NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

Report 13

Conversion to One-Person Operation of Rapid-Transit Trains

TRANSPORTATION RESEARCH BOARD
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Conversion to One-Person Operation of Rapid-Transit Trains

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AREAS OF INTEREST

Administration
Operations and Traffic Control
(Public Transit)

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Administrators, engineers, and many others in the transit industry are faced with a multitude of complex problems that range between local, regional, and national in their prevalence. How they might be solved is open to a variety of approaches; however, it is an established fact that a highly effective approach to problems of widespread commonality is one is which operating agencies join cooperatively to support, both in financial and other participatory respects, systematic research that is well designed, practically oriented, and carried out by highly competent researchers. As problems grow rapidly in number and escalate in complexity, the value of an orderly, high-quality cooperative endeavor likewise escalates.

Recognizing this in light of the many needs of the transit industry at large, the Urban Mass Transportation Administration, U.S. Department of Transportation, got under way in 1980 the National Cooperative Transit Research & Development Program (NCTRP). This is an objective national program that provides a mechanism by which UMTA's principal client groups across the nation can join cooperatively in an attempt to solve near-term public transportation problems through applied research, development, test, and evaluation. The client groups thereby have a channel through which they can directly influence a portion of UMTA's annual activities in transit technology development and deployment. Although present funding of the NCTRP is entirely from UMTA's Section 6 funds, the planning leading to inception of the Program envisioned that UMTA's client groups would join ultimately in providing additional support, thereby enabling the Program to address a large number of problems each year.

The NCTRP operates by means of agreements between UMTA as the sponsor and (1) the National Research Council as the Primary Technical Contractor (PTC) responsible for administrative and technical services, (2) the American Public Transit Association, responsible for operation of a Technical Steering Group (TSG) comprised of representatives of transit operators, local government officials, State DOT officials, and officials from UMTA's Office of Technical Assistance.

Research Programs for the NCTRP are developed annually by the Technical Steering Group, which identifies key problems, ranks them in order of priority, and establishes programs of projects for UMTA approval. Once approved, they are referred to the National Research Council for acceptance and administration through the Transportation Research Board.

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The needs for transit research are many, and the National Cooperative Transit Research & Development Program is a mechanism for deriving timely solutions for transportation problems of mutual concern to many responsible groups. In doing so, the Program operates complementary to, rather than as a substitute for or duplicate of, other transit research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, or the Urban Mass Transportation Administration, U.S. Department of Transportation.

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FOREWORD

By Staff
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Research Board

This report will be of interest to a diverse audience of persons concerned with rail rapid-transit operations, equipment, and personnel. It contains information of use to those concerned with (a) productivity and cost effectiveness (e.g., members of governing boards, general managers, operations managers, chief engineers); (b) labor issues (e.g., labor relations managers, union representatives); (c) passenger and employee safety (e.g., safety managers); and (d) passenger and system security (e.g., security chiefs). The report also contains information of interest to designers of equipment and facilities required to meet the changing needs of transit systems.

In recent years the Federal Government has pursued a policy of reducing its operating assistance to transit agencies. This policy has resulted in ever increasing pressure on the rail rapid-transit systems to develop more cost-effective operating procedures. One approach to improving cost-effectiveness is to reduce the rapid-transit crew to a single operator. Although such reductions have taken place on a number of European systems, and all new U.S. systems have incorporated one-person operation, older U.S. systems continue to utilize two-person operation of multiple-unit trains.

This report presents the results of a study concerned with identifying and evaluating the issues and problems that are inherent to the conversion of older U.S. rapid-transit multiple-unit trains to one-person operation. It cites possible solutions and suggests a framework for making an economic assessment of the possible conversion of a specific system, line, or service from two- to one-person operation.

Based on this study's findings, it appears that the conversion of many of the six older U.S. rapid-transit systems with two-person operation of multiple-unit trains to one-person operation is technically feasible. The study acknowledges there are many problems that must be resolved to make such conversions possible. It makes no recommendations to convert any specific system. Rather it provides each agency with the wherewithal to decide the merits of conversion for itself using the economic analysis framework developed in the report. The application of such an economic analysis is necessary to identify and evaluate the possible cost increases and savings resulting from such conversions.

The report concludes that the conversion of the six older U.S. systems would most likely follow an evolutionary process, i.e., the systems will most likely convert those services, and/or lines that are most compatible to one-person operation first, followed by conversion of the less compatible services and/or lines over time. The most compatible services include new lines, lines or services with new or rehabilitated cars and/or facilities, and off-peak service.

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Mr. Joseph A. Hoess, Transportation Systems Section, Battelle Columbus Division, was the principal investigator. Messrs. Hoess and Murphy are the authors of this report.

The work was done under the general supervision of Mr. Hoess, who was responsible for the technical, operational, and economic-related aspects of the work. Mr. Murphy was responsible for the human resource and institutional aspects.

Finally, this study would not have been possible without the assistance and cooperation of the many (100) transit system management and union officials who gratuitously agreed to meet with the project team and contribute their experience and expertise to the project.

CONVERSION TO ONE-PERSON OPERATION OF RAPID-TRANSIT TRAINS

SUMMARY

There is increasing pressure to provide more cost-effective operation of heavy-rail rapid-transit trains. A major candidate for improving productivity is reduction of train crew size to one person. All of the older heavy-rail rapid-transit systems in the United States continue to have two-person operation of multiple-unit trains. These include: CTA (Chicago), GCRTA (Cleveland), MBTA (Boston), NYCTA (New York), PATH (New York-New Jersey), and SEPTA (Philadelphia). Of these six systems, only SEPTA has converted some multiple-unit train services (two) to one-person operation. (GCRTA and CTA operate some single-car trains with one-person crews but have two-person crews on multiple-unit trains.) All of the newer U.S. systems (i.e., systems which began operation on or after 1969) began service as one-person operation systems and have always operated in that mode.

This report presents the findings and conclusions of a study (1) to evaluate the issues that must be addressed in contemplating conversion of two-person systems to one-person operation including the identification of those issues unique to the particular systems, and (2) to develop a framework for an economic assessment of the effects of implementation of one-person operation. No recommendations that any specific rapid transit system be converted from two- to one-person train operation were to be made. That decision is left to the individual transit agencies to make after careful analysis of their specific conditions and needs.

The principal effort of this study was associated with visits to 16 heavy-rail rapid-transit systems in the United States and Europe to solicit opinions and obtain data and information relative to the issues, problems, and problem solutions associated with conversion of heavy-rail rapid-transit systems to one-person train operation. That work was supplemented by a review of the literature to identify definitive documents on the many topics of interest to this study.

The systems visited include: (1) the six U.S. two-person operation systems mentioned above; (2) four of the newer U.S. systems with one-person operation, i.e., BART (San Francisco), MARTA (Atlanta), PATCO (Philadelphia-Lindenwold), and WMATA (Washington); and (3) six European systems, i.e., BVG (Berlin), HHA (Hamburg), LT (London), RATP (Paris), SL (Stockholm), and VAL (Lille). All of the European systems visited except London and Lille have converted to one-person operation. London is in the process of converting and Lille has completely automatic unmanned trains. During the visits both system management and union officials were interviewed.

Management personnel at all of the U.S. and European heavy-rail rapid-transit systems visited that are presently operating with one-person train crews on multiple-unit trains are happy with that mode of operation and have no desire to convert to two-person train operation. They are satisfied with the safety, security, and operational performance of their systems and stated that they have no major or limiting problems in those areas.

With respect to labor problems, all of the newer systems that began operation from the first day of service with one-person operation of multiple-unit trains did not

encounter major labor opposition to one-person operation. All of the older systems, except Berlin, that have converted their entire system or only specific lines or services to one-person operation have encountered strong union opposition to such conversion. To date, such opposition has sometimes delayed but never completely stopped such conversion where it has been attempted. At the time of its conversion (i.e., mid-1960s), Berlin encountered little labor opposition because there was a labor shortage in Germany.

Three of the six U.S. two-person operation systems visited (CTA, GCRTA, and SEPTA) are very interested in conversion to one-person operation. SEPTA has already converted two special services on its Broad Street Line to one-person operation. Management personnel at the other three (MBTA, NYCTA, and PATH) stated that they have no plans or desire for such conversion at this time.

System management and union personnel interviewed at each of the six U.S. two-person operation rapid-transit systems visited were asked their opinion as to the major issues or problems that must be resolved in converting from two- to one-person operation of multiple-unit trains. Their responses are presented in the Overall Judgment of Systems Visited section of Chapter Two. A single composite listing of those individual system responses is presented below. This composite listing is a ranked listing with the issues or problems judged to be most important listed first. The ranking takes into consideration the frequency of citation and relative priority placed on the listed issues or problems by the six systems in question, plus the overall judgment of the research team based on the findings of the total study. In some cases, two or more issues or problems are judged to have equivalent rankings and are listed together under a common ranking. For example, car side door safety and union opposition are judged to be the most important issues or problems and are both assigned a ranking of one. The ranked listing of issues and problems follows.

1. Car side door safety and Union opposition.
2. Fire and Emergency evacuation between stations.
3. Reduced train operational performance resulting from increased time to recover from equipment, particularly door, failures, and increased station dwell time.
4. Security including perceived security.
5. Communication between train operator and central control, passengers on train and train operator, and passengers on station platforms and central control and possibly police.
6. One less on-board crew member to provide passenger information and assistance and detect problems.
7. Between car and end door safety.
8. On-board fare collection, Operator training, and Incapacitation of train operator.
9. Increased operator stress and Loss of a position to assign medically disqualified train operators to.

In addition to the foregoing issues or problems, there is some concern that new cars are still being delivered without provisions for future conversion to one-person operation. Also, while in most cases the reduced labor costs associated with one-person train operation should exceed the costs of conversion from two- to one-person operation, some systems are concerned that the costs of improving equipment reliability and upgrading facilities will in some cases offset such savings.

Potential solutions to most of the above issues or problems have been successfully demonstrated at European and/or U.S. one-person operation systems and are presented in the report. However, the systems, lines, or services converted to date generally have reliable rolling stock with full-width or convertible full-width operator cabs.

Also, while new one-person operation systems in the United States have demonstrated satisfactory door operation for trains up to 700 ft in length (i.e., BART), those systems generally have straight, unobstructed, relatively uncrowded station platforms. Many of the older U.S. two-person operation systems have less-reliable rolling stock, antiquated facilities, curved, obstructed and crowded platforms, and more severe security problems, thus increasing the difficulty of conversion.

While conversion of many of the six older U.S. heavy-rail rapid-transit systems with two-person operation of multiple-unit trains to one-person operation is believed to be feasible, it is believed that such conversion will generally follow an evolutionary process. That is, rather than system-wide conversion of all services and lines at one time, systems will most likely convert those services and/or lines that are most compatible to one-person operation first, followed by conversion of less compatible services and/or lines over time. The most compatible services include new lines, lines or services with new or rehabilitated cars and/or facilities, and off-peak service with shorter trains, fewer passengers, and longer headways. This process is presently being followed by SEPTA and London.

The most likely exception to this is GCRTA. GCRTA operates a single heavy-rail line (Red Line) with all island platforms except one. It plans to convert to all right-hand running in approximately 3 years. By that time, all of its older cars should be retired. All of its newer cars and cars on order have convertible full-width cabs with the operator console on the left-hand or platform side of the cab for right-hand running. At that time, it should be rather straightforward to convert the total system to one-person train operation. On the other hand, NYCTA may never choose to convert its crush-loaded, 10-car, 600-ft long, rush-hour trains to one-person operation.

Personnel and labor relations management people interviewed at all of the systems visited stated that train crew members displaced as a result of conversion to one-person train operation would either be used to improve service by running shorter more frequent trains, assigned to other job classifications, or absorbed through normal attrition. They would not be laid off. An evolutionary process for conversion to one-person operation will minimize the problems encountered with this approach.

