for the storage of revenue, media and carts.

FIGURE 2-3
AUTOMATIC BARRIER SYSTEM
TYPICAL STATION LAYOUT



Central Control would be equipped to monitor and control equipment located in the stations. Special media handling equipment would include high-speed ticket encoders for magnetically-encoding bus-to-rail transfers, passes and multi-trip tickets. Equipment for revenue processing would be similar to those used for the bus operation.

2.1.3 Media (Tickets, Passes, Transfers)

The automatic barrier system would require the use of tickets, passes and transfers that are both machine-readable and machine-encodable. The use of machine-readable transfers would require that buses carry two types of transfers: the paper coupons currently in use for bus-to-bus transferring and the encoded tickets for bus-to-rail transferring. Unless each bus is equipped with an optional unit capable of encoding transfers on demand, the transfers would need to be pre-encoded.

Experience on the MARTA system in Atlanta has shown that it is impractical to issue pre-encoded transfers with more than two time codes (one for morning, the other for afternoon/evening). A 12-hour time code would not provide the time control of the paper tear-off coupon currently in use on the bus system (twenty-minute intervals are standard). However, use of more discriminating time-coding would complicate the logistics of encoding and distributing these transfers.

2.1.4 Passenger Assistance

Assistance to patrons would be provided by both the equipment in the station and via telephone by Central Control operator. The equipment would be designed to assist the patron through each step of the fare collection system, using appropriate instructional displays and messages. In the event of ticket difficulties, the fare gate would direct the patron to either the add-fare machine or the passenger-assistance phone.

Central Control operators would be able to diagnose ticket problems when the ticket is inserted in a designated fare gate with special diagnostic capability. The operator would then be able to override some or all of the ticket codes to permit the patron to proceed through the fare gate. In the event the patron encounters difficulty with the equipment, such as bill, coin or ticket jams, the Central Control operators would notify field maintenance technicians.

2.1.5 Fare Enforcement

The automatic barrier system relies on its fare gates to check all fares. Policing of the fare collection system by transit personnel would be directed toward routine observation of fare gate usage to control fare gate hopping and the misuse of reduced fare passes and tickets.

2.2 SELF-SERVICE, BARRIER-FREE SYSTEM

The barrier-free fare collection system, commonly referred to as self-service, differs significantly in concept from the automatic barrier system. Instead of relying on fare gates, the barrier-free system utilizes fare inspectors to ensure that patrons are paying their proper fare. At any point along the trip, a fare inspector can ask to see the patron's ticket. Those patrons found not to have proof-of-payment (i.e., ticket, pass and/or transfer) that is valid at the point and time of inspection may be fined. In most cities, the fine is collected through the local courts; in Portland, fines are collected and processed by an independent collection agency, although contested fines go to court. The basic concept of barrier free fare collection is illustrated in Figure 2-4.

Whereas the barrier system fare gates inspect all fares, the fare inspectors in a barrier-free system examine only a small percentage. The level of inspection (which determines the probability of being inspected) should be set in conjunction with the amount of fine that is levied. The frequency of inspection and amount of fine should make it too costly for riders to habitually evade payment of fare.

2.2.1 Passenger Procedures

Procedures for use of the Metro Rail barrier-free fare collection system are illustrated in Figure 2-5.

Passengers making a single trip on Metro Rail would purchase a ticket from a ticket vendor at the start of their rail journey. The ticket would be printed with security code, time, date, station of purchase, fare type and destination zone. It would be valid only for immediate use.

Patrons transferring from a bus would carry both their vendor-purchased ticket and transfer coupon to show the fare inspector. The ticket would indicate that the fare received allowed a credit for the initial payment on the bus.

FIGURE 2-4
BARRIER-FREE SYSTEM PASSENGER FLOW CHART

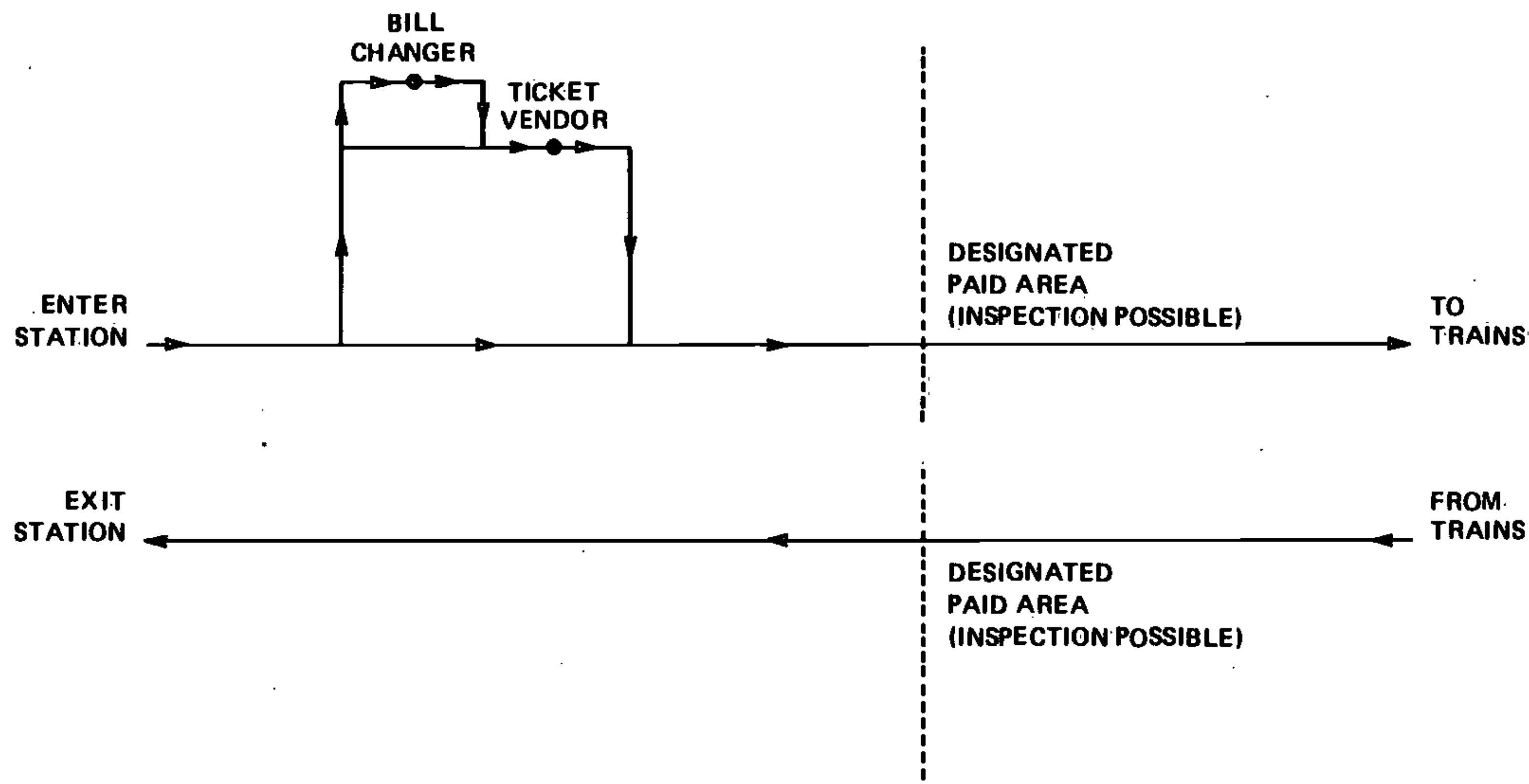


FIGURE 2-5
SELF-SERVICE BARRIER-FREE SYSTEM
PASSENGER PROCEDURES

	Sales Outlet	Bus	Entry Station Ticket Vendor (1)	Paid Areas & Trains Fare Inspector	Exit Station	Bus (2)
Pass	Purchase Pass →	Show Pass →		Show Pass on Request (3) →		Show Pass
or						
Multi-Trip	Purchase Multi-Trip →	Show Multi-Trip (As Pass) →	Validate Multi-Trip →	Show Ticket on Request (3) →		Show Ticket (As (Pass)
Bus/Rail Transfer		Pay Fare, Obtain Transfer →	Purchase Ticket →	Show Ticket and Bus/Rail Transfer (3) →		Show Ticket
Rail Single-Trip			Purchase Ticket →	Show Ticket (3) →		Show Ticket

(1) Change dollar bills in bill changer.
(2) Rail/bus transfer option.
(3) If reduced fare, show proper ID.

Similarly, patrons purchasing reduced fare tickets would require proof that they are eligible for that fare, if they are inspected.

When transferring to a bus from Metro Rail, the patron would surrender the vendor-purchase ticket to the bus driver. The ticket would indicate that the appropriate rail-to-bus transfer charge has been paid.

Patrons using monthly (or bi-weekly) passes would be entitled to an unlimited number of rides prior to the printed expiration date. The pass could be restricted to use only between the zones specified on the pass. Passes would be sold at sales outlets as at present.

If a multi-trip ticket is instituted in place of the unlimited ride pass, its use would be similar to that described for the barrier system. On the rail system the ticket would have a finite value. On the bus, the ticket would be used as a pass with an expiration date.

Use of the multi-trip ticket on the rail system would involve validating it at the start of each trip by inserting it in a ticket cancellor which would print the time, date and station on it. As with the barrier system, the full potential of multi-trip tickets will be realized if, in the future, optional ticket cancellors are installed on each bus, as in Portland, Oregon.

2.2.2 Equipment

Far less equipment is needed for a barrier-free system than for a barrier system. The equipment that is required need not be as complex either.

Equipment to be located in the stations would include:

- Ticket Vendors - that can print and sell single-trip tickets, and that can validate multi-trip tickets.
- Bill Changers - that can provide coin for use in the vendor.
- Passenger-Assistance Phones - that would permit the patron to obtain assistance from Central Control operators.

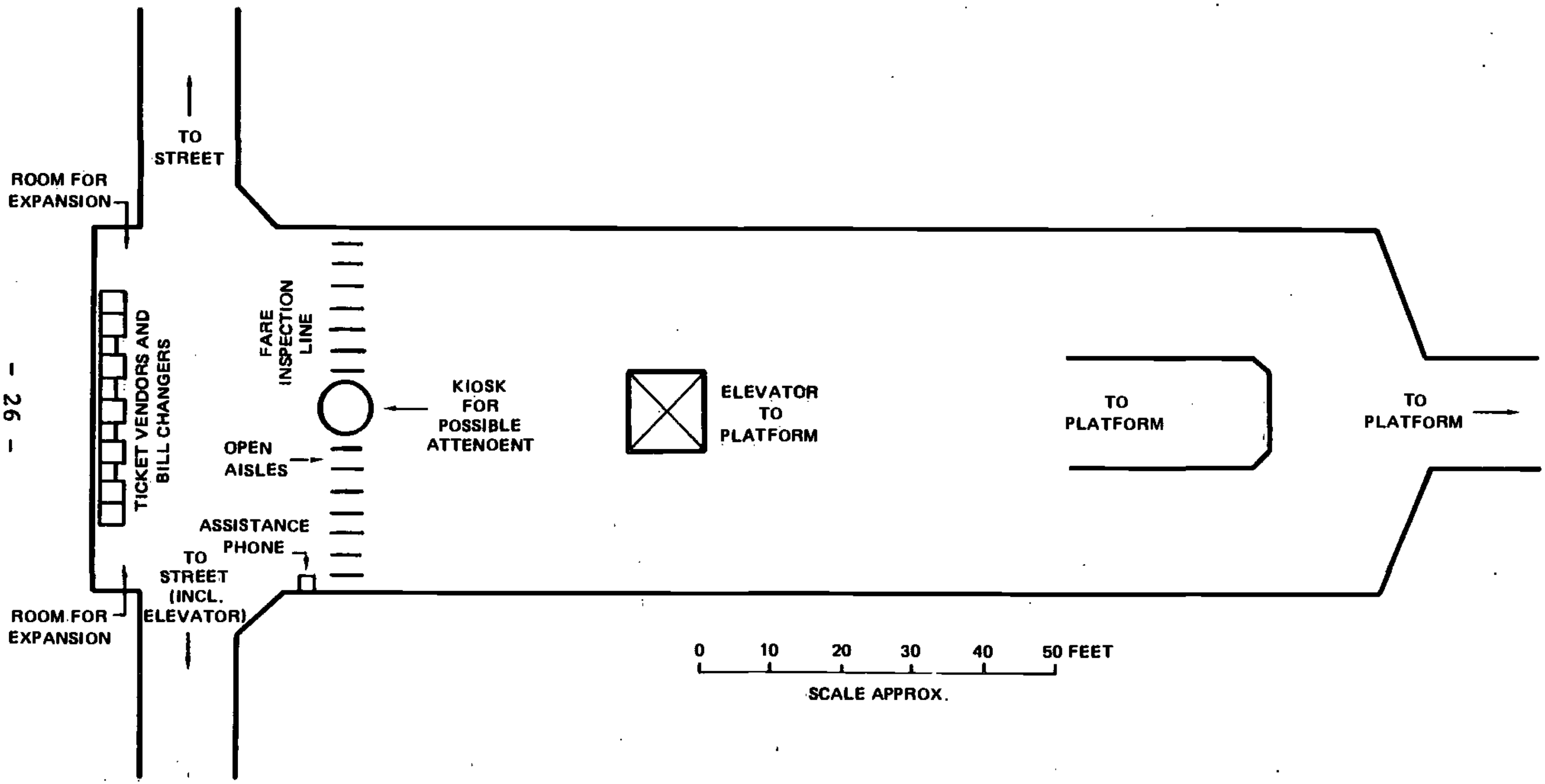
A typical station layout is illustrated in Figure 2-6.