The percent of employees classified as train conductors varies from 9 to 14 percent at U.S. two-person operation heavy-rail rapid-transit systems. It is unlikely that any eventual reduction in staff as a result of conversion to one-person operation would be so large. Additional employees will most likely be required in the following areas:

- Security/police department.
- Maintenance.
- Ad hoc platform attendants (i.e., at busy stations during peak hours).
- Supplemental crew members or wayside coverage persons at critical locations during peak commute hours.

Before proceeding with conversion of a specific system, line, or service to one-person operation, a comprehensive assessment of the economic worth of the conversion should be made. For such an assessment, investment or capital costs include all of the costs required to convert that specific system, line, or service from two- to one-person operation. Likewise, the future savings (or losses) resulting from that investment include the sum of all the differences in operating and maintenance costs between the two- and one-person operation versions of the specific system, line, or service over its useful life.

For comprehensive detailed analyses of the economic worth of conversion of specific heavy-rail rapid-transit systems, lines, or services from two- to one-person operation, the "net present value" measure of investment worth is preferred. The net present

value of an investment is the net present value of the expected cash flows associated with the investment over the life of the investment.

However, regardless of the specific measure of investment worth chosen, there are certain cost elements that are common to all. In general, these cost elements are related to the differences in costs between continued two-person operation and conversion to one-person operation. Listings of the cost elements that must be considered in a site specific economic analysis are presented in the report.

Where a new line or cars or overall rehabilitation of cars or facilities are being evaluated, it may be difficult to identify the marginal costs associated with one-person operation. In fact, in some instances and for some cost elements there may be little or no difference in the capital cost of the one- and two-person operation versions.

With respect to concerns that new cars are still being delivered without provisions for future conversion to one-person operation, the CTA staff has been evaluating alternative car design options. As a result of that effort, the staff has recommended to management the inclusion of convertible full-width cabs on all new rail cars. The reason for this is to provide the option of implementing one-person operation of multiple-unit trains at some point during the 30-year (plus) life of new equipment without requiring major car modifications. Such design studies should be incorporated into the planning and preparation of specifications for all new rail cars.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

PROBLEM STATEMENT AND RESEARCH OBJECTIVES

There is increasing pressure to provide more cost-effective operation of heavy-rail rapid-transit trains. A major candidate for improving productivity is reduction of train crew size to one person. This has been accomplished for all of the new rapid-transit systems beginning operation in the past 16 years. The older rapid-transit systems, however, continue to require a second crew member on board multiple-unit trains.

Battelle Columbus Division (BCD), in conjunction with the National Cooperative Transit Research and Development Program (NCTRP), recently conducted a study of the above proposition for improving the cost-effectiveness of heavy-rail rapid-transit systems. The objectives of that study were to:

1. Evaluate the issues that must be addressed in contemplating conversion of two-person systems to one-person operation including the identification of those issues unique to particular systems
2. Develop a framework for an economic assessment of the effects of implementation of one-person operation.

No recommendations that any specific rapid-transit system be converted from two- to one-person train operation were to be made. That decision is left to the individual transit agencies to make after careful analysis of their specific conditions and needs.

This report presents the results and findings of the study.

BACKGROUND

In 1969, the "Lindenwold Line" of the Port Authority Transit Corporation (PATCO) began operation under full automatic control, except for doors and public address announcements, and with one-person operation of all trains. It was the first instance of one-person revenue operation of multiple-unit, heavy-rail rapid-transit trains in the United States.

Since Lindenwold, five additional heavy-rail rapid-transit systems have gone into revenue service in the United States—all with one-person operation of trains. These systems are:

BART—Bay Area Rapid Transit District (San Francisco)
WMATA—Washington Metropolitan Transit Authority (Washington D.C.)
MARTA—Metropolitan Atlanta Rapid Transit Authority (Atlanta)
MDTA—Metropolitan Dade County Transportation Administration (Miami)

MTA—Mass Transit Administration of Maryland (Baltimore)

Thus, over the past 16 years, six new heavy-rail rapid-transit systems have begun operation in the United States. Every one of these new systems has one-person operation of all trains. Further, this development is not limited to the United States; it has occurred worldwide.

While all new U.S. systems use one-person operation of trains, essentially all of the older heavy-rail rapid-transit systems continue to require a second crew member on board each multiple-unit train.

Those systems include:

CTA—Chicago Transit Authority (Chicago)
GCRTA—Greater Cleveland Regional Transit Authority (Cleveland)
MBTA—Massachusetts Bay Transportation Authority (Boston)
NYCTA—New York City Transit Authority (New York City)
PATH—Port Authority Trans-Hudson Corporation (New York City)
SEPTA—Southeastern Pennsylvania Transportation Authority (Philadelphia)

Some of the older systems run single-car trains with one crew member on board. Also, very recently SEPTA began operation of 2- and 5-car trains with one-person crews. In the fall of 1983, SEPTA reopened its 1.9-mile Ridge Avenue Spur to the Broad Street Subway with one-person operation of the 2-car trains operated on that spur. In September 1984, SEPTA converted the 5-car trains operated on its Broad Street Express service from two- to one-person operation. SEPTA continues to operate all of its Broad Street Local and Market-Frankford Line trains with two-person train crews.

In Europe, many of the older systems have converted from two- to one-person train operation and new lines going into service since 1968 were designed for one-person operation. For example, the Berlin, Hamburg, Paris, and Stockholm Metros now have one-person train crews on all lines. Line 3 of the Stockholm Metro, which began service in 1975, and the Victoria Line of the London Metro, which began service in 1968, had one-person train crews from the initiation of service. Also, the London Metro is presently in the process of converting some of its older lines to one-person operation. The Hammersmith & City and Circle Lines were converted in the fall of 1984, and the District Line is scheduled for conversion in 1985.

RESEARCH APPROACH

The principal effort of this study was associated with visits to 16 heavy-rail rapid-transit systems in the United States and Europe to solicit their opinion and obtain data and information relative to the issues, problems, and problem solutions associated with conversion of heavy-rail rapid-transit systems to one-person train operation. That work was supplemented by a review of the literature to identify definitive documents on the many topics of interest to this study.

The systems visited are:

1. The six older U.S. heavy-rail rapid-transit systems listed in the Background section.
2. Four of the newer U.S. one-person operation systems listed in the Background section, i.e., BART, MARTA, PATCO, and WMATA. MDTA and MTA have only recently begun operations, and it was believed that they would have much less operating experience than the four one-person systems visited.
3. Six European Metro systems:

BVG—Berliner Vekehrs—Betriebe (Berlin, West Germany)
HHA—Hamburger Hochbahn A.G. (Hamburg, West Germany)
LT—London Transport Executive (London, England)
RATP—Regie Autonome des Transports Parisiens (Paris, France)
SL—AB Storstockholms Lokaltrafik (Stockholm, Sweden)
VAL—Vehicle Light Automatic (Lille, France)

The first five European systems are heavy-rail rapid-transit systems that either have or are in the process of converting to one-person train operation. The Lille system, which began operation in May 1983, claims to be the first fully automated, unmanned transit system operating in an open urban environment. (That claim is disputed by the Japanese, who claim that the unmanned urban system in Kobe, Japan, began operations in October 1982.) Although the subject of this study is "one-person" operation of multiple-unit trains, the Lille system was visited to examine the advanced technology available and used for unmanned urban operations.

During these visits, the principal researchers attempted to talk with both system management and labor union representatives. Generally they talked with the following types of people:

- Chief Transportation Officer and/or Director of Rail Operations
- Manager of Rail Equipment Engineering and Maintenance
- Manager of System Safety
- Police Chief
- Manager of Personnel/Labor Relations/Human Resources
- President/Business Agent of Local Operating Union

In a few cases, they talked with the system's General Manager. It was not always possible to make arrangements to talk with a union representative. In two cases, system management requested that the researchers not talk to the union because the system had no plans for converting to one-person operation and did not wish to raise a false issue with the union. In one case the union representative did not wish to talk with the researchers.

In soliciting information from the systems and unions visited, two types of inputs were requested. The first was their overall judgment as to the possibility of U.S. heavy-rail rapid-transit systems converting to one-person train operation. This included questions as to their satisfaction with the current mode of operation whether it be one-person or two-person operation; whether they had any future plans or desire to continue with or convert to one-person operation; and any major issues and/or problems they would face in converting to one-person operation. The second included elaboration on the issues and/or problems identified including descriptions of their current equipment, facilities, personnel policies, and possible solutions associated with those issues and/or problems.

In addition to discussions with system management and union

representatives, requests were made for any readily available published materials pertinent to the study. This generally included system description and statistical data, operating rules and procedures, union contracts, and awards of arbitrations with the union over reduction or elimination of job classifications. Only two systems indicated that they had made an in-house study of one-person operation. Those two systems provided short memorandums on the results of those studies. None of the systems indicated that they had made an economic study of one-person operation.

The literature search included a manual search of BCD's Transportation Library and an automated search of the Transportation Research Information Service (TRIS) holdings. The more applicable documents identified during the literature search were reviewed to identify relevant data and information useful to the study.

In evaluating the issues and problems identified, the responses obtained for individual issues were compared to determine the degree to which a consensus exists. Although quantitative data and information were desired, most of the information available was qualitative or judgmental in nature.

Identification of the specific issues and/or problems to be addressed was somewhat of an iterative process. The researchers initiated the process by identifying what they considered to be the major issues in converting to unmanned operation. As the system interviews progressed, a few additional issues and problems were identified along with equipment, facilities, procedures, and personnel policies used by individual systems for addressing or controlling those issues and problems.

The major issues or problems identified by this process are classified and discussed under the following section headings:

Technical and Operational Issues

- Train Control (including incapacitation of train operator)
- Car Side Door Control
- Station Dwell Time
- Between Car and End Door Safety
- Communications (including one less on-board crew member)
- Fire Prevention and Control
- Emergency Evacuation
- Security (crime and vandalism)
- Operational Performance
- On-Board Fare Collection

Human Resource and Institutional Issues

- Changes in Work Force
- Transit System Management Position
- Transit Labor Contract Provisions
- Transit Labor Union Position
- Transit Labor Related Regulations/Codes/Laws
- Transit Safety Related Regulations/Codes/Laws
- Timing of Conversion.

The economic issue was addressed separately through development of a framework for an economic assessment of the effects of implementation of one-person operation. This framework includes identification of cost elements that must be considered in a site-specific analysis and plan.

All of the above listed sections are presented in Chapter Two—Findings. The overall judgments of the systems visited along with the framework for economic assessment are also presented. The more general findings and their interpretation, appraisal, and application are presented in Chapter Three—Interpretation, Appraisal, Application. Generalized conclusions based on the findings are presented in Chapter Four—Conclusions and Suggested Research. Selected statistical data for each of the 16 systems visited are presented in Appendix A.

CHAPTER TWO

FINDINGS

This chapter presents the detailed findings of the study. First, each system visited is described in terms of the number of crew members on-board trains and regular station attendants at that system (i.e., Operating Personnel at Systems Visited). This is followed by a section presenting a summary of the overall judgment of the systems visited with respect to conversion to one-person operation of multiple-unit trains (i.e., Overall Judgment of Systems Visited). Next the technical, operational, human resource, and institutional issues or problems identified, along with potential solutions for each, are discussed. Finally, a framework for economic assessment is presented.

OPERATING PERSONNEL AT SYSTEMS VISITED

Table 1 presents a summary of train crew size and regular station and/or platform attendants for each of the 16 U.S. and European systems visited during the study. In addition to the regular station attendants listed, many of the systems assign additional station and/or platform attendants on an ad hoc basis, i.e., to specific high volume stations during peak commute hours.

Items of particular interest with respect to Table 1 include:

1. SEPTA and London have recently or are in the process

of converting some lines or services from two- to one-person train operation. Thus, those two systems are particularly relevant to this study.