When the ticketpurchased from the vendor is to allow rail-to-bus transfer, a special symbol would be printed on the ticket. This would be necessary to prevent transfer abuse, since there would be no barriers to the paid area where a transfer dispenser would normally be located.

As with the barrier system, revenue-handling carts would be required for each station to transport revenue and ticket stock.

Central Control would be equipped to monitor and control the fare collection equipment located in the station. Central Control capabilities would be less complex than with the barrier system, as there would be fewer units to monitor and a ticket encoding diagnostic capability would not be

FIGURE 2-6
SELF-SERVICE, BARRIER-FREE SYSTEM
TYPICAL STATION LAYOUT



required. Unlike the barrier system, a high-speed ticket encoder would not be required. Revenue processing equipment would, again, be similar to that used on the bus system. It should be noted that this equipment will not collect patronage data as in the barrier system; on-board surveys will be required.

2.2.3 Media

Because all proof of payment would be inspected manually by fare inspectors, the tickets, passes and transfers would not need to be machine-readable. Passes and transfers would be similar to those used on the bus system. Single-trip tickets would be printed by the vendor at time of purchase.

2.2.4 Passenger Assistance

As with the barrier system, assistance would be provided by both the equipment in the station and via telephone by the Central Control operators.

The equipment would be designed for ease of use. The Central Control operators would be available via telephone to help the patrons with any questions.

Fare inspectors who routinely rove the system would be available to offer assistance in using the system. Their presence would also provide added security to patrons.

2.2.5 Fare Enforcement

An important aspect of the barrier-free system is that patron fares be inspected periodically to control fare evasion. This must be accomplished in a manner that ensures that patrons are discouraged from riding without paying the proper fare. The patron must feel that the chances of being caught, together with the amount of the fine, are not worth the risk. If properly enforced, a fine that is set high enough to discourage most fare evasion for economic reasons could lead to recovery of most or all of the revenue normally lost through evasion.

On the Metro Rail system, patrons would be responsible for having valid proof of payment on the train, on the station platform and within a designated (and readily identifiable) portion of the station mezzanine. Teams of fare inspectors would rove the transit system inspecting proof of payment within the areas. Random inspection would consist of inspection of tickets held by all passengers on a selected car, train, platform, mezzanine or station. The stations would be designed to permit a large contingent of fare inspectors to inspect all patrons exiting the station.

Legislation for enforcement of fare evasion ordinances is already in-place in the State of California. Under P.U.C. Code 120450, anyone caught attempting to evade payment of fare may be fined up to $50. P.U.C. Code 120104 also permits any employee of a transit agency or any contracted personnel of the agency to cite violations if that person is present during the act. Special legislation has enabled the San Diego Metropolitan Transit Development Board to set higher fines after the second violation; this legislation could be amended to permit the SCRTD to do the same.

Under existing statutes, the San Diego MTDB receives 85 percent of any fines collected through municipal courts in the City and County of San Diego; the court system keeps the remaining 15 percent and assesses an additional $10 court fee on the defendant. A similar arrangement could be investigated for use in the City and County of Los Angeles.

CHAPTER 3

EVALUATION OF THE ALTERNATIVES

Evaluation of the two system alternatives focused on the degree to which each would meet certain criteria. These criteria established by the Metro Rail Project staff and the fare collection consultant, measured the achievement of the primary objectives stated in Chapter 1, as well as the impact on passengers and RTD operations. The criteria included:

- System flexibility;
- System cost;
- Fare enforcement;
- Administrative requirements; and
- Passenger convenience.

A summary comparison of the alternatives is presented in Table 3-1. The barrier-free system has some advantages over the automatic barrier system:

- It would be less costly to implement;
- It could be less costly to operate (assuming fare evasion levels will be at acceptable levels);
- It would be more convenient to use;
- It would be more reliable; and
- It would permit greater integration of bus and rail fares.

TABLE 3-1
EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES

Criterion	Conclusion	Automatic Barrier	Barrier-Free
System Flexibility	Both systems perform well.	. Can accommodate zone or distance-based fares. . Permits transferring between bus and rail fare structures. . Lack of media commonality can limit integration.	. Can accommodate zoned fares; difficult to implement distance-based fares. . Permits transferring between bus and rail fare structures. . Media commonality enhances integration of fares. . Can be unified with barrier-free on light rail system.
Cost	Barrier-free is superior; however, cost to courts unknown.	. $18.2 million capital investment. . $ 4.9 – 5.5 million annual operating cost. . $ 7.3 – 7.8 million annualized equivalent cost.	. $ 7.1 million capital investment. . $ 4.4 – 5.2 million annual operating cost. . $ 5.3 – 6.1 million annualized equivalent cost. . Cost incurred by courts in collection and prosecution of fines is unknown, but will be high; ability to recover costs must be further examined.

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EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES
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Criterion	Conclusion	Automatic Barrier	Barrier-Free
Fare Enforcement	Barrier is superior.	. All fares inspected. . Minimal jumping of fare gates expected. . Potential abuse of reduced fares. . Poor time control on transfers. . Ticket counterfeiting difficult.	. Small percentage of fares inspected. . Higher percentage of fare evasion anticipated. . Manual inspection controls abuse of reduced fares. . Good time control on transfers. . Ticket counterfeiting potential similar to bus system.
Administrative Requirements	Each system has its advantages.	. Requires encoding, distributing and recycling tickets, passes, and transfers specifically for Metro Rail use. . Requires bus driver to issue two types of transfers — bus and rail. . Places no burden on court system. . Can be designed to provide detailed ridership statistics. . Permits control of access to platform, in emergencies.	. Uses same passes, transfers as bus system. . Bus operator continues to dispense one type of transfer. . Adds to heavy burden on court systems. . Requires an extensive reporting system for evasion-related information. . Requires origin-destination surveys and passenger counts to collect ridership statistics.

TABLE 3-1

EVALUATION SUMMARY OF FARE COLLECTION SYSTEM ALTERNATIVES

(Continued)

Criterion	Conclusion	Automatic Barrier	Barrier-Free
Passenger Convenience	Barrier-free is superior.	. Requires three-six (3-6) steps to use. . Lower equipment reliability could inconvenience patrons more often; a failure will occur once every 200 to 800 passenger trips. . Risks no fine for making a mistake in using system.	. Requires one-three (1-3) steps to use. . Reliability could be higher; failure will occur every 500 to 2,000 trips. . Risks a fine for making a mistake; however, inspectors and courts can be given discretion in fining patrons.

The automatic barrier system, on the other hand, is the more traditional of the two alternatives:

- It would ensure collection of virtually all revenue;
- It would not require legislative action or regular use of the courts;
- It would provide the flexibility RTD requires;
- It would permit control of access to the platforms; and
- It could be designed to gather pertinent ridership statistics.

The evaluation is discussed by criterion in the sections that follow.

3.1 SYSTEM FLEXIBILITY

Flexibility of the system alternatives was assessed by the degree of fare structure complexity that could be achieved and by the degree of integration that would be possible with other modes in the region.

Overall, the two system concepts can be considered equally flexible. Each, however, has certain advantages over the other.

Fare Flexibility - Flexibility in setting fares was given a high priority in developing the system alternatives. Thus, each alternative meets this criterion. Either concept can provide a high degree of flexibility.

In terms of ultimate flexibility, the automatic barrier system concept has an advantage in its ability to accommodate multi-trip, stored-valued tickets with a distance-based fare structure, as with BART in San Francisco and WMATA in Washington. A barrier-free system works best with a limited number of zones; this prevents the system from becoming too confusing to the patron.

The barrier system has one disadvantage in that the potential for abuse of reduced single-trip fare and the cost of administration and control are such that it would be best not to accommodate that type of fare. The manual inspection process for barrier-free, on the other hand, is such that use of all reduced fares could be effectively controlled.

System Integration - As developed, either fare collection system for Metro Rail would permit integration with the existing fare structure and fare collection method of the bus system. Transferring between bus and rail would be possible. However, commonality of media would permit more cohesive integration with the barrier-free system. A barrier system would limit use of Metro Rail by pass holders to those with the machine-readable passes. Use of the rail system would not be possible with a printed bus pass, should SCRTD issue separate media for bus and rail passes. With the barrier-free system, it would be possible to permit any pass holder to use Metro Rail (even if a single-trip upgrade must be purchased at the ticket vendor).

Consideration must also be given to the fare-setting flexibility that would be possible on the bus system and the future light rail lines if the fare collection concept is expanded to those modes. The fare collection alternatives selected for Metro Rail should permit a unified fare structure to be implemented, with the flexibility to institute graduated fares region-wide.

In theory, either fare collection system could be adapted to fully integrate the fare structures and fare collection processes of all modes in the region. The program underway in Portland, Oregon will show how well self-service, barrier-free fare collection can be applied to regional bus systems in a North American city. Portland, with a zoned-fare structure, utilizes procedures and equipment that could be adapted to RTD.

Similarly, the testing in revenue service of magnetically-encoding read/write equipment on express buses in San Diego will demonstrate the adaptability of machine reading and encoding technology to the bus operating environment.

Further analysis would be required to determine the advantages and disadvantages of each system if it is adapted to bus and light rail operations. However, the self-service system appears to have operational advantages in that it may permit most passengers to board and alight from any door on the vehicle; the use of machine read/write technology would require control of both entry and exit through the front door.

3.2 SYSTEM COSTS

Preliminary engineering estimates indicate that the barrier-free system would be lower in both capital and in annual operating cost. Implementation of an automatic barrier system is estimated to cost approximately $18.2 million, while a barrier-free system is expected to require a capital expenditure of about $7.1 million, or 60 percent less. This difference is the result of the need for greater quantities of more complex equipment for the barrier system. The anticipated capital costs for each system are itemized in Tables 3-2 and 3-3 and are further detailed in Appendix D. Actual costs could vary by as much as 20 percent at the time of procurement due to terms of the procurement contract and degree of competition among manufacturers. The capital cost estimates do not include the construction of fare collection support facilities. If included, these could increase the advantage of barrier-free, because the barrier system may require larger facilities for equipment maintenance and media handling.

Operation and maintenance of the barrier system is estimated to cost $5.3 million annually, compared to $4.8 million for the barrier-free system. For the barrier system, maintenance of the more sophisticated equipment would be a major cost element. The major cost element for the barrier-free system would be the fare enforcement function. These operating cost estimates are itemized in Tables 3-4 and 3-5 and are further explained in Appendix E.

Sensitivity analyses were performed to determine the extent to which these operating and maintenance costs might vary under different conditions. The analyses examined the

TABLE 3-2

CAPITAL COST ESTIMATE – BARRIER SYSTEM (1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Fare Collection Equipment			
. Bill Changers	93	$ 11,000	$ 1,023,000
. Ticket Vendors	146	37,000	5,402,000
. Bi-Directional Fare Gates	106	26,000	2,756,000
. Uni-Directional Fare Gates	84	20,000	1,680,000
. Handicapped Fare Gates	23	4,500	103,500
. Booth Control Panels	23	13,000	299,000
. Transfer Dispensers	47	6,500	305,500
. Add-Fares	48	27,000	1,296,000
Communications and Central Control			
. Passenger Assistance Phone	23	1,000	23,000
. Central Control System	1	100,000	100,000
Support Equipment			
. Magnetic Encoders	3	140,000	420,000
. Revenue Carts	32	6,000	192,000
Installation			
. Station Equipment	16	2,500	40,000
. Central Data System	–	20,000	20,000
Other			
. Training and Manuals	–	200,000	200,000
. Spares and Test Equipment	–	800,000	800,000
. Initial Supply of Media	–	360,000	360,000
. Non-Recurring Costs	–	3,200,000	3,200,000
Total			$18,220,000

TABLE 3-3
CAPITAL COST ESTIMATE – BARRIER-FREE SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Fare Collection Equipment			
. Ticket Vendor w/Canceler	165	$ 25,000	$4,125,000
. Bill Changers	81	11,000	891,000
Communications and Central Control			
. Passenger Assistance Phone	23	1,000	23,000
. Central Control System	1	60,000	60,000
Support Equipment			
. Revenue Carts	32	6,000	192,000
Installation			
. Station Equipment	16	1,000	16,000
. Central Data System	–	15,000	15,000
Other			
. Training and Manuals	–	70,000	70,000
. Spares and Test Equipment	–	300,000	300,000
. Initial Supply of Media	–	146,500	146,500
. Non-Recurring Costs	–	1,254,000	1,254,000
Total			$7,092,500

TABLE 3-4
ANNUAL OPERATING AND MAINTENANCE COST ESTIMATE
BARRIER SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Labor Requirements			
. Field Technicians	37	$ 34,000	$1,258,000
. Shop Technicians	9	40,800	367,200
. Equipment Servicers	8	34,000	272,000
. Supervisors, Maintenance	4	40,400	161,600
. Revenue Servicers	3	28,700	86,100
. Ticket Encoding Clerks	6	28,700	172,200
. Transit Police	6	30,500	183,000
. Bill Handling Clerks	12	28,700	344,000
. Revenue Clerks	8	28,700	229,600
. Revenue Supervisors	3	31,600	94,800
Overhead Burden	—	25%	792,000
Materials and Supplies			
. Ticket Supply	—	358,700	358,700
. Parts and Miscellaneous	—	324,200	324,200
Contingency	—	15%	696,600
Total			$5,340,000

TABLE 3-5
ANNUAL OPERATING AND MAINTENANCE COST ESTIMATE
BARRIER-FREE SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Labor Requirements			
. Field Technicians	15	$ 34,000	$ 510,000
. Shop Technicians	3	40,800	122,400
. Equipment Servicers	4	34,000	136,000
. Supervisors, Maintenance	3	40,400	121,200
. Revenue Servicers	3	28,700	86,100
. Transit Police	8	30,500	244,000
. Fare Inspectors	39	27,700	1,080,300
. Supervisors, Inspectors	4	30,500	122,000
. Bill Handling Clerks	12	28,700	344,000
. Revenue Clerks	8	28,700	229,600
. Revenue Supervisors	3	31,600	94,800
Overhead Burden		25%	772,600
Materials and Supplies			
. Ticket Supply	—	151,500	151,500
. Parts and Miscellaneous	—	117,800	117,800
Contingency	—	15%	619,900
Total			$4,752,200

effects of increasing fare enforcement levels, increasing equipment reliability and utilizing a station attendant. This last assumption considered using the attendant for "finger-tip" maintenance of equipment. The results, presented in Table 3-6, show that for the possibilities considered, costs would range between $4.9 million and $5.4 million for barrier and $4.3 million and $5.2 million for barrier-free.