2. Both the Berlin and Hamburg systems are currently operating with one crew member on-board trains. Thus, they are said to be one-person train operation systems. However, both systems use station platform train dispatchers to observe the train doors and signal the train operator when to close the doors. The platform dispatcher, not the train operator, is responsible for door safety. Both systems employ more platform dispatchers than train operators. Thus, they have no significant manpower savings over systems with two-person train crews and unmanned stations, e.g., PATH.

3. BART essentially operates with one-person train crews but supplements that crew member with a second crew member at certain critical locations and heavy train loading conditions, i.e., the Transbay Tubes and Berkeley Hills Tunnel during peak commute hours in the direction of the heavy commute. NYCTA has a related practice. A "tunnel coverage supervisor" is stationed on the downstream side of the main flow of passengers for tunnels under the East and Harlem Rivers, i.e., on the Manhattan side of the tunnels during the a.m. peak and on the other side of the tunnels during the p.m. peak. His function is to provide assistance in the event a train breaks down in the tunnel and/or an emergency situation develops.

4. One of the two-person train crew systems (PATH), two of the one-person train crew systems (MARTA and PATCO), and the unmanned train system (Lille) essentially have unmanned stations. In addition to reducing train crew size, reduction of station personnel is also a method for increasing the productivity of rapid-transit systems.

Table 1. Summary of train crew size and regular station attendants.

System	Multiple-Unit Train Crew, no.	Regular Station Attendant[(a)]
CTA	2[(b)]	TA daytime/90% of stations unmanned at night
GCRTA	2[(c)]	TA peak hours/Most stations unmanned off peak
MBTA	2	TA
NYCTA	2	TA
PATH	2	Unmanned
SEPTA	2&1[(d)]	TA/Some stations unmanned at night
BART	1[(e)]	SA
MARTA	1	Unmanned
PATCO	1	Unmanned
WMATA	1	SA
Berlin	1	TD
Hamburg	1	TD
London	2&1[(d)]	TA
Paris	1	TA
Stockholm	1	TA
Lille	0	Unmanned

(a) SA-Station Attendant; TA-Ticket Agent; TD-Train Dispatcher.

(b) CTA operates single-car and 3-section articulated-car trains on its Skokie Line and single-car trains at night on its Evanston Line. Those single- and articulated-car trains are operated by one crew member.

(c) GCRTA operates single-car trains at night with one crew member.

(d) SEPTA and London have recently or are in the process of converting some lines or services from two- to one-person train operation.

(e) During peak commute hours, the California Public Utilities Commission (CPUC) requires BART to have a second crew member onboard trains passing through the Transbay Tubes and Berkeley Hills Tunnel in the direction of the heavy commute.

OVERALL JUDGMENT OF SYSTEMS VISITED

One-Person Operation Systems

Management personnel at all of the U.S. and European heavy-rail rapid-transit systems visited that are presently operating with one-person train crews on multiple-unit trains are happy with that mode of operation and have no desire to convert to two-person train operation. They are satisfied with the safety, security, and operational performance of their systems and stated that they have no major or limiting problems in those areas.

In the United States, all of the one-person multiple-unit train operation systems, except SEPTA, were conceived and designed for one-person train operation and have operated in that mode from the first day of revenue service. They had no history of two-person operation and did not encounter major labor opposition to one-person operation. SEPTA, which recently converted two of its services, i.e., the Ridge Avenue Spur and Broad Street Express service, from two- to one-person operation, encountered strong union opposition and both conversions were advanced to arbitration. In both cases, the union's request that SEPTA be ordered to cease one-person operation was denied. (The results of those arbitrations are discussed in the Transit Labor Union Position section.)

In Europe, all the systems visited, except Lille which is unmanned, have been or are in the process of being converted to one-person operation. Hamburg converted to one-person operation in the late 1950s, Berlin in the mid-1960s, Paris from 1963 to 1978, Stockholm in the 1970s, and London is currently in the process of such conversion. Little labor opposition was encountered at Berlin because there was a labor shortage at the time of the conversion. Hamburg, Paris, and Stockholm encountered strong union opposition but believe that such opposition would be greater today. Berlin, Hamburg, and Paris representatives stated that labor opposition to conversion to one-person operation tends to be greater in periods of general unemployment than in periods of full employment.

While London's Victoria Line, which began service in 1968, has always had one-person operation, London management has been negotiating with the union since that time to get an agreement for conversion of some of the older lines to one-person operation. Such an agreement was reached in 1982 after a period of 14 years. London is now in the process of converting some of its older lines to one-person operation.

U.S. Two-Person Operation Systems

Three of the six U.S. two-person operation systems visited (CTA, GCRTA, and SEPTA) are very interested in conversion to one-person operation of multiple-unit trains. Management personnel at the other three (MBTA, NYCTA, and PATH) stated that they have no plans or desire for such conversion at this time.

Of the first three systems, SEPTA has already converted two multiple-car train services to one-person operation, i.e., the two-

car trains operated on its Ridge Avenue Spur and the five-car trains operated in its Broad Street Express service. CTA is planning a new line to the south-west side of Chicago. Provisions are being made in the design of the new route and equipment to provide management with the option of one-person train operation. GCRTA has all island platforms, except for the E. 55th Street Station, and presently has right-hand running on the west side of Public Square and left-hand running on the east side. Management plans to convert to all right-hand running. This conversion should be completed in approximately 3 years. By that time, all of their older cars, which have right-hand corner cabs, should be retired. All of their newer cars have convertible full-width cabs with the operator console on the left-hand or platform side of the cab for right-hand running. At that time, it should be rather straightforward to convert to one-person train operation. (*Note:* A convertible full-width cab is one that has a two position door. On the front end of the train, the cab door is positioned perpendicular to the aisle to block off the aisle and provide for a full-width cab. At other locations in the train, the cab door is positioned longitudinally on one side of the aisle to close off the control area and make the other side available for passenger occupancy.)

A detailed discussion of the overall judgment of the six U.S. two-person train operation heavy-rail rapid-transit systems visited and a summary of the major problems associated with conversion to one-person train operation cited by each are presented in the following paragraphs.

CTA (Chicago)

As shown in Table 1, CTA presently operates with two-person train crews on all multiple-unit trains. It also operates with a few single- and articulated-car trains with one crew member. CTA is very interested in extending the use of one-person train crews to other operations. Management believes one-person operation of multiple-unit trains is inevitable. Most of the CTA management personnel interviewed do not see any insurmountable safety, security, or operational problems associated with conversion to one-person train operation of multiple-unit trains.

This does not mean that CTA management personnel do not see any problems associated with conversion to one-person operation. A number expressed concern for:

- *Emergency evacuation.* This is particularly hazardous in tunnels with smoke and fire.
- *Troubleshooting malfunctioning equipment.* This is a particular problem if the operator must leave the train.
- *Door safety.* The operator may have difficulty seeing rear doors on 8-car, 400-ft long trains.
- *Operator training.* CTA presently uses the conductor job classification as a training period for future motormen.
- *Security.* The existence of a conductor is often perceived by passengers as a security enhancement.
- *Fare collection.* CTA conductors assume fare collection responsibilities at low volume stations during the off-hours.
- *Union opposition.* Union opposition may be a major problem.

In addition, the Operations Planning Department is concerned that new rail cars being delivered today are not equipped for one-person operation.

CTA rail transit employees are represented by Local 308 of the Amalgamated Transit Union (ATU). The Local 308 union officials interviewed stated that passenger safety is the number one priority in train operation as far as they are concerned. There is need for at least two people on the train. At one time CTA had five-person train crews. The conductor is back-up for the motorman. The passenger feels safer and more comfortable when the conductor is visible and present.

The union interviewees mentioned that CTA already had one-person operation on two lines with single-car trains and that it was "OK" for that type of operation but not for heavy passenger loads. They do not believe a one-person operation could handle crowded 8-car trains during rush hours.

They believe employee security as well as passenger security is important because there have been attacks on employees. Before 1981 there were some transit security people but they were eliminated. Union interviewees believe there is not nearly enough protection. Although the Chicago Police Department has responsibility for transit, it has been in a lay-off posture and has not given the attention to CTA that is needed.

Union interviewees also brought up the matter of handicapped passengers who are now assisted by the conductor. (This subject is currently under study by CTA management.) Increased employee stress is also a concern. To thrust full responsibility in the rush hour for up to a thousand people on one person will escalate the stress problem for train operators. They are also concerned with train evacuation during a fire and felt that at least two on-board people are needed.

When asked what actions would be taken if the union was faced with the possibility of a reduction from two- to one-person operation, the union officials replied that many actions could be taken such as tradeoffs, negotiations, or arbitration. They also indicated there are other avenues such as going to the community or the press and possibly the courts.

GCRTA (Cleveland)

GCRTA operates one heavy-rail line (Red Line) and two light-rail lines. The Red Line currently operates with two-person train crews for multiple-unit trains and one-person train crews for single-car trains. Currently, GCRTA has no formal plans to convert to one-person train operation but management is in favor of such operation. The GCRTA management personnel interviewed do not see any insurmountable problems associated with one-person operation of multiple-unit trains. However, they indentified the following major issues and problems that must be satisfactorily resolved.

- *Safe door operation.* Operator must have good visibility of all doors.
- *Union negotiations.* Job description will change for operation of multiple-unit trains.
- *Passenger communications and assistance.* Conductor can communicate with passengers in second and third car. He can also assist passengers in case of sickness, e.g., heart attack.
- *Emergency evacuation.* GCRTA has very little of its right-of-way in tunnels, most is at grade. This may be of greater importance to systems with more mileage of track in tunnels or elevated.
- *Operational issues.* Conductor can help in cutting out doors and occasionally throw switch.

GCRTA management does not view one-person operation as a means to reduce staff. Rather they envision it as a method of improving service without an increase in staff, i.e., better deployment of staff. They also see such conversion as an evolutionary process.

The entire GCRTA work force, both rail and bus, is represented by a single union, i.e., Local 268 of the Amalgamated Transit Union (ATU). The Local 268 union official interviewed stressed the fact that the motorman and conductor are interchangeable. Each is qualified to do both types of work and in many situations they do. He believes the major problem with one-person operation of multiple-unit trains would be door safety. In this respect, he stated the system needs more than two persons on 4-car trains not fewer. He stated that in the past year three passeners were killed trying to cross tracks to board trains and to avoid paying fares. He also believes security is a real but not a major problem. A 36-person Transit Police Force is just too small to protect the system three shifts per day, seven days per week.

SEPTA (Philadelphia)

SEPTA's experience is particularly relevant to this study because it recently converted two of its services from two- to one-person operation. SEPTA presently operates two rapid-transit lines, the Broad Street and Market-Frankford Lines, and the Ridge Avenue Spur to the Broad Street Line. In the fall of 1983, SEPTA reopened the 1.9-mile Ridge Avenue Spur, which had been shutdown in 1981 for construction of the Center City Tunnel connection, with one-person operation of the 2-car trains operated on that spur. New Kawasaki-built cars with convertible full-width cabs are used for that service. In September of 1984, SEPTA converted its Broad Street Express service from two- to one-person operation. Five car trains consisting of the new Kawasaki cars wth convertible full-width cabs are used for that service also. SEPTA continues to operate all of its Broad Street Local and Market-Frankford Line trains with two-person train crews.

SEPTA management is enthusiastic about one-person operation of multiple-unit trains and does not see any major problems associated with conversion to one-person operation except possibly:

- *Union opposition.* SEPTA encountered strong union opposition to its conversion of both the Ridge Avenue Spur and Broad Street Express services to one-person operation. As discussed, both conversions were advanced to arbitration.
- *Door observation.* SEPTA management believes the train operator has adequate vision of the doors for 5-car trains. They have some concern in this respect if the train length were increased to 8-cars, i.e., 540 ft, and at curved platforms.
- *Increase in station dwell time.* A SEPTA representative reported that one-person train operation could result in a 15-sec increase in station dwell time at platforms on the opposite side of the train from the operator console. This is because of the extra time needed for the operator to set the brake, get up from the console, walk across the cab, and then retrace these steps after closing the doors.