An annualized equivalent cost analysis was undertaken to permit a comparison of overall costs. The costs presented in Tables 3-7 and 3-8 were used. Utilizing a 12 percent capital discounting rate as established by Metro Rail and a projected 20-year life of equipment, the annualized cost of barrier is expected to be $7.7 million with a range of $7.3 to $7.8 million. For barrier-free the annualized cost is expected to be $5.7 million, with a range of $5.3 to $6.1 million in 1982 dollars.

3.3 FARE ENFORCEMENT

The two system alternatives utilize very different methods to ensure that patrons will pay the proper fare.

The barrier system is superior in its ability to ensure proper payment by all but an insignificant number of patrons. A substantially higher number could evade fare payment on the barrier-free system. If properly implemented, however, any revenue loss can be completely or mostly recovered by the collection of fines.

TABLE 3-6
OPERATING AND MAINTENANCE COST VARIATIONS
(1982 DOLLARS)

Barrier System		
Anticipated O&M Cost	$5,340,000	
Best Reliability Estimate	(425,000)	
Lower Cost Range		$4,915,000
Anticipated O&M Cost	$5,340,000	
Worst Reliability Estimate	106,000	
Upper Cost Range		$5,446,000
Barrier-Free System		
Anticipated O&M Cost	$4,752,200	
Best Reliability Estimate	(127,452)	
Lower Evasion Rate (4%)	(276,648)	
Lower Cost Range		$4,348,100
Anticipated O&M Cost	$4,752,200	
Worst Reliability Estimate	81,000	
Increased Inspection Rate	359,600	
Upper Cost Range		$5,192,800

TABLE 3-7
BARRIER SYSTEM ANNUALIZED COST ESTIMATE
(1982 DOLLARS)

Annualized Capital Cost Equivalent:	
$18,220,000 * 0.133879 = (12%, 20 yrs.)	$2,439,000
Less Annualized Salvage Value Equivalent	
($18,220,000 * 0.05) * 0.013879	($13,000)
Anticipated Annual O&M Costs:	$5,340,000
Total Annualized Cost Estimate:	$7,766,000

Sensitivity Analysis

Lowest Estimate of O&M Costs: $4,915,000	$7,341,000
Highest Estimate of O&M Costs: $5,466,000	$7,872,000

TABLE 3-8
BARRIER-FREE SYSTEM ANNUALIZED COST ESTIMATE
(1982 DOLLARS)

Annualized Capital Cost Equivalent:	
$7,092,500 * 0.133879 = (12%, 20 yrs.)	$950,000
Annualized Salvage Value Equivalent	
($7,092,500 * 0.05) * 0.013879	($5,000)
Annual O&M Costs:	$4,752,000
Total Annualized Life Cycle Cost Estimate:	$5,697,000

Sensitivity Analysis

Lowest Estimate of O&M Costs: $4,348,000	$5,293,000
Highest Estimate of O&M Costs: $5,193,000	$6,138,000

Automatic Barrier - With the barrier system, evasion of fare payment may occur in two ways. Some patrons may jump the fare gates. Others may purchase or steal reduced fare tickets or passes from students or senior citizens, when they themselves are ineligible to use them. Counterfeitting of machine-readable tickets should, however, be very difficult.

It is difficult to estimate the amount of cheating that would occur in Los Angeles. In 1976, the Atlanta transit system surveyed rail systems to determine estimated fraud rates; they reported estimates of less than 0.5 percent to 2.0 percent.[1] More recently, in a survey by Booz, Allen, PATCO (Philadelphia) and MARTA (Atlanta) reported "insignificant" fare evasion.[2] BART, on the other hand, reported that it had been losing one percent of total revenue to misuse of reduced-fare, multi-trip tickets. Stepped-up policing of fare gate activity subsequently cut this figure in half.[3]

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(1) Metropolitan Atlanta Rapid Transit Authority, "No-Barrier Fare Collection," Transportation Research Record, 612, June 1976.

(2) Booz, Allen & Hamilton Inc., Surveys of PATCO and MARTA, April 1982.

(3) Booz, Allen & Hamilton Inc., Interview with BART Assistant Treasurer, June 1982.

On the Metro Rail, the loss of 0.5 percent to 1.0 percent of potential revenue due to fare gate jumpers or misuse of reduced fares could translate into \$0.28 million to \$0.56 million annually.(4)

<u>Barrier-Free</u> - Fare evasion is inevitable with the barrier-free system. Some patrons will prefer not to purchase tickets, despite the risk of inspection and fine. If the combination of inspection level and amount of fine is sufficiently high, most passengers will find it uneconomical to evade the fare.

It is difficult to determine the fare evasion that could be expected on Metro Rail, as this would be the first application to rail rapid transit in the U.S. and the first application to transit in the Los Angeles area. The Atlanta transit authority examined analogous self-service situations when it was analyzing fare collection alternatives for its rail rapid transit system - - then in the planning stage - - and estimated that a barrier-free fare collection system would result in 2.0 to 6.5 percent of the riders cheating the fare.(5)

Actual experience with barrier-free fare collection in other North American cities has been more positive. Reported evasion rates range from 0.3 percent in San Diego

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(4) Based on an average 60¢ fare, as defined by Metro Rail staff for planning purposes.

(5) Metropolitan Atlanta Rapid Transit Authority, "No-Barrier Fare Collection," <u>Transportation Research Record, 612</u>, June 1976.

(with 41 percent inspection) to 1.0 percent in Edmonton and Calgary (with 2 to 5 percent inspection).(6)

There is no reason to expect that fare evasion would differ among transit modes. While passenger volumes would be higher on a rapid transit system, the controlled environment of enclosed stations should expedite the inspection of fares. It is unknown, however, if patrons in Los Angeles would be more prone to evading fare than in the smaller cities of San Diego, Edmonton and Calgary.

If we assume that six percent of the riders on Metro Rail will try to evade fares, the potential revenue loss could be $3.4 million annually. A properly designed fine structure and enforcement program can recover most or all of this through the fines collected. In fact, regardless of the actual evasion rate, with an average fare of 60¢, an average fine of $25, and the return of 85 percent of the fines collected, only 2.8 percent of the total fare evaders would need to pay the fine for the RTD to recover the loss of revenue. Thus, if six percent of all passengers are inspected (catching six percent of the fare evaders), then half of those caught would need to pay the fine for RTD to recover the loss of revenue.

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(6) Booz, Allen & Hamilton Inc., <u>Fare Collection Technology Assessment</u>, prepared for the Metro Rail Project, August 1982.

3.4 ADMINISTRATIVE REQUIREMENTS

Assessment of administrative requirements focused on those which would be unique to each alternative. Overall, each system would introduce certain administrative complexities to the RTD, and neither appears to have a clear advantage over the other.

The barrier system's unique administrative requirements would be a result of the necessary machine-readable media. A new system for encoding, distributing and possibly recycling transfers, passes and tickets would be necessary. The use of machine-readable transfers would also place added responsibility on the bus operators who would need to distinguish between patrons requesting transfers to the bus and those requesting transfers to Metro Rail. Additional administrative requirements would be related to management of equipment maintenance and spare parts inventory control, which would be more complex due to the number of units and the associated reliability. One administrative advantage of the barrier system would be the ability to collect detailed ridership statistics on a continuous basis.

Administrative issues associated with barrier-free would be related to fare enforcement. An extensive reporting system would also be required to track offenders and the status of their citations. Records to control repeat offenders would be needed, along with an action plan to curb repeated offenses. Further analysis is necessary to determine the appropriate division of responsibilities between the court systems and RTD, as well as the procedures by which the court systems in Los Angeles might best process these cases. A significant increase in court capacity may be necessary to handle the additional case load created by the fare evasion citations, particularly if evasion levels are high and a significant number choose to contest the fine in court. Currently, 20,000 traffic and 145,000 parking citations are written in the City of Los Angeles each month.[7] Depending upon the evasion rate, Metro Rail could add between 18,000 and 48,000 fare citations to this load. Special state legislation would also be necessary to institute the appropriate judicial processes. Another administrative requirement of the barrier-free system is management of the manual collection of ridership statistics through the conduct of regular passenger counts and origin-destination studies.

3.5 PASSENGER CONVENIENCE

Passenger convenience is judged by a series of measures, namely:

- The number of steps required to use the system;
- The probability that a malfunction will occur; and
- The penalty incurred by not understanding the system or making a mistake.

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(7) Interview with Mr. Lott, Chief of Traffic Division, L.A. Municipal Court, September, 1982.

Overall, the barrier-free system is judged to be more convenient to the passenger. On a regular basis, fewer steps would be required for its use. A passenger using a barrier-free system is also less likely to encounter a malfunction. On the negative side, the patron who inadvertantly does not have the proper fare risks a warning or fine, a penalty not matched on the barrier system. These issues are discussed in detail below.

Steps Required - With an automatic barrier system, the number of steps required would range from three to six. Everyone would need to use the fare gates and either a ticket vendor, sales outlet (pass) or bus (transfer). Some might also require use of the bill changers, transfer dispensers and add-fare machines.

The barrier-free concept generally requires nothing more than the purchase of a ticket at the start of the trip from either a ticket vendor, sales outlet (passes) or bus (transfer). For the system alternative defined for Metro Rail, a bill changer may also be required. Including inspection, therefore, a patron would require one to three steps to use the system.

System Reliability - At any point during its use, an equipment malfunction may cause patron inconvenience. Based on estimates of equipment reliability provided by Kaiser Engineers, an equipment failure may be expected to occur once every 200 to 800 trips on the automatic barrier system. By comparison, the average patron may encounter a mechanical failure once every 500 to 2,000 trips on the barrier-free system. The frequency of failure could be nearly three times greater for the barrier system, because of the greater quantity and complexity of equipment.

Impacts of Mistakes - The barrier system would be less severe in dealing with patron mistakes. If the correct fare is not paid, the fare gate will not permit the patron through the fare gate aisle. Add-fare units would permit a patron to pay the additional fare required.

On the barrier-free system, a patron caught without the correct fare risks a fine. As mentioned previously, however, the enforcement program can be developed in a manner that gives both the inspectors and courts discretion with regard to issuing warnings or setting the level of fine.

CHAPTER 4
CONCLUSIONS

Evaluation of the two system alternatives does not point to a clear favorite. The barrier-free system would have certain operational and cost advantages to RTD. Compared to the automatic barrier system, it would:

- Cost much less to implement;
- Cost less to operate;
- Be more convenient for the passenger to use;
- Be more reliable; and
- Permit more complete integration of bus and rail fares.

If a self-service, barrier-free system is implemented on the region's planned light rail lines, a similar implementation on Metro Rail would permit a fully unified fare structure and fare collection system among these rail lines. In addition, with barrier-free fare collection, all fare types, including reduced single-trip fares, could be accommodated without difficulty or risk of abuse.

The key concern with the barrier-free system is the lack of experience in a city comparable to Los Angeles or on a system the size of Metro Rail. It cannot be projected with any certainty how the cultural diversity unique to Los Angeles will influence the degree of public acceptance of the barrier-free concept and the resulting magnitude of fare evasion. A high evasion rate would severely tax the local court system with added case load. If public reaction and a high case load make the fines unenforceable, the RTD would stand to lose a significant amount of revenue. Furthermore, if the RTD were to experiment with barrier-free fare collection, and the results were unsatisfactory, the cost to RTD and the inconvenience to passenger of converting to a barrier system would be high.

The automatic barrier system offers a more traditional means of collecting fares. It is in widespread use in various forms on rail transit throughout North America, and experience in comparable cities indicates that public acceptance is likely to be high. Compared to the barrier-free system it would:

- Ensure collection of virtually all rail revenues;
- Be independent of the court system;
- Not require special legislation;
- Provide the flexibility that RTD needs to set and adjust Metro Rail fares; and
- Permit control of patron access to the platforms in emergencies.

The barrier system could also be designed to provide detailed ridership statistics on a regular basis.

An automatic barrier system can be expected to have the relative disadvantage of higher cost, lower system reliability, and lower passenger convenience. The encoding, distribution and possible recycling of machine-readable tickets, passes and transfers could also be an administrative disadvantage.

Given the current concerns associated with the barrier-free system, it is recommended that Metro Rail be designed to accommodate an automatic barrier system, and that operational and design criteria be developed for this system. At the same time, RTD can continue to monitor the experiences of other systems having barrier-free fare collection; further analysis can be conducted at a later date. The facilities requirements for the barrier system are such that a barrier-free system is not precluded should a future determination be made to implement it.

APPENDIX A:

DETAILED DESCRIPTION OF SYSTEM OPERATIONS

APPENDIX A:

DETAILED DESCRIPTION OF SYSTEM OPERATIONS

This appendix contains a series of tables detailing the functional aspects of system operations for both the barrier and barrier-free alternatives. The tables present the specific passenger procedures, media requirements, personnel responsibilities and equipment functions utilized in the comparative analysis.

TABLE A-1
AUTOMATIC BARRIER SYSTEM
PASSENGER PROCEDURES

Fare Element	Locations	Activity
Regular Single-Trip (Rail Only)	Entry Station	. Purchase ticket to destination rail station from ticket vendor. . Insert ticket into fare gate, enter through gate. . Retain ticket for exit.
	Exit Station	. Insert ticket into fare gate, exit through gate (ticket is captured). . If not valid for exit, use add-fare machine as described below.
Regular Single-Trip (Rail-Bus)	Entry Station	. Same as above, with the following addition: . While in paid area of station, purchase transfer ticket from transfer dispenser.
	Exit Station	. Same as above; retain tarnsfer for boarding bus.
	Bus	. Present transfer to bus operator.
Regular Single-Trip (Bus-Rail)	Bus	. Pay bus fare plus transfer charge. . Obtain machine-readable transfer ticket.
	Entry Station	. Insert transfer ticket into ticket vendor. . Pay proper fare to destination (less credit for transfer) into vendor. . Take reencoded ticket from vendor. . Insert ticket into fare gate, enter through gate. . Retain ticket for exit.
	Exit Station	. Insert ticket into fare gate, exit through gate (ticket is captured). . If not valid for exit, use add-fare machine as described below.

TABLE A-1
AUTOMATIC BARRIER SYSTEM
PASSENGER PROCEDURES
(Continued)

Fare Element	Locations	Activity
Regular Single-Trip (Bus-Rail-Bus)	Bus	. Same as above.
	Entry Station	. Same as above; purchase transfer ticket from transfer dispenser.
	Exit Station	. Same as above; retain transfer for boarding bus.
	Bus	. Present transfer to bus operator.
Regular Multi-Trip (Rail)	Sales Outlet	. Purchase pre-encoded fixed-value ticket.
	Entry Station	. Insert ticket into fare gate, enter through gate. . Retain ticket for exit.
	Exit Station	. Insert ticket into fare gate, exit through gate. . Retain ticket for future use. . If not valid for exit, use add-fare machine as described below.
Regular Multi-Trip (Rail-Bus)		. Same as above; on bus, display ticket for inspection by bus driver; retain for future use.
Regular Multi-Trip (Bus-Rail)		. Same as above; on bus, display ticket for inspection by bus operator; retain ticket for rail use.
Regular Multi-Trip (Bus-Rail-Bus)		. Same as above; on bus, display ticket for inspection by bus operator.

TABLE A-1
AUTOMATIC BARRIER SYSTEM
PASSENGER PROCEDURES
(Continued)

Fare Element	Locations	Activity
Regular Monthly or Bi-Weekly Pass (All Trips)	Sales Outlet	. Purchase machine-readable pass.
	Bus	. Display pass to bus operator.
	Entry Station	. Insert pass into fare gate; enter through gate. . Retain pass for exit.
	Exit Station	. Insert pass into fare gate; if not valid for exit, use add-fare machine as described below; exit through gate. . Retain pass for future use. . Display pass to bus operator.
Reduced Single-Trip		. Not offered.
Reduced Multi-Trip		. Same procedure as Regular Multi-Trip. . Must present proper ID when purchasing ticket and when boarding bus.
Reduced Monthly or Bi-Weekly Pass		. Same procedure as Regular Pass. . Must present proper ID when purchasing pass and when boarding bus.

* * * * *

Add-Fare Procedure	Exit Station	. If ticket or pass is not valid for exit, go to add-fare machine: — insert ticket or pass — pay additional fare as shown by machine — take ticket or pass . Insert ticket or pass in fare gate, exit through gate.

TABLE A-2

AUTOMATIC BARRIER SYSTEM DESCRIPTION OF MEDIA

Media	Type	Point of Sale or Issue
Machine-Readable Ticket	. Regular single trip	. Ticket vendors
	. Regular multi-trip	. Sales outlet
	. Reduced multi-trip	. Sales outlet
Machine-Readable Pass	. Regular monthly pass	. Sales outlet
	. Reduced-fare monthly pass	. Sales outlet
Machine-Readable Transfer	. Regular bus-rail transfer	. Bus operators
Printed Transfer	. Regular rail-to-bus transfer	. Transfer dispenser

TABLE A-3
AUTOMATIC BARRIER SYSTEM
DESCRIPTION OF PERSONNEL

Personnel	Functions
Central Control Operators	. Assist patrons via phone from central location. . Diagnose ticket problems via handicapped gate console diagnostic capability. . Release fare gate for passenger entry, if required. . Monitor system equipment, notify technicians of problems, via Supervisor of Communications. . Control system equipment status via remote control. . Monitor system equipment area via CCTV to provide security. . Address station area via public address.
Field Maintenance Technicians	. Maintain/repair equipment in the field through component change-out.
Shop Maintenance Technicians	. Overhaul equipment, heavy equipment repair, repair components in shop.
Equipment Servicers	. Collect revenue from ticket vendors, add-fare machines and transfer dispensers. . Restock change bins in ticket vendors and add-fare machines with coin. . Restock tickets in ticket vendors and transfer dispensers. . Remove captured tickets from fare gates.
Revenue Collectors	. Transport revenue carts from station to central counting facility.
Ticket Encoders	. Encode transfers and monthly passes for distribution to bus divisions and sales outlets.
Security Guards	. Provide security during revenue collection.

TABLE A-4
AUTOMATIC BARRIER SYSTEM
DESCRIPTION OF EQUIPMENT

Equipment	Features
Fare Gate	. Controls entry to and exit from paid area of station . Tripod turnstile permits entry or exit of one patron with insertion of valid ticket or pass . Accepts machine-readable tickets or passes via ticket transports, one for entry direction, one for exit direction . Reads and writes ticket/pass encoding on both entry and exit: – Verifies ticket/pass validity, including time, date, and/or location of use – Encodes to prevent passback of passes – Deducts fare of trip from total value of ticket during exit sequence . Captures expended or expired tickets and passes; returns others to patron . Displays appropriate message to patron on both entry and exit, including a diagnosis of ticket problem (if appropriate) and on exit the remaining value of the ticket . Internal clock can be utilized to reject tickets or passes not valid for time of day of attempted use . Microprocessor will permit flexibility in programming fare gate logic . Gate can be set either locally or by remote control from central control for single or bi-directional operation; can also be removed from service or permitted to free-wheel

TABLE A-4
AUTOMATIC BARRIER SYSTEM
DESCRIPTION OF EQUIPMENT
(Continued)

Equipment	Features
Handicapped Gate	. Swing gate opens in either direction, shuts automatically
	. Accepts machine-readable tickets, and passes via ticket transport
	. Ticket verification features similar to fare gate as above
	. Can be programmed to accept only handicapped and district passes
	. Has diagnostic capability linked to central control
	. Can be set to override selected ticket codes or opened by remote control from central control
Ticket Vendor	. Displays fare due when button to desired destination is pressed. Fare displayed decreases to zero as balance of fare is deposited
	. Accepts U.S. coins in coin slot.
	. Accepts in ticket-insert slot bus-issued machine-readable transfers or low-value multi-trip tickets as credit toward purchase
	. Encodes and issues machine-readable tickets with appropriate value to destination
	. Gives change with purchase
	. Internal time clock adjusts fare levels if peak/off-peak fare differential is implemented
	. Coin deposit is escrowed until completion of ticket purchase

TABLE A-4
AUTOMATIC BARRIER SYSTEM
DESCRIPTION OF EQUIPMENT
(Continued)

Equipment	Features
Passenger-Assistance Phone	. Located in line with fare gates so as to be accessible to patrons on either side . Links passenger with central control
Transfer Dispenser	. Accepts U.S. coins, in exact change . Issues rail-to-bus transfer, printed with date, time and station . Located in paid area of station
Bill Changer	. Accepts dollar bills . Vends dollar coins . Located in paid and free area
Add-Fare	. Accepts U.S. coins . Reads inserted ticket and calculates additional fare required to exit . Displays fare due and decrements amount as balance is deposited . Re-encodes ticket for exit with payment of additional fare . Gives change with upgrade of ticket

TABLE A-4
AUTOMATIC BARRIER SYSTEM
DESCRIPTION OF EQUIPMENT
(Continued)

Equipment	Features
Central Control Equipment	. Monitor status of station equipment, control equipment
	. Permit diagnosis of tickets inserted into designated fare gate
	. Permit communication with passenger via PABX system
	. Permit public address of passengers in station
	. Monitor station equipment area via CCTV
High Speed Magnetic Encoder	. Encodes passes for use in fare gates
Revenue Cart	. Push cart with vault for transporting revenue; also transports ticket stock

TABLE A-5
SELF-SERVICE, BARRIER-FREE SYSTEM
PASSENGER PROCEDURES

Fare Element	Locations	Activity
Regular Single-Trip (Rail Only)	Entry Station	. Purchase ticket to desired rail destination from ticket vendor.
	Platform/Train	. Present ticket upon request to fare inspector.
	Exit Station	. No activity required.
Regular Single-Trip (Rail-Bus)	Entry Station	. Purchase ticket to desired rail destination with transfer capability from ticket vendor.
	Platform/Train	. Present ticket upon request to fare inspector.
	Exit Station	. No activity required; retain ticket for boarding bus.
	Bus	. Present ticket to bus operator.
Regular Single-Trip (Bus-Rail)	Bus	. Pay bus fare plus transfer charge.
		. Obtain transfer coupon.
	Entry Station	. Purchase ticket from vendor (with credit for transfer coupon).
	Platform/Train	. Present ticket and transfer upon request for fare inspector.
	Exit Station	. No activity required.
Regular Single-Trip (Bus-Rail-Bus)		. Same as above, with the following additional step:
		. Present bus transfer coupon and rail ticket to second bus operator to board second bus.

TABLE A-5
SELF-SERVICE, BARRIER-FREE SYSTEM
PASSENGER PROCEDURES
(Continued)

Fare Element	Locations	Activity
Regular Multi-Trip (Rail)	Sales Outlet	. Purchase multi-trip ticket between desired zones.
	Entry Station	. Insert ticket into cancellor; retain as proof-of-payment.
	Platform/Train	. Present ticket upon request by fare inspector.
	Exit Station	. No activity required.
Regular Multi-Trip (Rail-Bus)		. Same as above, with the following additional step:
		. Display ticket to bus driver to board bus.
Regular Multi-Trip (Bus-Rail)	Sales Outlet	. Purchase multi-trip ticket between desired zones.
	Bus	. Display ticket to bus operator.
	Entry Station	. Insert ticket into ticket cancellor.
	Platform/Train	. Present ticket upon request by fare inspector.
	Exit Station	. No activity required.
Regular Multi-Trip (Bus-Rail-Bus)		. Same as above with the following additional steps:
		. Display ticket to second bus operator when boarding second bus.
Regular Monthly or Bi-Weekly Pass (All Trips)	Sales Outlet	. Purchase monthly pass.
	Bus	. Display pass to bus operator.
	Entry Station	. No activity required.
	Platform/Train	. Present pass on request to fare inspector.
	Exit Station	. No activity required; retain pass.
Reduced Single-Trip		. Same procedure as Regular Single-Trip.
		. Present proper ID and ticket to fare inspector on request and to bus driver when transferring to bus.
Reduced Multi-Trip		. Same procedure as Regular Multi-Trip.
		. Present proper ID and ticket to fare inspector on request and to bus driver when transferring.
Reduced Monthly Pass		. Same procedure as Regular Pass.
		. Present proper ID and pass to fare inspector on request and to bus driver when transferring.

TABLE A-6
SELF-SERVICE BARRIER FREE SYSTEM
DESCRIPTION OF MEDIA

Media	Types	Point of Sale or Issue
Printed Tickets	. Regular single-trip to desired zone with/without transfer or with transfer credit	Ticket Vendors
	. Reduced single-trip to desired zone with/without transfer or with transfer credit	
	. Regular multi-trip	Sales Outlets
Printed Pass	. Regular montly pass	Sales Outlets
	. Reduced monthly	Sales Outlets
Transfer Coupon	. All bus-to-rail transfers	Bus Operators

TABLE A-7
SELF SERVICE BARRIER FREE SYSTEM
DESCRIPTION OF PERSONNEL

Personnel	Functions
Fare Inspectors	. Inspect proof-of-payment held by patrons within designated area of station or onboard trains.
	. Issue citation to patron lacking proper and valid proof-of-payment.
	. Assist patrons with service information.
Central Control Operators	. Monitor and control equipment status via remote control.
	. Notify technicians of problems with equipment.
	. Monitor system equipment area via CCTV to provide security.
	. Assist patrons via PABX phone from central location.
	. Address station area via public address.
Field Maintenance Technicians	. Maintain/repair equipment in the field through component changeout.
Shop Maintenance Technicians	. Overhaul equipment, perform heavy repairs, repair components in the shop.
Servicers	. Collect revenue from ticket vendors.
	. Restock change bins in ticket vendors with coins.
	. Restock tickets in ticket vendors.
Revenue Collectors	. Transport revenue carts from station to central counting facility.
Security Guards	. Provide security during revenue collection.