SEPTA rail-transit employees are represented by Local 234 of the Transportation Workers Union (TWU). Officials of that local did not wish to meet with the project team because of ongoing arbitration actions.

MBTA (Boston)

While MBTA recently (late 1981) reduced train crew size from three to two persons, MBTA management is not anxious to reduce the train crew from the current two persons to one person. They strongly believe that, for MBTA, reduction of the train crew from two to one person would have a much greater impact on operations and safety and would be more difficult and costly to implement than reducing the crew from three to two persons was. The principal reasons given for this position are:

- *Reduced operating performance.* The remaining conductor on the train is required to free up doors that hang up on snow and ice in the winter, lock-out malfunctioning doors, and leave the train to cut out malfunctioning brakes and key a train by a signal. Without the second man, station dwell time would increase and on-time performance would be reduced significantly. Before MBTA could seriously consider one-person operation, it would have to completely revise its maintenance policies, procedures, and level of effort.
- *Emergency evacuation and fire.* MBTA is an old system with oil-soaked wooden ties. Fire is always a danger. Management wants the extra man to assist in case of fire and to help with emergency evacuation. Evacuation walkways are old and frightening. Communications with passengers need to be improved particularly in emergency situations.
- *Door safety.* Four-car trains are the longest trains currently operated by MBTA. They are planning on operating 6-car trains in the future. For 6-car trains, door safety could be a problem for one-person operation.
- *Union opposition.* MBTA management believes the union would strongly oppose conversion to one-person operation.

Security was not negatively affected by the conversion from three- to two-man operation. The number of conductors was reduced by 66, but 39 MBTA police officers were added. Crime is at the lowest level in 15 years and is steadily decreasing. There was no discernable reduction in ridership at night.

MBTA rail transit employees are represented by Local 589 of the Amalgamated Transit Union (ATU). Officials of Local 589 said they would oppose any move to reduce the size of train crews at MBTA to one-person. They identified the primary problem with one-person operation at MBTA as safety, particularly with respect to fires and emergency evacuation. The second priority problem identified was security. They suggested that the savings in the reduction of train crews from three to two persons was mitigated by the need to hire additional police. Concern was also expressed with respect to who would troubleshoot problems with the equipment. The conductor is sometimes required to get down from the train and pull valves underneath the train or key a train by a signal and occasionally serves as a switchman or flagman.

Local 589 officials also stated that new systems can operate with one on-board person because they can be designed to do so. However, older systems have the problems of wooden ties and structures, grease on the roadbed, antiquated signal systems, as well as curved platforms making door visibility impossible.

Additionally, the conductor position is a good place to assign medically disqualified train operators.

NYCTA (New York)

NYCTA presently operates with two-person train crews. NYCTA management is happy with two-person train operation and stated that it has no plans for converting to one-person operation in the immediate future. They further stated that because of the present deteriorated condition of the physical plant and equipment, there are numerous issues of a higher priority than one-person train operation at this time. However, once the system is returned to a state of good repair, they will be studying this possibility.

Various NYCTA management persons interviewed gave different reasons and priorities for not converting to one-person operation. In general, the considerations cited as being most important are:

- *Door safety.* Side door visibility is poor even with the conductor located in the middle of the train. Maximum train length is 600 ft and many stations have curved platforms. Some stations require mirrors on the platform to assist the conductor to see the doors on the ends of the train even though he is located in the middle of the train. The performance of mirrors is considered poor. Also, the train operator would not be able to watch the doors for a short distance after train start-up. All but approximately one-fifth of the cars currently in service would have to be modified to permit one-person operation. However, the above one-fifth of present cars plus new cars being placed in service could easily be converted to one-person operation.
- *Emergency evacuation.* When attempting to evacuate a crush loaded 10-car train, particularly if there is a fire, a second person is invaluable. The train operator is instructed to stay with the radio and get help. The conductor takes care of the passengers.
- *Equipment malfunction.* With one-person operation it will take longer to trouble shoot trains. This will increase train delays. NYCTA operates with 2-min headways during peak hours and 5-min headways during off-peak hours. To move large numbers of people, increased delay times cannot be tolerated. Reliability of older cars would have to be increased substantially. Also, the conductor provides a second set of eyes and ears to detect problems, equipment malfunctions, fires, etc.
- *Security.* Elimination of the conductor would reduce security, particularly perceived security, and require additional transit policemen.
- *Incapacitated operator.* In the event of injury or incapacitation of the operator, the conductor is available to take charge of the situation.
- *Union opposition.* NYCTA management believes the union would strongly oppose conversion to one-person operation.

NYCTA rail transit employees are represented by Local 100 of the Transportation Workers Union (TWU). Management representatives at NYCTA requested that the project team not interview union officials on this subject because they did not wish to raise false issues at this time.

PATH (New York-New Jersey)

PATH currently operates with two-person train crews. PATH management is happy with two-person train operation and stated that it has no intention of converting to one-person operation in the foreseeable future.

Recently, PATH studied one-person train operation and concluded that although technically feasible, it is neither a practicable nor an appropriate operational conversion for PATH at this time. The considerations cited as being most important are:

- *Emergency evacuation and fire.* PATH is reluctant to eliminate the presence of a second crew member because of the danger of fire and/or emergency evacuation in the tunnels under the Hudson River. On March 16, 1982, a serious fire occurred on a PATH train. It was necessary to evacuate 450 people from a tunnel under the Hudson River. PATH management does not believe that one person could have handled that evacuation.

- *Security and information.* The elimination of the conductor's position would remove a visible authority figure on-board the train who presently provides passengers a sense of security. Furthermore, the conductor responds to passenger illness and unusual situations that may arise between stations and answers passenger questions. These are necessary functions that would otherwise not be performed because the motorman, located in the front cab, must necessarily give his full attention to driving the train.

- *Equipment malfunction.* There are numerous instances where an equipment malfunction or unusual situation would require, in the absence of a conductor, either expensive back-up equipment systems or additional personnel or would cause excessive delays if the motorman leaves his cab to perform activities now done by the conductor.

PATH is currently engaged in a $136 million Safety Improvement Program. This program includes installation of tunnel and terminal emergency ventilation systems, additional tunnel emergency exists, new water standpipe systems, improved tunnel lighting, and fire hardening of cars. This work will be completed in 4 or 5 years and PATH intends to reconsider the issue of one-person train operation at that time. However, a memorandum on the current study cautions that an optimistic view should not be taken as to the possible implementation of one-person operation even after the PATH Safety Improvement Program is completed.

PATH is unique among the systems visited in that it is considered to be a railroad rather than a transit operation. As such, it is subject to the rules and regulations of the Federal Railroad Administration, and its labor-management relations are subject to the Railway Labor Act. PATH is also unique in that train crew members are represented by two unions. Train operators are members of the Brotherhood of Locomotive Engineers (BLE). Conductors are represented by the United Transportation Union (UTU). PATH believes that the UTU would strongly oppose a conversion to one-person operation. Management representatives at PATH requested that the project team not interview union officials on this subject because they do not wish to raise false issues at this time.

TECHNICAL AND OPERATIONAL ISSUES

Train Control

Three specific issues or problems related to train control with one-person operation were identified.

1. Are automatic train controls or cab signals required for one-person train operation?
2. With one crew member on board, should passengers be able to stop a train between stations?
3. What if the single train operator becomes incapacitated?

The findings with respect to these issues are presented in the following paragraphs.

Train Control Requirements

Table 2 presents a summary of train control and signal type for the systems visited. Note that neither automatic train control nor cab signals are required for one-person operation. SEPTA has manual train control and wayside signals on its recently converted Ridge Avenue Spur and Broad Street Express service. Most of the Berlin, Hamburg, and London lines have manual train control and wayside signals, and Stockholm has manual train control with cab signals.

Of the systems with both automatic and manual train control modes, PATCO requires train operators to regularly (one trip per day) operate in the manual mode so that they maintain proficiency in manual operation. Paris operates in the automatic mode during the day when short headways are required and in the manual mode at night. MARTA encourages but does not require train operators to occasionally use the manual control mode. WMATA does not encourage manual control operation. All of the systems with automatic train control attempt to keep the operator alert by having him announce stations and by observing and controlling the closing of the car side doors.

While automatic train control is not required for one-person operation, the interviewees expressed both pro and con opinions as to its desirability. Proponents of automatic train control cited the following advantages:

- Elimination of human error.
- More consistent train operation and shorter headways.
- Energy conservation.
- Smoother ride.
- Less train operator stress.

Proponents of manual train control cited the following advantages:

- Less driver boredom.
- Better control of braking at outdoor stations in rain, snow, or sleet.
- Lower initial and maintenance costs.

Passenger Emergency Stop

With respect to the second issue, heavy-rail rapid-transit cars typically have emergency stop devices, e.g., pull cords or handles, for passengers. This is believed to be a carryover from railroad practice. Eleven of the 16 systems visited presently have such passenger emergency stops on trains. The problem with such devices is that they stop the train wherever they are pulled, e.g., in a tunnel between stations. Also, typically a train crew member must go to the car in which the device was pulled to reset it before the train can be moved.

One of the major issues or problems identified for one-person train operation is emergency evacuation of passengers from a train between stations, particularly with smoke or fire in a tunnel. To reduce the likelihood of emergency evacuation between stations, a number of systems are converting their passenger emergency stop systems to passenger emergency alert systems. With such systems, passengers cannot stop the train between stations. Rather they can stop the train at the next station and/or alert the train operator of the problem. Then the train operator or central control makes the decision whether to stop or proceed to the next station.

A brief summary of present and future passenger emergency stop or alert provisions for the systems visited is presented below.

- *BART and WMATA.* No passenger emergency stop. Passenger intercom to driver.
- *MARTA.* Passengers have access to emergency stop button on left side of all intermediate cabs but the passenger's attention is not drawn to the button. Also, passenger intercom to driver.
- *PATCO.* No passenger emergency stop. Passenger alarm buttons in each car. Buzzer sounds in operator's cab. Red door light indicates car in which alarm button was pushed.
- *SEPTA.* SEPTA recently converted its cars from a passenger emergency stop system to a passenger alert system similar to the PATCO system above.

Table 2. Summary of train control and signal type.

System	Normal Mainline Train Control, M/A[(a)]	Signal Type, C/W[(b)]
CTA	M	C&W[(c)]
GCRTA	M	C&W[(d)]
MBTA	M-Blue & Orange Lines	W
	A-Red Line	C
NYCTA	M	W
PATH	M	W
SEPTA	M	W
BART	A	C
MARTA	A&M	C&W
PATCO	A&M	C
WMATA	A&M	C
Berlin	M-All lines except 4 & 9	W
	A-Lines 4 & 9	C
Hamburg	M-All lines except PUSH[(e)]	W
	A-PUSH section of Line 1	C
London	M-All lines except Victoria	W
	A&M- Victoria Line	C
Paris	A&M	C
Stockholm	M	C
Lille	A (unmanned)	Not Applicable

(a) M - Manual; A - Automatic

(b) C - Cab; W - Wayside

(c) The majority of the CTA system has cab signals. However, the downtown subways and Congress St. Route have wayside signals.

(d) GCRTA is in the process of converting from wayside to cab signals.

(e) PUSH - Process-Computer Controlled Underground Railway Automation System Hamburg.