TABLE A-8
SELF-SERVICE BARRIER-FREE SYSTEM
DESCRIPTION OF EQUIPMENT

Equipment	Features
Ticket Vendor	. Accepts U.S. coins, SCRTD tokens
	. Issues printed single-trip to desired destination with choice of the following conditions: – Trip Type: rail only; credit for transfer from bus; added charge for transfer to bus – Fare Type: regular or reduced (E/H or student)
	. Displays fare when appropriate buttons are pushed for destination, trip type and fare type; displayed amount decrements as fare is deposited
	. Internal clock may be utilized to adjust fares by time of day if peak/off-peak differential is implemented
	. Coin is escrowed until transaction is completed and ticket is issued
	. Gives change with ticket purchase
Ticket Cancellor	. Housed within ticket vendor
	. Accepts multi-trip tickets into ticket slot
	. Prints station, time and date on ticket
	. Cuts portion of ticket for print-line control

TABLE A-8
SELF-SERVICE BARRIER-FREE SYSTEM
DESCRIPTION OF EQUIPMENT
(Continued)

Equipment	Features
Passenger Assistance Phone	. Located near ticket vendors, links passenger to central control operator
Central Control Equipment	. Monitors status of station equipment, control equipment . Permits communication with passenger . Permits public address of passengers in station . Monitors station equipment area via CCTV screens
Bill Changer	. Accepts dollar bills . Bends dollar coin . Located near ticket vendors
Revenue Cart	. Push cart with vault for transporting revenue; also carries ticket stock

APPENDIX B:

METRO RAIL PATRONAGE ESTIMATION

APPENDIX B:

METRO RAIL PATRONAGE ESTIMATION

This appendix contains information pertaining to the development of patronage estimates used in the fare collection subsystem alternatives analysis. All ridership estimates are predicated on the work conducted by Barton-Aschman Associates as presented in Patronage Impact of Possible Future Line Extensions, Phase II (March, 1982). The report provided the daily ridership projections, morning peak hour volumes, and morning peak twenty-minute volumes by station for the design year 1995 (Tables B-1 through B-3). Based on these projections, nominal patron arrival rates were estimated for use in sizing the fare collection subsystem (Table B-4). Peak passenger arrival rates were developed using the following assumptions:

- Boarding passengers will arrive at stations at a constant rate throughout the peak twenty-minute period;
- Trains will operate at 3.5-minute headways in the peak period in 1995;
- Two trains may arrive at any station at the same time (i.e., one inbound and one outbound); and
- Morning peak twenty-minute boardings equal evening peak twenty-minute alights, and morning peak twenty-minute alights equal evening peak twenty-minute boardings.

The percentage of riders making intermodal transfers in 1995 was estimated in the Alternatives Analysis/Environmental Impact Statement sponsored by UMTA in April 1980. Transfers are estimed by station for the morning peak hour, evening peak hour and weekday total (Table B-5).

Peak hour passenger volumes and nominal arrival rates were developed for the year 2020 to establish the ultimate capacity requirements of the fare collection subsystem. These estimates were developed based on both a 50 and a 72 percent growth factor over design year volumes (1995), as shown in Table B-6 through B-9.

TABLE B-1
METRO RAIL DAILY RIDERSHIP VOLUMES
(1995)

Station	Boardings Inbound	Boardings Outbound	Boardings Total	Link Volume
Union Station	—	28,500	28,500	
				28,500
1st/Broadway	—	12,200	12,200	
				40,700
5th/Broadway	7,100	28,800	35,900	
				62,400
7th/Flower	3,900	22,400	26,300	
				80,900
Wilshire/Alvarado	8,700	10,000	18,700	
				82,200
Wilshire/Vermont	20,500	10,700	31,200	
				72,400
Wilshire/Normandie	10,000	6,400	16,400	
				68,800
Wilshire/Western	15,400	9,600	25,000	
				63,000
Wilshire/La Brea	11,500	3,800	15,300	
				55,300
Wilshire/Fairfax	21,600	8,200	29,800	
				41,900
Fairfax/Beverly	4,400	3,200	7,600	
				40,700
Fairfax/Santa Monica	7,800	4,700	12,500	
				37,600
Hollywood/Cahuenga	15,500	5,300	20,800	
				27,400
Hollywood Bowl	1,300	100	1,400	
				26,200
Universal City	12,400	600	13,000	
				14,400
North Hollywood	14,400	—	14,400	
Total	154,500	154,500	309,000	

Source: *Barton-Aschman Associates,* Patronage Impact of Possible Future Line Extensions, Phase II, *March 1982.*

TABLE B-2
1995 MORNING PEAK HOUR STATION VOLUMES

Station	Boardings Inbound	Boardings Outbound	Alightings Inbound	Alightings Outbound
Union Station	—	7,110	1,750	—
1st/Broadway	—	2,110	2,040	—
5th/Broadway	350	3,700	6,540	1,840
7th/Flower	120	2,970	4,990	1,040
Wilshire/Alvarado	1,580	1,250	2,320	1,420
Wilshire/Vermont	3,640	1,550	2,210	3,390
Wilshire/Normandie	1,810	430	1,980	1,620
Wilshire/Western	3,350	1,260	2,150	2,100
Wilshire/LaBrea	2,610	490	890	1,480
Wilshire/Fairfax	3,180	760	2,280	4,050
Fairfax/Beverly	890	280	900	650
Fairfax/Santa Monica	2,140	600	1,050	730
Hollywood/Cahuenga	2,990	470	1,490	2,380
Hollywood Bowl	250	10	20	190
Universal City	3,490	80	120	1,100
North Hollywood	4,330	—	—	1,080
Total	30,730	23,070	30,730	23,070

Source: Barton-Aschman Associates, Patronage Impact of Possible Future Line Extensions, Phase II, *March 1982.*

TABLE B-3
MORNING PEAK TWENTY-MINUTE STATION VOLUMES
(1995)

	Boardings			Alightings		
	Inbound	Outbound	Total	Inbound	Outbound	Total
Union Station	—	2,702	2,702	665	—	665
1st/Broadway	—	802	802	775	—	775
5th/Broadway	133	1,406	1,539	2,485	699	3,184
7th/Flower	46	1,129	1,175	1,896	395	2,291
Wilshire/Alvarado	601	475	1,076	882	540	1,422
Wilshire/Vermont	1,383	589	1,972	840	1,288	2,128
Wilshire/Normandie	688	164	852	753	616	1,369
Wilshire/Western	1,273	479	1,752	817	798	1,615
Wilshire/LaBrea	992	186	1,178	338	563	901
Wilshire/Fairfax	1,209	289	1,498	867	1,539	2,406
Fairfax/Beverly	338	107	445	342	247	589
Fairfax/Santa Monica	813	228	1,041	399	278	677
Hollywood/Cahuenga	1,136	179	1,315	566	905	1,471
Hollywood Bowl	95	4	99	8	72	80
Universal City	1,326	31	1,357	46	418	464
North Hollywood	1,646	—	1,646	—	412	412
Total	11,679	8,770	20,449	11,679	8,770	20,449

Source: Barton-Aschman Associates, Patronage Impact of Possible Future Line Extensions, Phase II, *March 1982.*

TABLE B-4
1995 PEAK PATRON ARRIVAL RATES
(PASSENGERS/MINUTE)

Station	Morning Boardings	Morning Alightings	Evening Boardings	Evening Alightings
Union Station	135	111	33	451
1st/Broadway	40	129	39	134
5th/Broadway	77	531	159	257
7th/Flower	59	382	115	196
Wilshire/Alvarado	54	237	71	179
Wilshire/Vermont	99	355	106	329
Wilshire/Normandie	43	228	69	142
Wilshire/Western	88	269	81	292
Wilshire/LaBrea	59	150	45	196
Wilshire/Fairfax	75	401	120	250
Fairfax/Beverly	22	98	30	74
Fairfax/Santa Monica	52	113	33	174
Hollywood/Cahuenga	66	245	74	219
Hollywood Bowl	5	13	4	17
Universal City	68	77	23	226
North Hollywood	82	69	21	274
Total	1,024	3,408	1,023	3,410

Calculations:

- *Boardings/min. = Peak 20-minute boardings/20 minutes.*
- *Alightings/min. = Peak 20-minute alightings/6 trains.*

TABLE B-5
1995 PERCENT OF PATRONS ARRIVING BY BUS

Station	Weekday	A.M. Peak Hour	P.M. Peak Hour
Union Station	43%	43%	44%
1st/Broadway	43%	41%	45%
5th/Broadway	43%	38%	45%
7th/Flower	43%	37%	45%
Wilshire/Alvarado	45%	31%	51%
Wilshire/Vermont	59%	53%	65%
Wilshire/Normandie	61%	55%	68%
Wilshire/Western	61%	56%	67%
Wilshire/La Brea	61%	55%	68%
Wilshire/Fairfax	76%	64%	85%
Fairfax/Beverly	52%	27%	66%
Fairfax/Santa Monica	50%	28%	65%
Hollywood/Cahuenga	60%	43%	71%
Hollywood Bowl	10%	8%	19%
Universal City	55%	47%	78%
North Hollywood	45%	42%	61%
Cumulative Total	52%	–	–

Source: *U.S. Department of Transportation, Urban Mass Transportation Administration,* Alternatives Analysis/Environmental Impact Statement/Report on Transit System Improvements in the Los Angeles Regional Core, April 1980.

TABLE B-6
2020 MORNING PEAK HOUR STATION VOLUMES
(50% GROWTH FACTOR)

Station	Boardings	Alightings
Union Station	10,650	2,635
1st/Broadway	3,165	3,070
5th/Broadway	6,080	12,565
7th/Flower	4,630	9,040
Wilshire/Alvarado	4,245	5,605
Wilshire/Vermont	7,770	8,275
Wilshire/Normandie	3,350	5,400
Wilshire/Western	6,900	6,385
Wilshire/LaBrea	4,650	3,560
Wilshire/Fairfax	5,900	9,495
Fairfax/Beverly	1,755	2,340
Fairfax/Santa Monica	4,110	2,670
Hollywood/Cahuenga	5,190	5,825
Hollywood Bowl	390	315
Universal City	5,345	1,830
North Hollywood	6,500	1,620
Total	80,630	80,630

TABLE B-7
2020 PASSENGER ARRIVAL RATES
(PASSENGERS/MINUTE)
(50% GROWTH FACTOR)

Station	Morning		Evening	
	Boardings	Alightings	Boardings	Alightings
Union Station	203	100	50	405
1st/Broadway	60	117	58	120
5th/Broadway	116	477	239	231
7th/Flower	88	343	172	176
Wilshire/Alvarado	82	213	106	161
Wilshire/Vermont	149	314	157	295
Wilshire/Normandie	64	205	103	127
Wilshire/Western	131	243	121	262
Wilshire/La Brea	88	135	68	177
Wilshire/Fairfax	122	361	180	242
Fairfax/Beverly	33	89	44	67
Fairfax/Santa Monica	79	101	51	156
Hollywood/Cahuenga	99	221	110	197
Hollywood Bowl	7	12	6	14
Universal City	103	70	35	203
North Hollywood	124	62	31	247
Total	1,548	3,063	1,531	3,080

APPENDIX C:

FARE COLLECTION SYSTEM SIZING

APPENDIX C:

FARE COLLECTION SYSTEM SIZING

This appendix details the methodology utilized to estimate fare collection equipment requirements for both the barrier and barrier-free systems. Equipment requirements for 1995 were developed as a foundation for capital cost estimation; equipment needs for 2020 were estimated to ensure that adequate room for expansion is incorporated into station design.

The types of station fare collection equipment addressed in this process are listed in Table C-1. Based on an evaluation of experience at comparable transit systems, tempered by the current SCRTD ridership mix by fare category (Table C-2), system flow charts were developed for both the barrier and barrier-free alternatives depicting the percentage of total patrons expected to use each equipment category (Figures C-1 and C-2).

The equation presented in Table C-3 was used to estimate equipment requirements in a comprehensive and consistent manner. The fare collection systems are sized to accommodate the maximum passenger flows as projected for the peak twenty-minutes of service. The peak twenty-minute period (i.e., A.M. or P.M.) varies from station to station as shown in Appendix B. Peak demand also varies for individual equipment categories. For instance, some categories must be sized for the greatest volume of boarding passengers (e.g., ticket vendors), while others must be sized for the greatest volume of alighting patrons (e.g., add-fare machines).

TABLE C-1
FARE COLLECTION EQUIPMENT

Barrier System

- o Bill Changer
- o Ticket Vendor
- o Bi-Directional Fare Gate
- o Uni-Directional Fare Gate
- o Handicapped Fare Gate
- o Booth Control Panel
- o Transfer Dispenser
- o Add-Fare
- o Assistance Phone

Barrier-Free System

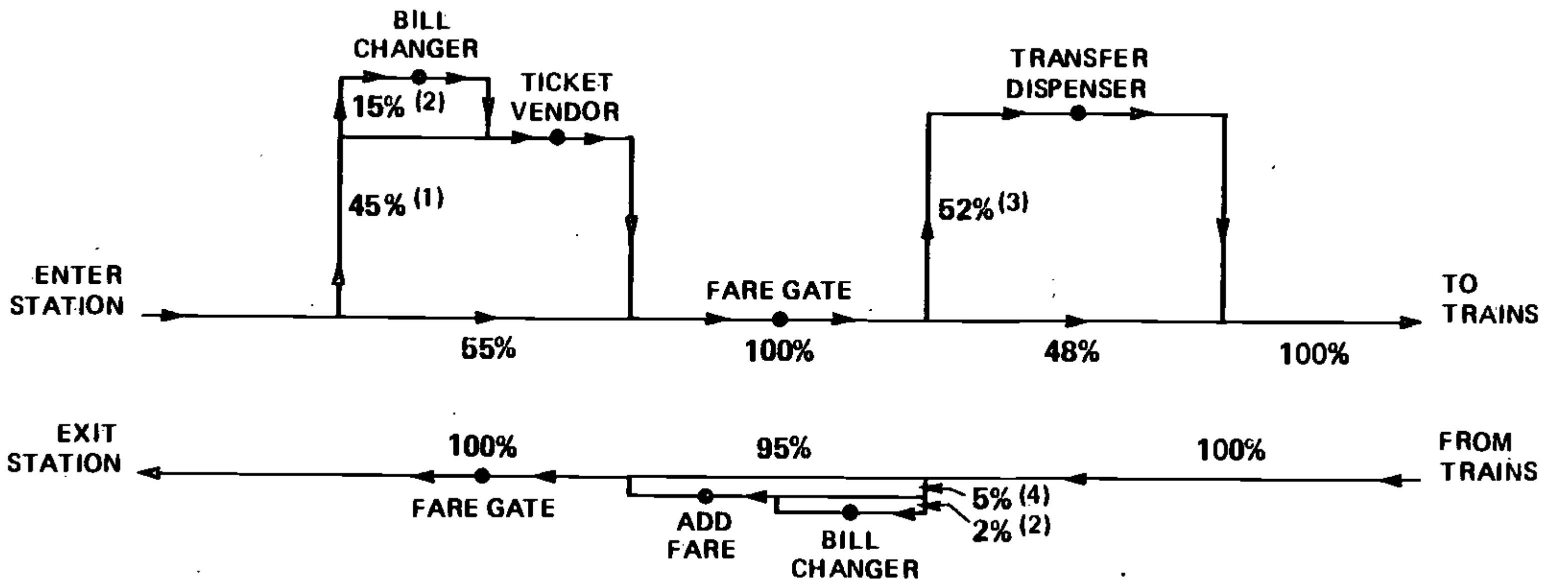
- o Bill Changer
- o Ticket Vendor/Validator
- o Assistance Phone

TABLE C-2
PERCENT OF PATRONS USING EACH FARE ELEMENT

Fare Elements	Percent of Riders
Full Fare	
o Single Trip	41.2%
o Multiple Trip	29.3%
Reduced Fare	
o Multiple Trip	29.5%
Total	100.0%

Source: *Booz, Allen & Hamilton Inc.*, Evaluation of the SCRTD Fare Structure, June 1982.

FIGURE C-1
BARRIER SYSTEM PASSENGER FLOW CHART



NOTES:

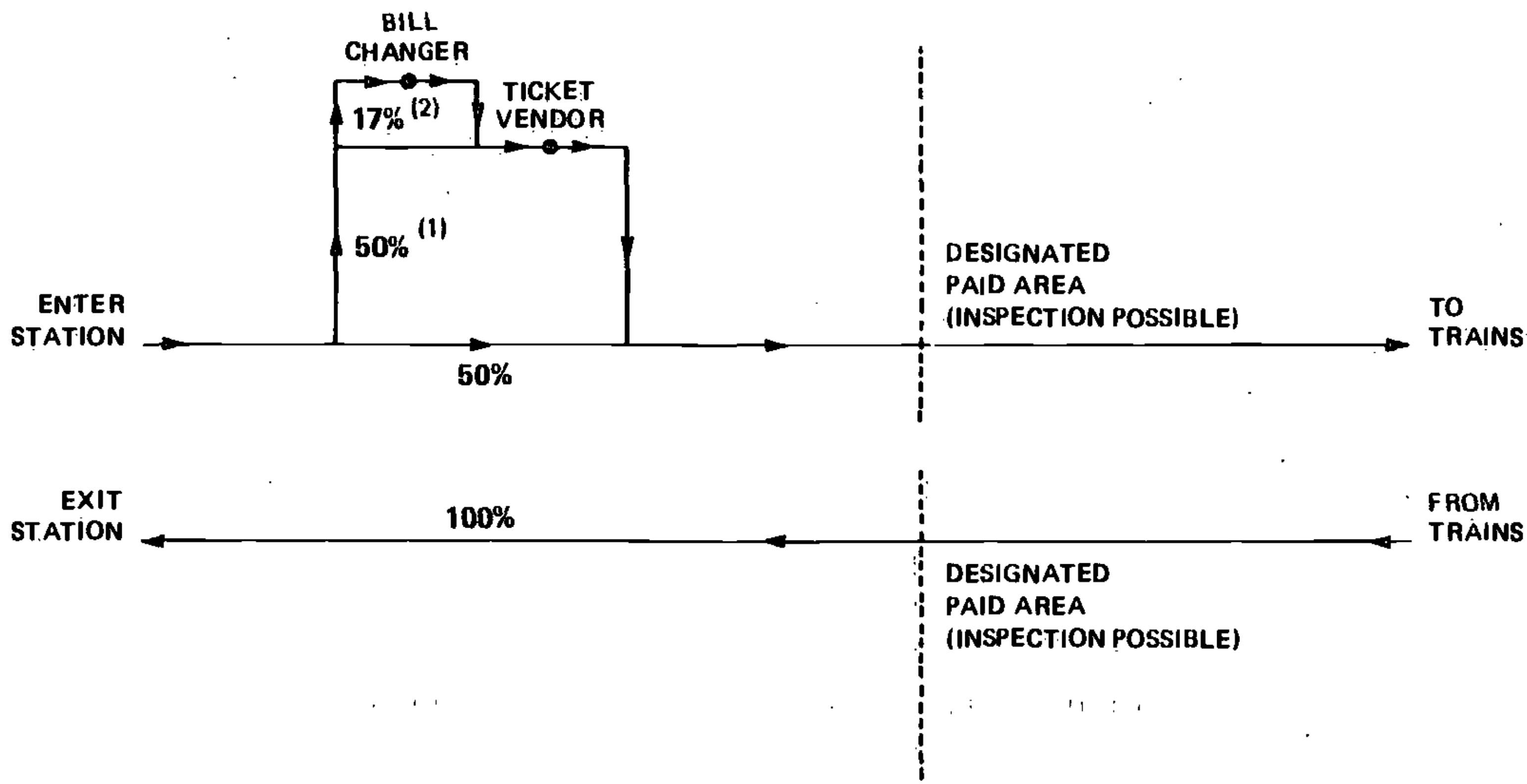
(1) Derived from analysis of current bus ridership by fare element

(2) Percentage of patrons using bill changers is based on PATCO experience

(3) Percentage of patrons making intermodal transfers based on METRO RAIL estimate (Appendix B)

(4) Percentage of patrons using addfare based on WMATA experience

FIGURE C-2
BARRIER-FREE SYSTEM PASSENGER FLOW CHART



NOTES:

(1) Derived from analysis of current bus ridership by fare element

(2) Based on current PATCO experience

TABLE C-3
EQUATION FOR ASSESSING EQUIPMENT REQUIREMENTS

Equipment Requirement per Mezzanine =

$$\left[\frac{(P \div T) * M * U}{R}\right] * 1/A$$

WHERE:

- P = Peak arrival rate in passengers per minute
- T = Established clearing time in minutes
- M = Mezzanine factor
- U = Proportion of patrons using the equipment
- R = Nominal processing rate in passengers per minute
- A = Anticipated availability rate

The equipment sizing equation has six primary inputs:

- Arrival rate,
- Claring time,
- Mezzanine factor,
- Proportion users,
- Processing rate, and
- Availability rate.

Each of these factors are further discussed below.

Arrival Rate - The rate at which patrons arrive at the respective fare collection equipment in the peak twenty-minute period.

Clearing Time - The maximum time allotment for accommodation of all patrons arriving in one minute.

Mezzanine Factor - For stations with two mezzanines this factor provides a contingency for patron processing to allow for less-than-perfect distribution of riders between mezzanines.

Proportion Users - This statistic describes the anticipated proportion of total patrons using any one category of equipment.

Processing Rate - The rate at which a particular category of equipment processes passengers.

Availability Rate - The proportion of total operating time that a particular piece of equipment is actually in-service.

The resulting equipment requirement is modified to meet established minimums as necessary. The actual parameters used in the analysis are presented in Tables C-4 and C-5 for barrier and barrier-free systems respectively. The actual results of the analysis are presented in Tables C-6 through C-13 for the years 1995 and 2020.

TABLE C-4
EQUIPMENT SIZING PARAMETERS
BARRIER SYSTEM

EQUIPMENT REQUIREMENTS

Bill Changers
... Provide one bill changer for every two ticket vendors.
... Provide one bill changer for every two addfare machines.
... Minimum: 3 per mezzanine.

Ticket Vendors
... Arrival Rate: use peak with greater number of boardings.
... Clearing Time: 1.0 minutes.
... Mezzanine Factor: 1.0 for stations with one mezzanine; 0.6 for those with two.
... Proportion Users: 0.45.
... Processing Rate: 5 passengers per minute.
... Availability Rate: 0.90.
... Minimum: 2 per mezzanine.

Bi-Directional and Uni-Directional Fare Gates
... Arrival Rate: use peak with greatest number of alightings.
... Clearing Time: 1.5 minutes for exiting patrons; 1.0 for entering.
... Mezzanine Factor: 1.0 if one mezzanine; 0.6 if two.
... Proportion Users: 1.00.
... Processing Rate: 30 passengers per minute.
... Availability Rate: 0.90.
... Minimum: 2 per mezzanine.

Handicapped Fare Gates
... Provide one handicapped fare gate per mezzanine.

Booth Control Panels
... Provide one control panel per mezzanine.

Transfer Dispensers
... Arrival Rate: use peak with greater number of boardings.
... Clearing Time: 1.0 minutes.
... Mezzanine Factor: 1.0 if one mezzanine; 0.6 if two mezzanines.
... Proportion Users: varies by station (see Table B-5).
... Processing Rate: 25 passengers per minute.
... Availability Rate: 0.90.
... Minimum: 2 per mezzanine.

Add-Fare Machine
... Arrival Rate: use peak with greater number of alightings.
... Clearing Time: 1.0 minutes.
... Mezzanine Factor: 1.0 if one mezzanine; 0.6 if two.
... Proportion Users: 0.05.
... Processing Rate: 5 passengers per minute.
... Availability Rate: 0.90.
... Minimum: 2 per mezzanine.

Assistance Phones
... Provide one assistance phone per mezzanine.

TABLE C-5
EQUIPMENT SIZING PARAMETERS
BARRIER-FREE SYSTEM

EQUIPMENT REQUIREMENTS

- o Bill Changers
  - Provide one bill changer for every two ticket vendors.

- o Ticket Vendors
  - Arrival Rate .... use peak with greater number of boardings
  - Clearing Time .... 1.0 minutes
  - Mezzanine Factor .... 1.0 for stations with one mezzanine; .... 0.6 for those with two
  - Proportion Users 0.50
  - Processing Rate .... 5 passengers per minute
  - Availability Rate 0.90

- o Assistance Phones
  - Provide one assistance phone per mezzanine.

TABLE C-6
1995 STATION EQUIPMENT REQUIREMENTS PER MEZZANINE BARRIER SYSTEM

Station	Bill Changer	Ticket Vendor	Bi-Directional Fare Gate	Uni-Directional Fare Gate	Handi-capped Fare Gate	Booth Control Panel	Transfer Dispenser	Add-Fare	Assistance Phones
Union Station	5	8	6	4	1	1	2	2	1
1st/Broadway	3	3	2	2	1	1	2	2	1
5th/Broadway	6	10	7	4	1	1	2	3	1
7th/Flower	4	7	5	4	1	1	2	2	1
Wilshire/Alvarado	4	7	5	4	1	1	2	2	1
Wilshire/Vermont	4	6	5	4	1	1	2	2	1
Wilshire/Normandie	4	7	5	4	1	1	2	2	1
Wilshire/Western	5	9	7	4	1	1	3	2	1
Wilshire/La Brea	4	6	4	4	1	1	2	2	1
Wilshire/Fairfax	4	7	5	4	1	1	2	2	1
Fairfax/Beverly	3	3	3	2	1	1	2	2	1
Fairfax/Santa Monica	3	5	3	4	1	1	2	2	1
Hollywood/Cahuenga	5	8	6	4	1	1	2	2	1
Hollywood Bowl	3	2	2	2	1	1	2	2	1
Universal City	4	7	5	4	1	1	2	2	1
North Hollywood	3	5	3	4	1	1	2	2	1
			73	58	16				

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TABLE C-7
1995 SYSTEM EQUIPMENT REQUIREMENTS BY STATION
BARRIER SYSTEM

Station	Bill Changer	Ticket Vendor	Bi-Directional Fare Gate	Uni-Directional Fare Gate	Handi-capped Fare Gate	Booth Control Panel	Transfer Dispenser	Add-Fare	Assistance Phones
Union Station	10	16	12	8	2	2	4	4	2
1st/Broadway	6	6	4	4	2	2	4	4	2
5th/Broadway	12	20	14	8	2	2	4	6	2
7th/Flower	8	14	10	8	2	2	4	4	2
Wilshire/Alvarado	4	7	5	4	1	1	2	2	1
Wilshire/Vermont	8	12	10	8	2	2	4	4	2
Wilshire/Normandie	4	7	5	4	1	1	2	2	1
Wilshire/Western	5	9	7	4	1	1	3	2	1
Wilshire/La Brea	4	6	4	4	1	1	2	2	1
Wilshire/Fairfax	8	14	10	8	2	2	4	4	2
Fairfax/Beverly	3	3	3	2	1	1	2	2	1
Fairfax/Santa Monica	3	5	3	4	1	1	2	2	1
Hollywood/Cahuenga	5	8	6	4	1	1	2	2	1
Hollywood Bowl	3	2	2	2	1	1	2	2	1
Universal City	4	7	5	4	1	1	2	2	1
North Hollywood	6	10	6	8	2	2	4	4	2
System Total	93	146	106	84	23	23	47	48	23

TABLE C-8
1995 STATION EQUIPMENT REQUIREMENTS PER MEZZANINE
BARRIER-FREE SYSTEM

Station	Bill Changer	Ticket Vendor	Assistance Phones
Union Station	4	9	1
1st/Broadway	2	3	1
5th/Broadway	5	11	1
7th/Flower	4	8	1
Wilshire/Alvarado	4	8	1
Wilshire/Vermont	3	7	1
Wilshire/Normandie	4	8	1
Wilshire/Western	5	10	1
Wilshire/La Brea	3	7	1
Wilshire/Fairfax	4	8	1
Fairfax/Beverly	2	3	1
Fairfax/Santa Monica	3	6	1
Hollywood/Cahuenga	4	8	1
Hollywood Bowl	2	3	1
Universal City	4	8	1
North Hollywood	3	6	1