- *CTA, GCRTA, MBTA, and NYCTA.* Passenger emergency stop.
- *PATH.* Present cars have passenger emergency stop. Future PA-4 cars will have both passenger emergency stop and passenger alarm (buzzer) system. May add passenger alarm to older cars. PATH intends to retain the passenger emergency stop device along with the alarm (buzzer) device. PATH management wants a passenger to be able to to stop the train if someone falls from the train or platform.
- *Berlin.* Present cars have passenger emergency stop. Future cars will not. Rather, a passenger emergency alert will light an indicator light on the operator's console to signal the operator to stop at the next station.
- *Hamburg.* Cars have passenger emergency pull handles but operator can override the brake from the operator's console.
- *London.* Present cars have passenger emergency stop. New cars will have passenger alert system.
- *Paris.* Previously had passenger emergency stop. For new cars, passenger emergency stop is only active at stations. Between stations operator is alerted and passenger intercom is activated. Operator is directed to stop at next station.
- *Stockholm.* Present cars have passenger emergency stop. In the future, passenger emergency stop will only be active at stations and one train length out of station.
- *Lille.* Present cars have passenger emergency stop. Future trains will proceed to the next station before stopping.

The trend away from passenger activated emergency stop devices for transit trains is greater in Europe than in the United States. In France, the French Ministry of Transportation has passed a regulation that requires future transit trains to proceed to the next station before stopping after a passenger emergency handle/cord is pulled. In West Germany, a similar federal regulation was recently passed. In the United States, most of the one-person train operation systems have such provisions, e.g., BART, WMATA, PATCO, and SEPTA, but the older two-person operation systems generally do not.

In conclusion, for one-person train operation, it may be desirable to provide a:

- Passenger emergency stop system that will permit the train to proceed to the next station before stopping.
- Passenger emergency stop system that is only active at or in close proximity to station platform.
- Passenger emergency alert system (intercom and/or buzzer) rather than passenger emergency stop system.
- Passenger emergency stop system that activates service or emergency brakes that can be overridden or revoked by the train operator from his operating position.

Provision of a passenger intercom to the driver for use with such systems may be desirable.

Incapacitation of Train Operator

Two of the systems visited cited the possibility of a train operator being incapacitated, injured, or trapped in the train cab as a problem for one-person operation. However, other systems thought this to be an unlikely problem. Two systems said they never had an incapacitated or trapped train operator. Two other systems could only recall one such instance in the past 20 years. In addition, all of the systems with manual train control have a "deadman" control to stop the train in the event of the incapacitation of the train operator. For their deep tunnels, London has developed a method for alerting central control via the radio in the event the deadman control on any train is activated.

Car Side Door Control

Safe operation of the passenger side doors is one of the major issues or problems identified for one-person train operation. Specific issues or problems related to this subject include:

1. Can the train operator adequately observe the doors along the full length of the train?
2. What devices are available to assist the train operator in observing the doors at curved platforms?
3. What other devices are available to assist in safe door operation?
4. Must the train operator continue to observe the doors after the train begins to move?
5. What operator cab and door control modifications are required for one-person train operation?

The findings with respect to these issues are presented in the following paragraphs.

Door Observation Distance

With respect to the first issue, for all present two-person operation systems (see Table 1), the conductor controls the doors and is typically located near the middle of the train. Thus, the maximum distance he must see along the side of the train is approximately one-half train length. For one-person train operation, the train operator is located in the front of the first car. If he is to control the side doors, he must look back along the full length of the train.

Table 3 presents a summary of maximum train length, location in the train of the person operating the train doors, and the maximum distance that person must look along side of the train while closing the passenger side doors, for each of the systems visited. Items of particular interest with respect to Table 3 include:

1. Even for two-person operation systems in the United States, the conductor is required to observe the doors for a distance of up to 300 ft at NYCTA and PATH and 340 ft at SEPTA.
2. For SEPTA's one-person operation Broad Street Express service, the operator is located at the front of the first car. For the two-person operation Broad Street Local service, the conductor is located at the rear of the fifth car. Thus, regardless of whether one- or two-person operation is used, the crew member operating the doors must look along the full length of the train, i.e., 340 ft.
3. In the United States, for new one-person operation systems (e.g., MARTA, WMATA, and BART) the train operator is required to observe the doors for distances of 600 to 700 ft.
4. In Europe, Paris and Stockholm operate one-person operation trains up to 300 and 492 ft in length, respectively. London recently converted the Hammersmith and City Line from

Table 3. Summary of maximum train length, location of person operating doors, and maximum door observation distance.

System	Maximum Train Length, No. of Cars	Car Length, ft.	Maximum Train Length, ft.	Location of Person Operating Doors(a)	Maximum Door Observation Distance, ft.
CTA	8	48	384	3R & 4F	240
GCRTA	6	48	288	2R & 3F	192
	4	75	300	2R & 3F	150
MBTA	4	70	280	3F	140
NYCTA	11	51	561	5R & 6F	306
	10	60	600	5R & 6F	300
	8	75	600	5F	300
PATH	7	51	357	1R & 2F	306
SEPTA	6(b)	55	330	4R & 5F	220
	5(c)	68	340	1F or 5R	340
BART	10	70	700	1F	700
MARTA	8	75	600	1F	600
PATCO	6	68	408	1F	408
WMATA	8	75	600	1F	600
Berlin	6	52½	315	1F	N.A.(d)(e)
	8	42½	340	1F	N.A.(d)
Hamburg	8	46	368	1F	N.A.(d)
	9	43	387	1F	N.A.(d)
London	8(f)	53	424	8F	371
	6(g)	51	306	1F	306
	6(h)	60	360	1F	360
Paris	6	50	300	1F	300
Stockholm	8	61½	492	1F	492
Lille	4(i)	43	172	Unmanned	N.A.

(a) F - Front; For example 4F = Front of 4th car in train. R - Rear; For example 3R = Rear of 3rd car in train.
(b) Market-Frankford Line
(c) Broad Street Line
(d) Train side doors are monitored by train dispatcher on platform who signals the train operator when to close them.
(e) N.A. - Not Applicable
(f) Metropolitan Main Line
(g) Hammersmith & City Line
(h) District Line
(i) Maximum train length. Presently operating with 2-car trains.

two- to one-person operation. Maximum train length on that line is 306 ft. Conversion of the District Line, which has a maximum train length of 360 ft, is scheduled shortly. The conductor on the two-person operation Metropolitan Main Line is located at the front of the last car and has a maximum door observation distance of 371 ft.

5. Several European systems (e.g., Berlin and Hamburg) place responsibility for door safety on a train dispatcher located in the center of the station platform. The dispatcher signals the train operator when to close the doors.

In conclusion, for new, one-person train operation systems in the United States, satisfactory door operation has been demonstrated for trains up to 700 ft in length. Those systems generally have straight, unobstructed, relatively uncrowded station platforms. For older systems, with more obstructed and crowded station platforms, satisfactory door operation has been demonstrated with maximum door observation distances up to approximately 400 ft (e.g., London and PATCO). This latter length is as long or longer than the *present* maximum train lengths at all of the older U.S. two-person operation systems except NYCTA.

Door Observation Aids

The above maximum door observation distances apply to straight platforms. At curved platforms the distance along the side of the train visible to the crew member controlling the doors could be less. Two devices are presently employed to assist crew members in observing the train doors at curved platforms, i.e., mirrors and closed circuit television (CCTV). Table 4 presents a summary of the present use of mirrors and/or CCTV to assist in observation of car side doors at the systems visited. Note that while CCTV is extensively used for this purpose in Europe, almost no CCTV is presently used for this purpose in the United States. The only U.S. station where CCTV is presently being used in regular service to assist in monitoring train side doors is CTA's Loyola station on the North-South Route.

PATCO has recently lengthened its platforms to accommodate 8-car trains. The island platforms are slightly curved on one side. The operator can see the full length of 6-car trains but not of 8-car trains on the curved side of the platform. PATCO is experimenting with CCTV for use with 8-car trains. Contrast problems have been encountered with the CCTV monitor on elevated platforms during the daytime as the light varies with the position of the sun and amount of cloud cover. As one possible method of overcoming this, PATCO is experimenting with having the cameras on the platform but the monitor in the train cab. All present CCTV systems have the monitor located on the platform. PATCO has not yet solved all of its problems with CCTV for observing car side doors.

At Berlin and Hamburg, CCTV is used to monitor the train doors along the unattended platform of stations with side platforms and only one platform train dispatcher. At Berlin, mirrors are sometimes used to assist the train dispatcher observe the train doors along attended curved platforms. Hamburg uses CCTV for this purpose. They tried mirrors a number of years ago and experienced poor results.

For two-person operation at London, the conductor uses neither mirrors nor CCTV to observe doors. At curved platforms,

Table 4. Summary of use of mirrors and/or closed circuit television (CCTV) to assist in observation of car side doors.

System	Present Use of Mirrors	Present Use of CCTV	Comments
CTA	3-Stations	1-Station	Possibly 13 stations would require mirrors or CCTV for one-person operation
GCRTA	None	None	
MBTA	Curved Platform Stations	None	Few conductors use mirrors
NYCTA	Some Stations	None	
PATH	None	None	
SEPTA	1-Station	None	
BART	None	None	All straight platforms
MARTA	None	None	All straight platforms
PATCO	2-Terminals	None	Experimenting with CCTV for use with 8-car trains
WMATA	2-Stations	None	
Berlin	Some Stations	Yes	Platform train dispatcher uses CCTV to see unattended platform
Hamburg	None	Yes	Same as Berlin
London	None	None	Two-person operation
	Yes	Yes	One-person operation, CCTV is only used at curved platforms
Paris	Yes	Yes	
Stockholm	None	Yes	
Lille	None	None	CCTV used for platform security but not for door operation

he walks out on the platform to observe the doors. He then walks back to the train to close the doors. The train is not started until an indicator light indicates that all doors are closed. For one-person operation, London has large mirrors located on both straight and curved platforms just ahead of the front of a stopped train. CCTV is used only for curved platforms. At straight platforms, the train operator can either stay at the console and look out the windshield at the mirror on the platform to observe the side of the train over its entire length or he can step out onto the platform through a cab door to directly observe the side of the train. At curved platforms, the operator stays at the console and uses the mirror to observe the doors on the first few cars and one or two CCTV monitors adjacent to the mirror to observe the doors on the following cars.

At Paris, the train operator either steps out onto the platform through a cab door to directly observe the side of the train or stays seated at the console and observes the side of the train by means of a mirror and two or three CCTV monitors located on the platform just ahead of the front of a stopped train. The mirror is used to see the doors on the first two cars and the CCTV monitors to observe the doors on the following cars. The mirror and CCTV monitors are used at both straight and curved platforms. Paris management reported that they have no trouble seeing CCTV monitors at above-ground stations. They put sunshields on the cameras and monitors if the sun shines on them.

Stockholm uses no mirrors and only uses CCTV to assist the driver in viewing the side of the train at curved platforms and at a very few busy stations with straight platforms to see the doors on the rear of 8-car trains. At straight platforms, the operator steps onto the platform through a cab door to directly observe the side of the train over its entire length. He announces door closing and closes the doors via a hand-held public address system microphone and "door-close" button on the end of a flexible cord attached to the car. At curved platforms, the operator steps onto the platform and directly observes the doors on the first two cars and one or two CCTV monitors to observe the doors on the following cars. Stockholm reported that sunlight and contrast are a problem at some above-ground stations, e.g., the sun moves and sometimes shines into a camera. At some above-ground locations, they use extensive shrouding around the cameras and monitors to minimize this problem.

In addition to lighting contrast problems at above-ground stations, other problems cited for CCTV include high cost of installation and maintenance and high required reliability to minimize the frequency of system failure. Also, mirrors must frequently be cleaned and adjusted and their performance is often judged to be marginal.

In conclusion, although CCTV and mirrors are extensively used in Europe to assist the train operator in observing the car side doors at both curved and straight platforms, they are not trouble-free and their use must be carefully tested and evaluated for specific applications.