TABLE C-9
1995 SYSTEM EQUIPMENT REQUIREMENTS BY STATION
BARRIER-FREE SYSTEM

Station	Bill Changer	Ticket Vendor	Assistance Phones
Union Station	8	18	2
1st/Broadway	4	6	2
5th/Broadway	10	22	2
7th/Flower	8	16	2
Wilshire/Alvarado	4	8	1
Wilshire/Vermont	6	14	2
Wilshire/Normandie	4	8	1
Wilshire/Western	5	10	1
Wilshire/La Brea	3	7	1
Wilshire/Fairfax	8	16	2
Fairfax/Beverly	2	3	1
Fairfax/Santa Monica	3	6	1
Hollywood/Cahuenga	4	8	1
Hollywood Bowl	2	3	1
Universal City	4	8	1
North Hollywood	6	12	2
System Total	81	165	23

TABLE C-10
2020 STATION EQUIPMENT REQUIREMENTS PER MEZZANINE
BARRIER SYSTEM

Station	Bill Changer	Ticket Vendor	Bi-Directional Fare Gate	Uni-Directional Fare Gate	Handicapped Fare Gate	Booth Control Panel	Transfer Dispenser	Add-Fare	Assistance Phones
Union Station	8	14	6	4	1	1	3	2	1
1st/Broadway	3	4	2	2	1	1	2	2	1
5th/Broadway	9	17	8	4	1	1	3	3	1
7th/Flower	7	12	6	4	1	1	2	2	1
Wilshire/Alvarado	7	12	6	4	1	1	2	2	1
Wilshire/Vermont	6	11	6	4	1	1	3	2	1
Wilshire/Normandie	7	12	6	4	1	1	3	2	1
Wilshire/Western	8	15	10	4	1	1	5	2	1
Wilshire/La Brea	6	10	5	4	1	1	3	2	1
Wilshire/Fairfax	7	13	6	4	1	1	4	2	1
Fairfax/Beverly	3	5	3	2	1	1	2	2	1
Fairfax/Santa Monica	5	9	5	4	1	1	3	2	1
Hollywood/Cahuenga	7	13	7	4	1	1	3	2	1
Hollywood Bowl	3	2	2	2	1	1	2	2	1
Universal City	7	12	5	4	1	1	4	2	1
North Hollywood	5	9	3	4	1	1	2	2	1

TABLE C-11
2020 SYSTEM EQUIPMENT REQUIREMENTS BY STATION
BARRIER SYSTEM

Station	Bill Changer	Ticket Vendor	Bi-Directional Fare Gate	Uni-Directional Fare Gate	Handicapped Fare Gate	Booth Control Panel	Transfer Dispenser	Add-Fare	Assistance Phones
Union Station	16	28	12	8	2	2	6	4	2
1st/Broadway	6	8	4	4	2	2	4	4	2
5th/Broadway	18	34	16	8	2	2	6	6	2
7th/Flower	14	24	12	8	2	2	4	4	2
Wilshire/Alvarado	7	12	6	4	1	1	2	2	1
Wilshire/Vermont	12	22	12	8	2	2	6	4	2
Wilshire/Normandie	7	12	6	4	1	1	3	2	1
Wilshire/Western	8	15	10	4	1	1	5	2	1
Wilshire/La Brea	6	10	5	4	1	1	3	2	1
Wilshire/Fairfax	14	26	12	8	2	2	8	4	2
Fairfax/Beverly	3	5	3	2	1	1	2	2	1
Fairfax/Santa Monica	5	9	5	4	1	1	3	2	1
Hollywood/Cahuenga	7	13	7	4	1	1	3	2	1
Hollywood Bowl	3	2	2	2	1	1	2	2	1
Universal City	7	12	5	4	1	1	4	2	1
North Hollywood	10	18	6	8	2	2	4	4	2
System Total	**143**	**250**	**123**	**84**	**23**	**23**	**65**	**48**	**23**

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TABLE C-12
2020 STATION EQUIPMENT REQUIREMENTS PER MEZZANINE
BARRIER-FREE SYSTEM

Station	Bill Changer	Ticket Vendor	Assistance Phones
Union Station	8	16	1
1st/Broadway	2	5	1
5th/Broadway	9	18	1
7th/Flower	6	13	1
Wilshire/Alvarado	7	14	1
Wilshire/Vermont	6	12	1
Wilshire/Normandie	6	13	1
Wilshire/Western	8	17	1
Wilshire/La Brea	5	11	1
Wilshire/Fairfax	7	14	1
Fairfax/Beverly	3	6	1
Fairfax/Santa Monica	5	10	1
Hollywood/Cahuenga	7	14	1
Hollywood Bowl	2	2	1
Universal City	6	13	1
North Hollywood	5	10	1

TABLE C-13

2020 SYSTEM EQUIPMENT REQUIREMENTS BY STATION

BARRIER-FREE SYSTEM

Station	Bill Changer	Ticket Vendor	Assistance Phones
Union Station	16	32	2
1st/Broadway	4	10	2
5th/Broadway	18	36	2
7th/Flower	12	26	2
Wilshire/Alvarado	7	14	1
Wilshire/Vermont	12	24	2
Wilshire/Normandie	6	13	1
Wilshire/Western	8	17	1
Wilshire/La Brea	5	11	1
Wilshire/Fairfax	14	28	2
Fairfax/Beverly	3	6	1
Fairfax/Santa Monica	5	10	1
Hollywood/Cahuenga	7	14	1
Hollywood Bowl	2	2	1
Universal City	6	13	1
North Hollywood	10	20	2
System Total	135	276	23

APPENDIX D:

CAPITAL COST ESTIMATION

APPENDIX D:

CAPITAL COST ESTIMATION

Capital cost estimates for the barrier and barrier-free systems are presented in Tables D-1 and D-2, respectively. These cost estimates are based on the equipment requirements analysis (Appendix C), current bid prices on fare collection equipment, and recent purchases of equipment by other transit systems. It should be noted that the nature of the fare collection equipment market prevents a precise estimation of capital costs. The degree of "customizing" necessary and the possibility of a joint procurement process with another transit agency result in cost variations of plus or minus twenty percent.

A key input in the capital cost estimation process was the unit cost estimates provided by Kaiser Engineers shown in Tables D-3 and D-4.

TABLE D-1
CAPITAL COST ESTIMATE – BARRIER SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Fare Collection Equipment			
. Bill Changers	93	$ 11,000	$ 1,023,000
. Ticket Vendors	146	37,000	5,402,000
. Bi-Directional Fare Gates	106	26,000	2,756,000
. Uni-Directional Fare Gates	84	20,000	1,680,000
. Handicapped Fare Gates	23	4,500	103,500
. Booth Control Panels	23	13,000	299,000
. Transfer Dispensers	47	6,500	305,500
. Add-Fares	48	27,000	1,296,000
Communications and Central Control			
. Passenger Assistance Phone	23	1,000	23,000
. Central Control System	1	100,000	100,000
Support Equipment			
. Magnetic Encoders	3	140,000	420,000
. Revenue Carts	32	6,000	192,000
Installation			
. Station Equipment	16	2,500	40,000
. Central Data System	–	20,000	20,000
Other			
. Training and Manuals	–	200,000	200,000
. Spares and Test Equipment	–	800,000	800,000
. Initial Supply of Media	–	360,000	360,000
. Non-Recurring Costs	–	3,200,000	3,200,000
Total			$18,220,000

TABLE D-2
CAPITAL COST ESTIMATE — BARRIER-FREE SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Fare Collection Equipment			
. Ticket Vendor w/Canceler	165	$ 25,000	$4,125,000
. Bill Changers	81	11,000	891,000
Communications and Central Control			
. Passenger Assistance Phone	23	1,000	23,000
. Central Control System	1	60,000	60,000
Support Equipment			
. Revenue Carts	32	6,000	192,000
Installation			
. Station Equipment	16	1,000	16,000
. Central Data System	—	15,000	15,000
Other			
. Training and Manuals	—	70,000	70,000
. Spares and Test Equipment	—	300,000	300,000
. Initial Supply of Media	—	146,500	146,500
. Non-Recurring Costs	—	1,254,000	1,254,000
Total			$7,092,500

TABLE D-3
CAPITAL UNIT COST ESTIMATES
AUTOMATIC BARRIER SYSTEM

ASSEMBLY OR AREA	UNIT COST
Fare Collection Equipment	
. Bill Changers	$ 11,000
. Ticket Vendors	37,000
. Bi-Directional Fare Gates	26,000
. Uni-Directional Fare Gates	20,000
. Handicapped Fare Gates	4,500
. Booth Control Panels	13,000
. Transfer Dispensers	6,500
. Add-Fares	27,000
Communications and Central Control	
. Passenger Assistance Phone	1,000
. Central Control System	100,000
Support Equipment	
. Magnetic Encoders	140,000
. Revenue Carts	6,000
Installation	
. Station Equipment	2,500
. Central Data System	20,000
Other	
. Training and Manuals	200,000
. Spares and Test Equipment	800,000
. Initial Supply of Media	360,000
. Non-Recurring Costs	3,200,000

Source: *Kaiser Engineers, Inc., Technical Memorandum on Fare Collection Equipment Cost Estimates, September 22, 1982.*

TABLE D-4
CAPITAL UNIT COST ESTIMATES
BARRIER-FREE SYSTEM

ASSEMBLY OR AREA	UNIT COST
Fare Collection Equipment	
. Ticket Vendor w/Canceler	$ 25,000
. Bill Changers	11,000
Communications and Central Control	
. Passenger Assistance Phone	1,000
. Central Control System	60,000
Support Equipment	
. Revenue Carts	6,000
Installation	
. Station Equipment	1,000
. Central Data System	15,000
Other	
. Training and Manuals	70,000
. Spares and Test Equipment	300,000
. Initial Supply of Media	146,500
. Non-Recurring Costs	1,254,000

Source: *Kaiser Engineers, Inc., Technical Memorandum on Fare Collection Equipment Cost Estimates, September 22, 1982.*

APPENDIX E:

OPERATING COST ESTIMATION

APPENDIX E:

OPERATING COST ESTIMATION

This appendix details the assumptions and information used in developing annual operating and maintenance cost estimates for the alternative fare collection systems. The financial analysis was an iterative process, with each major cost category evaluated according to the variables driving its cost. Throughout the evaluation, comparisons were made with other fixed guideway systems to test for reasonableness and accuracy. The results of the financial analysis are presented in Tables E-1 and E-2. Probable cost variations are presented in Table E-3, providing the anticipated range of operating and maintenance costs. All cost estimates are in constant (1982) dollars to facilitate comparative analysis.

Labor, which accounts for the majority of the total operating expense, is disaggregated by functional classification to facilitate cost estimation as shown in Table E-4. Each labor category was analyzed according to the unique requirements of system operations, as described below.

Field technicians are required to respond to all fare collection equipment failures at Metro Rail stations. Variables impacting the size requirements of the field staff include patron transaction rates for individual equipment types, equipment reliability by category (includes both hard and soft failures), equipment availability and spares by

TABLE E-1
ANNUAL OPERATING AND MAINTENANCE COST ESTIMATE
BARRIER SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Labor Requirements			
. Field Technicians	37	$ 34,000	$1,258,000
. Shop Technicians	9	40,800	367,200
. Equipment Servicers	8	34,000	272,000
. Supervisors, Maintenance	4	40,400	161,600
. Revenue Servicers	3	28,700	86,100
. Ticket Encoding Clerks	6	28,700	172,200
. Transit Police	6	30,500	183,000
. Bill Handling Clerks	12	28,700	344,000
. Revenue Clerks	8	28,700	229,600
. Revenue Supervisors	3	31,600	94,800
Overhead Burden	—	25%	792,000
Materials and Supplies			
. Ticket Supply	—	358,700	358,700
. Parts and Miscellaneous	—	324,200	324,200
Contingency	—	15%	696,600
Total			$5,340,000

TABLE E-2
ANNUAL OPERATING AND MAINTENANCE COST ESTIMATE
BARRIER-FREE SYSTEM
(1982 DOLLARS)

Item	Quantity	Unit Cost	Total Cost
Labor Requirements			
. Field Technicians	15	$ 34,000	$ 510,000
. Shop Technicians	3	40,800	122,400
. Equipment Servicers	4	34,000	136,000
. Supervisors, Maintenance	3	40,400	121,200
. Revenue Servicers	3	28,700	86,100
. Transit Police	8	30,500	244,000
. Fare Inspectors	39	27,700	1,080,300
. Supervisors, Inspectors	4	30,500	122,000
. Bill Handling Clerks	12	28,700	344,000
. Revenue Clerks	8	28,700	229,600
. Revenue Supervisors	3	31,600	94,800
Overhead Burden		25%	772,600
Materials and Supplies			
. Ticket Supply	–	151,500	151,500
. Parts and Miscellaneous	–	117,800	117,800
Contingency	–	15%	619,900
Total			$4,752,200

TABLE E-3
OPERATING AND MAINTENANCE COST VARIATIONS
(1982 DOLLARS)

Barrier System		
Anticipated O&M Cost	$5,340,000	
Best Reliability Estimate	(425,000)	
Lower Cost Range		$4,915,000
Anticipated O&M Cost	$5,340,000	
Worst Reliability Estimate	106,000	
Upper Cost Range		$5,446,000
Barrier-Free System		
Anticipated O&M Cost	$4,752,200	
Best Reliability Estimate	(127,452)	
Lower Evasion Rate (4%)	(276,648)	
Lower Cost Range		$4,348,100
Anticipated O&M Cost	$4,752,200	
Worst Reliability Estimate	81,000	
Increased Inspection Rate (9%)	359,600	
Upper Cost Range		$5,192,800

TABLE E-4
LABOR FUNCTIONAL CLASSIFICATION

Field Technician:	Repair equipment to the subassembly level; perform both corrective and preventive maintenance on fare collection equipment; respond to all station maintenance problems associated with fare collection; may perform equipment modifications and repairs in shop when directed by shop technician.
Shop Technician:	Repair fare collection equipment subassemblies brought in by field technician by diagnosing problem to component level; initiate equipment modifications as necessary.
Equipment Servicer:	Stock and restock station fare collection equipment with media and change; retrieve captured tickets and transfers, and empties revenue from machines into revenue cart.
Supervisor, Maintenance:	Supervise, train and control all maintenance personnel assigned to fare collection.
Revenue Servicer:	Deliver all revenue carts containing ticket stock and change to station safe rooms, and retrieve revenue carts loaded with station revenues; may assist in stocking and unloading revenue carts.
Ticket Encoding Clerk:	Operate high-speed encoder, and tag and package all encoded passes, tickets and transfers. (Barrier only).
Transit Police:	Responsible for revenue security; assists equipment servicers and revenue servicers; on barrier-free system, transit police assist fare inspectors as well.
Fare Inspector:	Inspect patron fares both on-board and in stations, and issue tickets for evasion where appropriate. (Barrier-free only.)
Bill Handling Clerk:	Manually process mixed one- and five-dollar bills and operate currency counting machines.
Revenue Clerk:	Responsible for stocking and re-stocking revenue carts with change and ticket stock; operate coin counting machines and package coin revenue.
Supervisor, Revenue:	Direct, train and control all revenue and media processing personnel.

station, and technician response and repair time. The reliability estimates for fare collection equipment were provided by Kaiser Engineers in the memorandum included in this appendix. The resulting staff size was compared to BARTD, WMATA, MARTA and PATCO to assess reasonableness.