Other Devices for Safe Door Operation

With respect to the third issue, devices other than CCTV and mirrors used to assist in safe door operation include:

- Interlocking of car side doors with train propulsion and/or braking system.
- Sensitive door edges.
- Warning chimes or announcement that doors are about to close.
- Platform lighting along side of train.
- Passenger-activated emergency stop devices both on the cars and platforms.

In the United States essentially all car side doors are interlocked with the propulsion and/or brake system. This prevents train start-up until after all the doors are closed. In Europe, London, Paris, Stockholm, and Lille presently have such interlocks. Hamburg is in the process of adding them to all cars. Berlin uses them on its two lines with automatic train control, Lines 4 and 9, only. The interlocks at Berlin, Hamburg, and Stockholm are only active during train start-up.

Of the 16 systems visited, three (CCTA, MARTA, and Lille) have sensitive door edges. NYCTA had sensitive door edges at one time but removed them because passengers held them open increasing station dwell time. CTA, MARTA, and Lille management said this was not a major problem.

To minimize possible increases in dwell time, doors with sensitive edges are fairly "aggressive". For example, at CTA the doors do not retract, they just relieve the closing force on the door. This makes it easier to push open or retract something caught in the door. At MARTA, the doors recycle once and then close on the object with a force of 8 to 10 lb. At Lille, if an obstruction is encountered, the doors open slightly and then quickly close again.

Eleven of the 16 systems visited have warning chimes, buzzers, bells, whistles, and/or announcements that the doors are about to close. On its newer cars, CTA has public address (PA) speakers on the outside of the cars so the conductor can make announcements to people on the platform entering the train.

Good lighting along the side of the train when it is berthed at station platforms is essential to the train operator's ability to adequately see the doors along the full length of the train. Good lighting is more important for one- than for two-person operation because the maximum door observation distances are longer. Possibly the best lighting arrangement is two or three parallel continuous strings of florescent lights along the entire platform edge located just above the top of the cars and back 1 or 2 ft from the edge of the platform. Many of the two-person operation systems already have this lighting arrangement but may wish to increase its intensity for one-person operation. Special attention should be given to the lighting of above-ground stations. With the variable light intensity, contrast and shadow problems at those stations, the visibility along underground platforms is frequently superior to that along above-ground ones.

Passenger-activated emergency stop or alert devices located on cars were discussed in the preceding section. One alternative for such devices is to make them active at or in close proximity to station platforms only. With such a system, a passenger on the train observing someone caught in a door while boarding could stop the train in the proximity of the platform but could not stop the train between stations. Also, the European systems visited typically have a passenger-activated emergency train stop device located prominently on station platforms. The principal reason for this device is to stop trains in the event someone falls from the platform to the track. However, such devices can also be used to stop the train in the event someone is observed to be caught in a door. Some U.S. systems have an emergency third-rail power trip station on or near station platforms but it is not readily accessible to passengers nor are its presence and purpose publicized.

All of the above devices have been successfully demonstrated at the systems mentioned and are availale to assist in safe door operation.

Observation of Doors After Train Start-Up

For most two-person train operation systems, the conductor is instructed to continue watching the car side doors after they are closed until the train has moved either one-car length or some other specified distance along the platform. This permits the conductor to see if someone is caught in a door and being dragged by the train. With one-person operation, the single train operator is generally instructed to observe the track ahead of the train prior to train start-up. Thus, he is not able to observe the side doors after train start-up. Table 5 presents a summary of car side door observation practices after train start-up for the systems visited.

For safety reasons, GCRTA specifically instructs the conductor to have his head inside the train before it begins to move. Some of the clearances with obstructions along the platform are small. Also, on occasion, irate passengers who missed the train have struck the conductor.

BART is the only U.S. one-person system visited where the train operator continues to watch the side doors after the train starts up. For one-person operation at London, the train operator can remain at the operator console and look back along the train via a mirror on the station platform. For a short distance (a few meters) after train start-up, the operator can still see the mirror to check the side of the train. Interestingly enough, on London's Victoria Line, the cab side windows are interlocked with the propulsion system so the single train operator cannot have his head out the window after train start-up.

Satisfactory door operation has been demonstrated at both one- and two-person operation systems without observation of the car side doors after train start-up. Door interlocks with the propulsion and/or braking system are used by all of the systems that do not continue to observe the car side doors after train start-up.

Operator Cab and Door Control Modifications

The final issue related to Car Side Door Control has to do with required operator cab and door control modifications for one-person train operation. For almost all of the systems visited, some platforms are located on both sides of the train. Thus, for one-person train operation, the single operator located at the front of the first car must be able to see and control the doors on both sides of the train. Without extensive use of CCTV and/or mirrors, this requires that the operator have access to windows and door control switches on both sides of the train. This, in turn, generally requires that the operator cab be either a full-width or convertible full-width cab.

Table 6 presents a summary of the cab type and operator console location for the existing and on-order rolling stock at each of the six U.S. two-person train operation systems visited. Also presented is an indication of the extensiveness of the car modifications required if those cabs are to be converted to full-width or convertible full-width cabs with door control switches for doors on both sides of the train. Note that minor or no modifications are required for the Pullman and Tokyu cars at GCRTA, the MBTA cars, the R-44, R-46, R-62, and R-68 cars at NYCTA, and the Kawasaki cars at SEPTA. All of the other cars would require major modifications.

The R-62 cars at NYCTA are particularly interesting in that they are currently running in two-person operation with right-hand corner cabs. However, they have built-in features that would permit them to be converted easily to convertible full-width cabs for one-person operation.

Also, as part of the development process for the next railcar specifications, CTA's Operations Planning Department has been evaluating alternative design options. As a result of that effort, the department recommended to management the inclusion of convertible full-width cabs on all new railcars. The reason for this is to provide the option of implementing one-person multiple-unit train operation at some point during the 30-year (plus) life of new equipment without requiring major car modifications.

CTA personnel interviewed believe the following car design features are required for one-person train operation:

- Convertible full-width cab to provide additional seating capacity when the cab is not at the head, operating end of the train.
- Door controls on both sides of cab.
- Sliding window sash on both sides of cab.
- Step on both sides of cab to assist operator in seeing out when operating doors.
- Passenger intercom for vocal communication with train operator.

Preliminary studies by CTA indicate that if the first four features are included in the original design of the car, there should be no increase in the price of the equipment. The passenger intercom may add $1,000 to the price of a car. Also, with convertible full-width cabs, the net effect on seating capacity will be an increase of approximately six seats per 8-car train. The cab design could also be compatible with current operation, providing a conductor position for two-person operation during a transition period and/or for on-board fare collection in off-hours.

Station Dwell Time

A potential problem frequently cited for one-person operation is a possible increase in station dwell time and, thus, an increase in scheduled run time from terminal to terminal. The increased station dwell time is generally associated with full-width or convertible full-width cabs with the operator console located on one side of the cab and the door open and close switches located on the sides of the cab next to the cab side windows. At station platforms located on the opposite side of the train from the console, the train operator conceivably, but not necessarily, could be required to perform the following actions before starting the train.

1. Set train brakes.
2. Stand up from console.
3. Walk across cab.
4. Open side window.
5. Extend head out window and observe train side doors and platform.

Table 5. Summary of car side-door observation practices after train start-up.

System	Continue to Observe Doors After Train Start-up, Yes/No	Distance Doors Observed and Comments
CTA	Yes	1-car length for two-person train operation
	No	Single-car, one-person train operation
GCRTA	No	
MBTA	Yes/No	Guards must remain at their duty position until all doors are closed and train starts to move
NYCTA	Yes	3-car lengths or until conductor reaches end of platform, whichever distance is shorter
PATH	Yes	Short distance during rush hours
SEPTA	Yes	Insuring that the doors are closed by observation as the train leaves the station, for two-person train operation
	No	One-person train operation
BART	Yes	Short distance after train start-up
MARTA	No	
PATCO	No	
WMATA	No	Operator observes doors until train starts to move
Berlin	Yes	Train dispatcher on platform watches doors
Hamburg	Yes	Train dispatcher on platform watches doors
London	Yes	2- or 3-car lengths for two-person operation
	Yes	Few meters via mirror for one-person operation
	No	Victoria Line with automatic train control
Paris	No	
Stockholm	No	
Lille	No	Unmanned train and station

Table 6. Summary of operator cab type and extensiveness of car modifications required for one-person train operation.

System	Car Series	Cab Type(a)	Operator Console Location(b)	Required Car Modifications
CTA	All	RC	R	Major
GCRTA	St. Louis(c)	RC	R	Major
	Pullman	CFW	L	None
	Tokyu	CFW	L	None
MBTA	All	FW	R	Minor
NYCTA	R-42 & Earlier	RC	R	Major
	R-44 & R-46	FW	R	None
	R-62	RC(d)	R	Minor
	R-68	FW	R	None
PATH	All	RC	R	Major
SEPTA	Budd	RC	R	Major
	Kawasaki(e)	CFW	R	None

(a) RC - Right Corner; FW - Full-Width; CFW - Convertible Full-Width

(b) R - Right; L - Left

(c) St. Louis cars should be retired in about three years.

(d) R-62 cars presently have right-hand corner cabs but have built in features that would permit them to easily be converted to convertible full-width cabs.

(e) Kawasaki cars are being used for SEPTA's one-person train operation on the Ridge Avenue Spur and Broad Street Express service.

6. Activate door-open switch.
7. Activate door-close switch.
8. Observe that all doors are clear and all door indicator lights are out.
9. Retract head and reverse Actions 4 through 1.

A brief summary of the impact of one-person operation on station dwell time for a number of the one-person operation systems visited is presented as follows:

- *BART, MARTA, and WMATA.* In the automatic train control mode at these properties, there is little, if any, increase in dwell time except for door opening at MARTA. At BART and WMATA, the doors open automatically after the train stops at the platform. At MARTA, the operator must activate a door-open switch on either side of the train. At all three systems, the train normally starts after the doors are closed and before the operator returns to the console. When in the manual control mode at MARTA and WMATA, the operator must return to the console prior to train start-up. BART has no full performance manual control mode.
- *PATCO.* There is little, if any, increase in dwell time at PATCO except occasionally at terminals. At PATCO all of the platforms are on the same side of the train as the operator console. The exception to this is at the terminals where the trains berth on either the right or left side of the platform. For those occasions when a train is preparing to leave a terminal and the platform is on the right side, a large mirror is located on the platform to enable the operator to observe the doors. As an alternative to the mirror, a set of door switches is located just inside the right side door on the cab-end of the car. The operator has the option of leaving the cab, stepping out the front-right-side door to the platform, and operating all of the doors except that one from that position. After reentering the car, he closes the right-front door. This has the advantage of providing better visibility of the doors but increases the dwell time to approximately 30 sec. These latter door switches need only be used for every other terminal stop.
- *SEPTA.* A SEPTA representative reported that one-person train operation could result in a 15-sec increase in dwell time for platforms on the opposite side of the train from the operator console. At such platforms, the operator performs all of the actions listed at the beginning of this section during a station stop.
- *Berlin and Hamburg.* There is no increase in dwell time at these properties. At Berlin and Hamburg the train operator does not leave the console to observe or operate doors. The doors are watched by a train dispatcher, on the platform, who signals the operator when to close the doors.
- *London and Paris.* There is no increase in dwell time at these properties. For one-person operation at London and Paris, the train operator either can stay at the console and look out the windshield at mirrors and/or CCTV on the platform to observe the side of the train over its entire length or he can step out onto the platform through a cab door to directly observe the side of the train. For the former case, there is little or no increase in station dwell time.

An independent assessment of SEPTA's reported time of 15 sec for the operator to perform all of the actions listed at the beginning of this section was conducted by the project team at NYCTA with an R-46 car. The R-46 car has a full-width cab with the operator console on the right-hand side, door control switches on both sides, and is suitable for one-person train operation. The tests were conducted on a parked train with the air supply system operating so the time required to set and release the air brakes would be included in the measured test times. A summary of the results of those tests is presented below. Eight seconds were required to:

- Move master controller to the "full service brake" position (Note: If the master controller handle is released anywhere except the "full service brake" position, the deadman control will activate the emergency brakes. The service brakes can be released in 1 or 2 sec. The emergency brake requires 18 sec.)
- Stand up from seated position at console.
- Walk across cab.
- Open window.
- Extend head out window.
- Push door-open button.

Eight seconds were also required to:

- Retract head from window after exterior door lights go out.
- Close window.
- Walk across cab.
- Sit down at console.
- Release "full service" brakes.

This results in an estimated 16-sec increase in dwell time for platforms on the opposite side of the train from the operator console for one-person train operation and correlates well with SEPTA's estimate of 15 sec.

One possible method for reducing this increase in station dwell time would be to install a "door-open" switch for the doors on the left side of the train on the operator console. This would permit the operator to open the doors on the left side of the train before getting up from the console. A good, readily visible platform position indicating system and/or a mirror or CCTV monitor would be required to guard against the operator opening

the doors on the far side of the train with the rear of the train extending beyond the end of the platform. For this latter arrangement, it would require approximately 2 sec to set the service brakes and activate the "door-open" button, reducing the total increase in station dwell time from 16 to 10 sec. Another 1 or 2 sec might be saved by having the window power closed and controlled from the console.

In conclusion, the potential increase in station dwell time with one-person operation can essentially be eliminated through:

- Use of automatic train control, such as at BART, MARTA, and WMATA, to automatically open the doors and enable the train to be started before the operator returns to the console.
- Use of mirrors and/or CCTV, such as at London and Paris, to enable the operator to observe the doors on either side of the train without leaving the console.
- Having all or essentially all of the platforms on the console side of the train, such as at PATCO.

If none of the foregoing solutions is practical, the increase in station dwell time may be as high as 16 sec at stations with platforms on the opposite side of the train from the operator console. To minimize this increase in station dwell time, careful consideration should be given to the location of the door "open" buttons and window opening/closing provision as discussed earlier. Also, much effort should be devoted to the human-factor aspects of the cab and cab equipment design including experiments with cab mockups before finalizing the cab design for new or retrofitted cars.

Between Car and End Door Safety

None of the systems visited identified between car and end door safety as a *major* issue or problem for conversion from two- to one-person train operation. However, because of the removal of an observer from the train and longer observation distances along the side of the train for the single operator, car and/or platform modifications may be beneficial for some of the present two-person operation systems to enhance between car and end door safety with one-person operation.

Two principal safety hazards exist in the between car area of multiple-unit trains.

1. If a large gap exists between adjacent cars along the platform edge, there is some danger that a blind passenger will mistake the gap for a door opening and fall off the platform between cars. Also, for one-person operation of manually controlled trains, there is some concern about the possibility of passengers boarding between cars during the interval required for the operator to return to the console at station platforms on the opposite side of the train from the console.
2. For passeners on the train, there is some danger that a person passing between cars of a multiple-unit train will fall from the train.

A third related hazard is that if a train has end doors on the ends of the train, a passenger may exit the train to the track through those doors other than during a supervised emergency evacuation.

While the above hazards exist for both two- and one-person train operation, they are of somewhat greater concern for one-person than two-person operation. One reason for this is that the single train operator may have to look a longer distance along the side of the train when it is berthed next to the platform. A second is the time interval for the train operator to return to the console as mentioned above. If someone falls off the platform between cars, the train operator may be less likely to observe it. In addition, the gap between adjacent cars generally is wider for the older two-person systems than for the new one-person systems. A third reason is that a second crew member on the train provides some limited additional capability for observing or being alerted that someone has fallen off the train between cars or exited the train through an end door.

A summary of between car and end door safety features at the systems visited along with resulting conclusions is presented in the following paragraphs.

Between Car Safety Features

For heavy-rail rapid-transit systems, a variety of methods and devices are used to reduce the likelihood of passengers falling from station platforms or boarding trains between cars. Generally, the newer one-person operation systems in the U.S. and the European systems visited have relatively small to moderate gaps between adjacent cars along the platform edge. Except for the small to moderate gaps between cars, none of those systems (except Lille) use special devices to prevent people from falling off the platform or boarding trains between cars. The Lille system is unmanned and has a train screen with automated doors along the entire platform edge.

Most of the older two-person operation systems in the United States have larger gaps between adjacent cars, and some have special devices to prevent people from falling off the platform or boarding trains between cars. The devices include: (1) long steel-coil springs; (2) rubber straps; and (3) "gates" mounted between the outer edges of adjacent cars. ("Gates" are spring-loaded telescoping barriers mounted on both sides of both ends of cars. When two cars are coupled together, the ends of corresponding gates contact each other and are compressed to form a continuous barrier between the outer edge of the coupled cars.) When the train is stopped at stations, these devices line up along the platform edge and form a between car barrier along the edge of the platform.

The specific devices used at U.S. two-person systems are:

CTA—No special devices (CTA staff has recommended some type of barrier to discourage boarding between cars.)
GCRTA—No special devices, except long steel-coil springs between cars of old St. Louis married pairs
MBTA—"Gates"
NYCTA—"Gates" on 50- and 60-ft long cars; three long steel-coil springs on 75-ft long cars
PATH—Rubber straps
SEPTA—"Gates"

In addition, as previously discussed, the European systems visited typically have a passenger-activated emergency train stop device located on station platforms. The principal reason for this device is to stop trains in the event someone falls from the platform to the track. Some U.S. systems have such a device but it is not readily accessible to passengers.

Car End Door Safety Features

Almost all rapid-transit trains have end doors on both ends of all cars. The only exception to this in the United States is BART, which has end doors between adjacent cars but not on the ends of trains. In Europe, the Hamburg system has no end doors on any cars, and the Paris and Lille systems have end doors between adjacent cars but not on the ends of trains. The Berlin, London, and Stockholm systems have end doors on both ends of all cars.

In the United States, car end doors *between adjacent cars* are almost always unlocked. Exceptions to this are MBTA and NYCTA for 75-ft long (R-44, R-46, and R-68) cars only for which all end doors are locked. At MBTA, in an emergency, passengers can break a glass cover and pull a ring to unlock the end doors. At NYCTA the 75-ft long cars have electric locks on end doors. These doors are normally kept locked; any crew member can unlock all the end doors within the train from any cab console.

All of the U.S. systems, except BART, attempt to discourage movement between cars with varying degrees of success. Most of the cars have warning signs stating that the end doors are not to be used for passing between vehicles while the train is moving or that they are for emergency exit only, and MBTA and NYCTA for 75-ft long cars lock the end doors. BART has designed the between car passage to be relatively hazard free and does not have signs nor do they discourage passage between cars.

All of the older U.S. systems, except MBTA and NYCTA for 75-ft long cars, have chains (typically three) connected between adjacent cars on both sides of the end doors to reduce the likelihood of passengers falling from the train between cars. Also, two of the newer systems, i.e., BART and MARTA, have flexible bellows completely enclosing the walkway between the cars. MARTA only has these bellows between the cars in a married pair. Some of the newer systems have neither chains nor bellows between cars but the longitudinal clearance between cars at the sides of the end doors is only 7 or 8 in.

Practice varies in the United States relative to the locking of car end doors *on the ends of trains*. For example, all of the older two-person systems, except CTA, lock the car end doors on the ends of trains. Of the newer one-person systems visited, MARTA and PATCO do not lock them, WMATA does, and BART does in essence because it has no end doors on the ends of trains. While MARTA and PATCO do not lock them, they have two or three manually released "dog" latches in addition to the normal door latch on these doors to prevent passengers from inadvertently opening the unlocked doors.

All of the European systems visited, except London, lock all car end doors whether they are between adjacent cars or on the ends of trains. Thus, there is no between car movement or end door exiting for any of those European systems, except London, during normal operation. There is a federal law in England that requires all end doors on rail transit cars to be unlocked during operation.

Conclusion

Car and/or platform modifications may be beneficial for some of the present two-person operation systems to enhance between car and end door safety with one-person operation. Such modifications could include:

- Either cars designed with relatively small gaps between cars or barriers installed between the outer edges of adjacent cars.
- Passenger-activated emergency devices installed on station platforms to stop the train in the event someone falls from the platform.
- Either between car passageways modified to be relatively hazard free or discouragement or prevention of passengers from moving between cars during normal operation by means of:
    - Warning signs
    - Multiple "dog" latches on unlocked doors
    - Locked doors with emergency means for opening by passengers, e.g., breakable glass or tear away covers over the door latch
    - Electric locks that are locked when the train is moving and unlocked when it is stopped
    - Fail-open electric locks that can be remotely locked
- Doors on the ends of trains treated as above.

Communications

All of the systems visited identified good communications between central control, train operators, passengers, police, fire, and other emergency personnel as a major issue for conversion to one-person train operation. Management personnel at one property stated emphatically that good communications may be the most important feature for successful one-person operation.

A summary of the communication systems at the systems visited along with resulting conclusions is presented in the following paragraphs.

Train Operator to Central Control

All of the systems have two-way radio communication between train operators and central control. Table 7 presents a summary of the car radio locations for each system. Note that all of the U.S. *one-person* operation systems have portable radios that the train operator carries with him whenever he leaves the cab. Representatives of those systems stated that it is important for one-person operation that the single train crew member be in contact with central control at all times. Thus, they are required to have the portable radio on their person whenever they leave the cab. They must also notify central control and obtain permission prior to leaving the cab. With two-person operation, one crew member can stay in a cab and maintain radio contact with central control while the second crew member goes to some other part of the train or down to the track to trouble-shoot a problem or lead an emergency evacuation. This is not possible with one-person operation.

Generally, the European systems visited make less use of portable radios for one-person operation. London management people said the operator does not always have to be in contact with central control and they do not believe the expense of portable radios is warranted.

At PATCO, the portable radio can be plugged into a powered receptacle on the operator console and is then used as part of a stationary cab system.

Table 7. Summary of train operator to central control communication method and car radio location.

System	Two-Way Radio, Yes/No	Car Radio Location: Fixed In Cabs	Car Radio Location: Portable	Comments
CTA	Yes		X	Operator and conductor must have radio on their person at all times.
GCRTA	Yes	X		
MBTA	Yes	X		
NYCTA	Yes	X		
PATH	Yes	X		
SEPTA	Yes	X		Older Budd cars
	Yes	X	X	New Kawasaki cars
BART	Yes	X	X	If operator leaves cab, he must take portable radio with him.
MARTA	Yes	X	X	Same
PATCO	Yes		X	Same
WMATA	Yes	X	X	Same
Berlin	Yes	X	n.d.*	
Hamburg	Yes	X	n.d.	
London	Yes	X		London management does not believe expense of portable radio is warranted
Paris	Yes	X		
Stockholm	Yes	X	n.d.	
Lille	Passenger intercom to central control			Unmanned trains

*n.d. - no data

Passengers on Trains

Table 8 presents a summary of the electronic communication systems for passengers on trains at the systems visited. Items of particular interest include:

1. All of the cars, except the older Budd cars at SEPTA and all Berlin cars except those on Lines 4 and 9, have a Public Address (PA) system. (Many of the on-board PA systems are of poor quality and the announcements are difficult to understand.)

2. Except for the SEPTA and Berlin cars without PA systems and the Lille system which is unmanned, station announcements are made by train crew members over the PA system. Representatives of one-person operation systems generally believe it is important to have the train operator announce station stops to help keep him alert. This is particularly true for systems with automatic train control.