It should be recognized that the field technician staff size can vary significantly with changes in equipment reliability. Furthermore, if station personnel are available to perform "finger-tip" maintenance (e.g., clear ticket or coin jams), the field staff requirements diminish further. The cost impacts of varying these two factors are shown in Table E-3 to provide a range of operating costs.

Shop technicians repair hard failures (e.g., component failures) at the central maintenance facility. The size requirements of the shop staff is a function of equipment reliability (hard failures only), patron transaction rates, the spare ratio, and response and repair time. The estimated requirement is similar to that of comparably sized systems.

Equipment servicers stock and empty station fare collection equipment as required. It is anticipated that a team will consist of two servicers and one transit policeman. Staff requirements are a function of preparation and travel time, servicing time, and the number of machines at each station.

Revenue servicers are responsible for the transport of revenue carts to and from the station safe room and the central revenue facility. It is anticipated that a team will consist of two servicers and two transit police. Considerations in size estimation include the frequency of revenue service required, preparation and travel time, and actual servicing time per station. A comparable system is employed by WMATA.

Ticket encoding clerks operate the high speed encoders and sort captured tickets for re-use. Staff size reflects the number and different types of tickets to be pre-encoded, as well as expected processing times. The results are comparable to requirements at WMATA and BARTD.

Transit police are responsible for revenue security. Staff size is determined by the number of revenue and equipment servicing teams and the number of police required at the central revenue facility. For the barrier-free system, additional police are required to assist fare inspectors. For the barrier system, it has been assumed that no additional police would be necessary to monitor fare gate usage.

Fare inspectors, used only on the barrier-free system, inspect patron fares and issue tickets for evasion. Estimating the appropriate staff size is difficult because of a variety of independent variables affecting inspection requirements. In theory a high inspection rate and substantial penalty for evasion will result in a low evasion rate.

The inspection strategy used in developing cost estimates entailed inspecting 100 percent of alighting patrons at any one or more station mezzanine(s) in the peak period, and using roving inspectors to examine fares both on-board and at the platform during off-peak periods. This strategy translates to inspecting 4.3 to 7.8 percent of peak riders and 14 to 18 percent of daily patrons.

Cost estimates are based on 6 percent evasion during both peak and off-peak periods. During the peak period, inspectors are assigned into four functional categories:

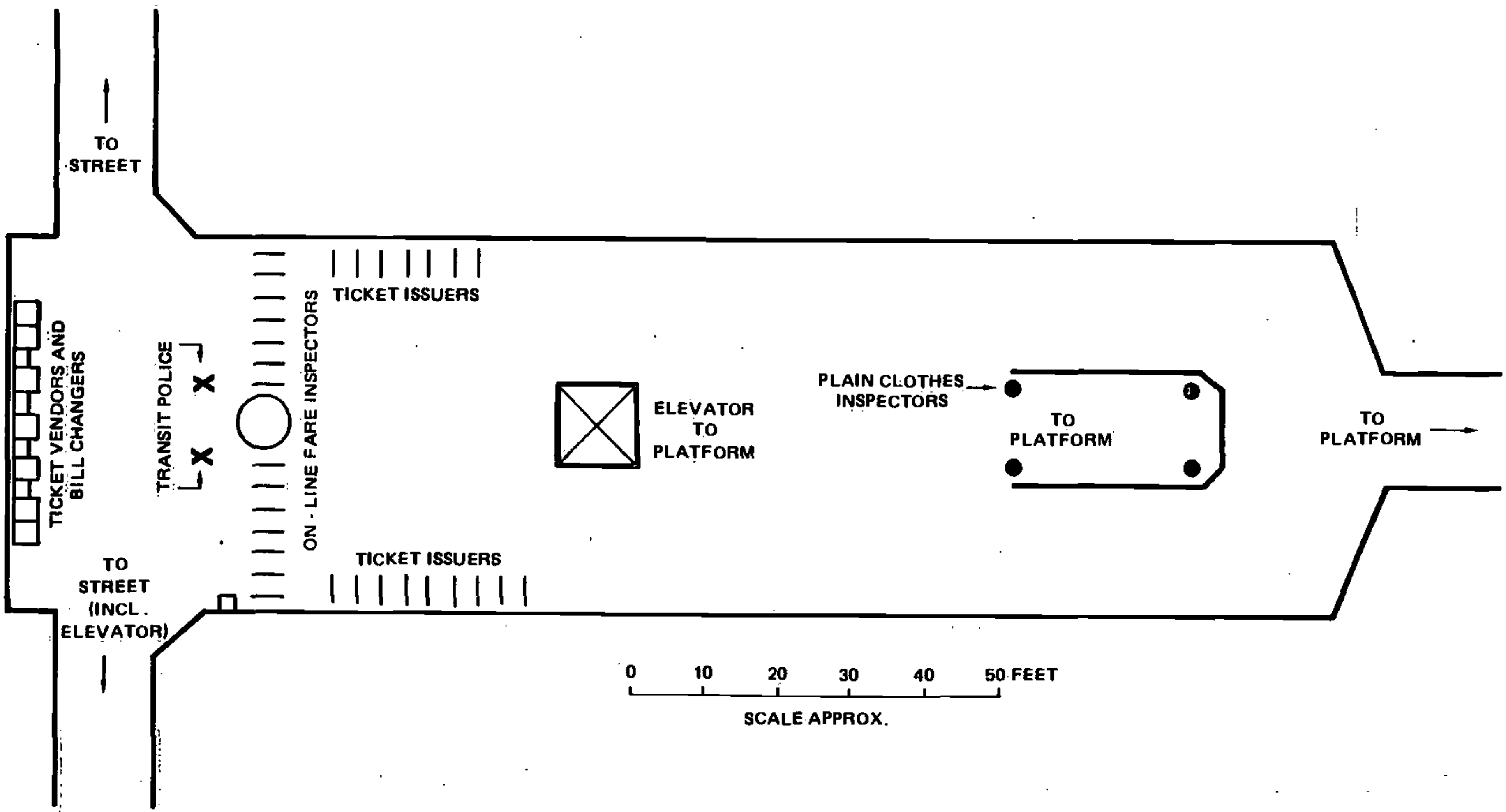
- On-line fare inspectors;
- Off-line ticket issuers;
- Plainclothes inspectors; and
- Uniformed transit police.

The on-line inspectors form a fare inspection line through which all patrons must pass. Patrons not possessing appropriate proof of payment are directed to ticket issuers on either side of the mezzanine. Plainclothes inspectors are posted on both ends of the escalators to catch patrons attempting to avoid inspection by re-entering the system. Uniformed transit police are located just beyond the inspection line to prevent patrons from pushing by inspectors. The general positioning of inspectors is shown in Figure E-1.

Using this strategy, inspector staff size is a function of peak patron arrival rates, relative processing rates, the anticipated evasion rate, and the percentage of patrons inspected. After calculating the "best estimate" (Table E-2), these factors were varied to obtain a range of possible costs (Table E-3). The minimal cost was calculated using a 4 percent evasion rate. The upper cost range was determined by increasing the inspection rates to 9.5 to 15.6 percent in the peak and 19 to 23 percent of total daily riders.

Bill handling clerks were sized according to an estimate of total revenue, the percent paid in bills and SCRTD's current bill sorting productivity rate.

FIGURE E-1
SELF-SERVICE, BARRIER-FREE SYSTEM
POSITIONING OF FARE INSPECTORS



Revenue clerks, responsible for coin processing and stocking revenue carts, are sized according to the time requirements involved in the conduct of these duties. The resulting staff size is comparable to WMATA's staff, and the duties are relatively the same.

All labor wages were estimated in conjunction with the Metro Rail staff based on job descriptions and current employee wages and benefits cost. The overhead burden was provided by SCRTD's accounting department and represents administrative burden (fringe benefits are included in wages).

Materials and supplies costs were disaggregated into ticket supply and parts and miscellaneous costs. Ticket costs are a function of patronage by category of ticket user and costs of each type of ticket. Current block prices were provided by SCRTD, PATCO and MTDB. Parts and miscellaneous costs are directly related to equipment reliability, complexity and costs.

A 15 percent contingency was included in the total operating cost estimate to allow for unanticipated expenses.

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September 28, 1982

Job #: 81152-406

WBS #: 14 CAE11 (.2)
Chrono

MEMO TO: F. Condos

FROM: for P. M. Burgess [signature]

SUBJECT: FARE COLLECTION RELIABILITY ESTIMATES

Ref. 1: IOM - F. Condos to P. M. Burgess, dated August 25, 1982, Subject: Fare Collection Equipment; Cost and Reliability Estimates

Ref.2: IOM - P. M. Burgess to F. Condos, dated September 22, 1982, Subject: Fare Collection Equipment Cost Estimates

The Ref. 1 memo requested reliability and cost estimates on fare collection concepts. The cost estimates were provided in the Ref. 2 memo.

Based on a review of fare collection reliability data from PATCO, BART, WMATA, CTA, PATH, ICG AND SDMTD, KE has prepared a table showing estimates for WORST possible and BEST possible failure rates. The failure rates provided in the enclosure are shown as "Transactions Between Failures" and "Failures Per Transaction". The table also shows the "soft" and "hard" failure rates that comprise the total failure rates. "Hard" failures are defined as those failures which require service by trained maintenance personnel. "Soft" failures are defined as those failures which may be cleared by station attendent. If the analysis is performed with the assumption that no attendents are provided, then these "soft" rates must require some maintenance labor to resolve even if no spare costs are associated with them.

New products, such as a swipe-through card reader, are being developed, which may enable Metro Rail to specify and procure fare collection equipment that is more reliable than equipment presently in use. If developments such as this occur between now and when the Metro Rail equipment is purchased and appropriate program approaches are adapted, then failure rates approximating the "Best" numbers can be equated. However, if Metro Rail must purchase equipment at existing levels of reliability development then failure rates approaching the "worst" numbers could occur.

We suggest that the initial evaluation between barrier and barrier-free systems utilize both "best" and "worst" case values. If the barrier system is selected for further in-depth analysis (WBS 16 activity) then the predictions can be further refined.

Any questions and/or comments on the subject material should be directed to Nick Brown or Kirk Rummel of our staff.

cc: J. Bergerson, KE
D. Gardner, SCRTD
E. Pollan, BAH
W. Rhine, SCRTD
JNB D. Wellington, KE

PMB:JNB:pl

AUTOMATIC FARE COLLECTION

RELIABILITY DATA

COMPONENT	WORST SOFT	WORST HARD	WORST TOTAL	BEST SOFT	BEST HARD	BEST TOTAL
FARE GATES *	890 .00112	7,700 .00013	800 .00125	8,333 .00002	20,000 .00005	6,000 .00017
TICKET VENDOR *	150 .00667	300 .00333	100 .01000	440 .00228	4,500 .00022	400 .00250
TRANSFER DISPENSERS *	1,052 .00095	3,300 .00030	800 .00125	20,000 .00005	5,000 .00020	4,000 .00025
ADD-FARE *	150 .00667	300 .00333	100 .01000	680 .00147	5,000 .00020	600 .00167
BILL CHANGER * **	222 .00450	2,000 .00050	200 .00500	2,220 .00045	4,550 .00022	1,500 .00067
HANDICAPPED GATE *	20,000 .00005	20,000 .00005	10,000 .00010	100,000 .00001	100,000 .00001	50,000 .00002
BUS-VALIDATOR *	1,430 .00070	3,300 .00030	1,000 .00100	20,000 .00005	5,550 .00018	4,300 .00023
TICKET MACHINE VALIDATOR **	1,280 .00078	5,000 .0020	1,020 .00098	2,550 .00039	10,000 .00010	2,040 .00049
BUS MOUNTED CANCELLOR **	2,220 .00045	5,570 .00018	1,590 .00063	6,670 .00015	16,700 .00006	4,760 .00021

LEGEND

Mean Transaction Between Failures → xxxxx

Failures Per Transaction → yyyyy

* - Barrier System

** - Barrier-free System