3. Many of the systems have provisions for central control personnel to talk directly to passengers on trains over the train PA system. This practice is increasing for new or future cars. For all present systems with this practice, except Lille, the train operator must activate a switch to connect central control to the train PA system. However, on future London cars, central control personnel will be able to talk to passengers on trains without intervention on the part of the train operator. This is being done to permit such communication in the event the operator is incapacitated.

4. In the United States, none of the older two-person operation systems have passenger intercoms for communication with the train operator. However, most of the newer one-person operation systems do. In Europe, the use of passenger intercoms is increasing for new or future cars. Many of the people interviewed believe passenger intercoms are a very desirable, if not required, feature for one-person train operation. (See discussion of results of CTA's evaluation of required car design features for one-person train operation in the Car Side Door Control section.)

5. As discussed in the Train Control section, to reduce the likelihood of emergency evacuation between stations, a number of systems are converting their passenger emergency stop systems to passenger emergency alert systems. For systems with passenger intercoms on trains, passengers can use those intercoms to alert the operator in case of an emergency. A few systems that do not have passenger intercoms on trains have or plan to install buzzer alarms for passengers to alert the operator in case of an emergency.

A number of interviewees cited loss of the conductor for answering passenger questions, assisting sick or incapacitated passengers or detecting problems as a problem for one-person operation. This is one of the reasons that many of the interviewees believe a passenger intercom for communication with the train operator is required for one-person operation. In the case of an incapacitated passenger, other passengers must be relied on to report this to the train operator who, in turn, can relay the message to central control. Provision of a passenger intercom or emergency alert system also provides passengers with a means of alerting the train operator to severe car defects, fires, or other problems. In addition, a good set of route, emergency procedure, and other informational signs can be developed and prominently displayed in all cars to provide needed information to the passengers.

Passengers On Station Platforms

All of the systems visited, except GCRTA, Berlin, and Paris, have a Public Address (PA) system direct from central control to station platforms. GCRTA plans to install such a system within 2 years. At Berlin and Paris, station PA announcements are made by the platform train dispatcher and station master only. Central control communicates with those station employees via telephone. They, in turn, can repeat messages from central control over the station PA system.

Three systems have PA speakers mounted on the outside of cars permitting the conductor on trains to address passengers on the platform. Those are CTA on its Series 2400 and higher cars, PATH on its PA-1, -2, -3, and future PA-4 cars, and SEPTA on its Kawasaki cars. With these speakers the conductor/operator can caution passengers on the platform to stand clear when the doors are closing.

Many systems have, or are experimenting with, two-way intercoms or telephones on station platforms for passenger use. These include:

GCRTA—Telephone to city police
MBTA—Experimenting at four stations with system to city police
PATH—Two-way communication to central control
SEPTA—Intercom to central control
MARTA—Telephone to zone center
WMATA—Currently installing intercom to station attendant in kiosk
Berlin—Intercom to central control on Line 4 platform only. For other lines, train dispatcher is located on platform

Table 8. Summary of electronic communication systems for passengers on trains.

System	Public Address (PA) System: Yes/No	Station Announcements(a)	Central Control(b)	Passenger Intercom,(c) Yes/No	Passenger Emergency Alert System
CTA	Yes	C	No	No	No
GCRTA	Yes	O	No-Present Yes-Future	No No	No No
MBTA	Yes	C	Yes (On some trains)	No	No
NYCTA	Yes	C	Yes	No	No
PATH	Yes	C	Yes	No	No-Present Buzzer-Future
SEPTA	Yes-Kawasaki No-Budd	O/C None	No No	No No	Buzzer Alarm Buzzer Alarm
BART	Yes	O	Yes (But discouraged)	Yes	Pass. Intercom
MARTA	Yes	O	Yes	Yes	Pass. Intercom
PATCO	Yes	O	No(d)	No(e)	Buzzer Alarm
WMATA	Yes	O	Yes	Yes	Pass. Intercom
Berlin	Yes-Lines 4&9 No-Other Lines	O None	Yes No	Yes No	Pass. Intercom Alert-Future
Hamburg	Yes	O	Yes	No-Present Yes-Future Yes-PUSH	No Pass. Intercom Pass. Intercom
London	Yes	O	No-Present Yes-Future	No No	No Alert-Future
Paris	Yes	O	No	No-Present Yes-Future	No Pass. Intercom
Stockholm	Yes	O	No-Present Yes-Future	No No	No No
Lille	Yes	Recorded	Yes	Yes	Pass. Intercom

(a) The following crew members make station announcements:
C - Conductor; O - Operator; O/C - Operator for one-person operation/Conductor for two-person operation.

(b) This column indicates whether or not central control personnel can talk directly to passengers on trains via the train PA system. In most cases, the train operator must actuate a switch to connect central control to the train PA system.

(c) Passenger intercom to train operator. Only Berlin Lines 4 and 9, Hamburg PUSH system, and Lille system have on-train passenger intercoms to central control.

(d) In the past PATCO had provisions for central control to talk directly to passengers on a train via the train PA system. However, it was removed because the train operators never used it.

(e) PATCO does not have a passenger intercom to the train operator. However, the operator's cab is not fully enclosed and passengers on the first car can talk to the operator directly.

Hamburg—Intercom to central control on PUSH line platforms only. For other lines, train dispatcher is located on platform

London—Intercom to station controller on Victoria Line platform only. Years ago they had passenger intercoms to station controller on other lines but they were vandalized and their operation was discontinued

Paris—Intercom to station master
Lille—Intercom to central control

In addition, at stations with regular station attendants (see Table 1), passengers can communicate directly with those attendants. Except for Berlin and Hamburg, the regular station attendants are not located on the station platforms. Rather, they are located in the fare-collection area of stations. Also, many of the stations have two-way intercoms or telephones to central control or the police in the fare-collection area of stations.

Police and Fire Departments

The principal mode of communication with police and fire departments is via direct line telephone from central control. In almost all cases to contact police or fire departments, passengers, train operators, and station attendants must first contact central control which, in turn, contacts the police or fire department via telephone. A few exceptions to this were identified with respect to contacting the police department including:

GCRTA—Passenger telephone to city police on station platforms
NYCTA—Few experimental passenger telephones to police in stations
MARTA—Passenger telephone to MARTA police in stations
PATCO—Train operator to transit police on two-way radio

Conclusion

Almost all of the persons interviewed believe that good communications are essential for successful one-person train operation. Features that provide this include:

- Two-way radio communication between the train operator and central control with portable radios for the operator so he can maintain two-way contact with central control at all times.
- PA system on cars for both train operator and central control announcements.
- Two-way intercoms or emergency alert device in all cars for communication between passengers and the train operator.
- PA system on station platforms for both central control and station attendant announcements.
- Two-way intercoms or telephones on station platforms and/or in fare-collection area for communication between passengers and central control and possibly police. This would be particularly important for unattended stations.

Fire Prevention and Control

Fire is one of the major safety issues or problems identified for one-person train operation. This is particularly true for fires between stations in tunnels. Fire is also a problem with two-person operation. However, with two-person operation, there is one additional person to detect the fire, fight it before arrival of fire department personnel, or help with an emergency evacuation if that should become necessary.

To compensate for the reduction in train crew size with one-person operation, a variety of actions are taken at the systems visited to reduce the probability of a fire occurring and minimize the resultant damage and/or injuries should one occur. Those actions are:

1. Fire hardening of cars through proper selection of materials and designs.
2. Strict enforcement of no smoking rules and frequent removal of paper and trash from cars.
3. Provisions for rapid detection of fires and notification of proper officials.
4. Provision for passenger access to fire extinguishers.
5. Fire hardening of tunnels including installation of reversible ventilation system and standpipes.
6. Provisions for moving train to next station if at all possible and for evacuation of passengers between stations as a last resort.
7. Preparation and coordination of emergency fire and evacuation plans with all affected agencies including transit personnel and police and local fire, police, and medical units. Training of personnel in required procedures and conducting practice drills to assure adequacy of plans, procedures, equipment, coordination, communications, and training.

Each of these items is briefly discussed in the following paragraphs.

Fire Hardened Cars

The need, methods, and materials for fire hardening cars should not come as a surprise to anyone since the Transbay Tube Fire at BART on January 17, 1979. Specifications for all new and rehabilitated cars since that time have included extensive specifications for fire resistant, low-smoke, low-toxicity materials, and fire resistant floors. The UMTA Recommended Fire Safety Practices for Rail Transit Materials Selection (*1*) provides guidance in this area.

Many of the systems visited have cars constructed of fire resistant stainless steel. This includes all cars at PATCO and SEPTA, Series 2200 and higher cars at CTA, Pullman and Tokyu cars at GCRTA, new Silver Bird cars at MBTA, R-38 and higher cars at NYCTA, and future PA-4 cars at PATH. In addition, PATH has specified a fire resistant blistering paint on the ends of the PA-4 cars.

No Smoking

Almost all of the cars at the systems visited have NO SMOKING signs. The smoking ban should be strictly enforced. Also, paper and trash are a fire hazard and should frequently be removed from cars.

Fire Detection and Notification

Automatic fire detection and suppression systems are generally not used on rail rapid transit cars. Thus, fire detection and suppression are dependent on human observation and actions. With removal of one crew member from trains, passengers must be relied on to a greater extent than previously for fire detection and notification and early suppression of above floor fires. This is one of the reasons cited for having a passenger

intercom or emergency alert system on all cars of one-person operation trains.

It may also be desirable for older systems considering conversion to one-person operation to reevaluate the use of automatic fire/smoke detection and suppression systems.

Fire Extinguishers

An intercom or emergency alert system will permit passengers to play a greater role in fire detection and notification. However, if passengers are to play an increased role in early suppression of above floor fires, they must have access to fire extinguishers. In the United States, all of the newer one-person operation systems, except WMATA, have fire extinguishers on each car that are accessible to passengers. BART has two per car behind breakable plastic with little theft. MARTA has one in each cab and one in a marked compartment in the middle of each car. PATCO has two per car, one is behind breakable glass and the other is in the electrical locker. WMATA has one in each cab but the cabs are locked and the extinguishers are not accessible to passengers.

All of the older U.S. two-person systems, except CTA, have fire extinguishers in locked cabs on each car. Thus, they are not readily accessible to passengers. NYCTA officials reported a problem with theft of fire extinguishers. CTA has fire extinguishers at each operator cab and conductor station. Those at conductor stations are readily accessible to passengers. CTA officials also said they had a theft problem.

Fire Hardened Tunnels

Modern subways have wet and/or dry standpipes, extensive reversible ventilation systems, and concrete ties. In the United States, all of the newer one-person operation systems, except PATCO, have such provisions. PATCO is currently proposing to install reversible fans and dry standpipes in its tunnel in Philadelphia.

Most of the older two-person operation systems have wooden ties. CTA has a local and remotely controlled reversible ventilation system and standpipes. NYCTA has forced ventilation for all under-river tubes and about half of the rest of the system. Newer tunnels have wet standpipes. Older ones have dry standpipes. MBTA and PATH currently have major tunnel upgrading projects underway including the ventilation and standpipe systems and replacement of wooden ties with concrete ties. SEPTA has manually controlled ventilation operated from the stations. GCRTA has only a very short length of its route in tunnels. At the airport terminal, it has forced ventilation and dry standpipes. Downtown it has wet standpipes and does not have forced ventilation.

Movement of Train to Next Station

All of the systems visited view evacuation of passengers between stations as a last resort, particularly in tunnels with fire and smoke. Every attempt should be made to unload passengers at a station platform. The principal exceptions to this are if a fire is discovered on the train before it enters a tunnel or if smoke is seen to be coming out of a tunnel. In both cases, the train operator is instructed not to enter the tunnel. The hazards associated with evacuating passengers between stations in tunnels are the principal motivation for the trend to convert passenger emergency stop systems to passenger emergency alert systems. This is discussed in the Train Control section.

Some of the newer systems have under and over car deluge systems located along the length of the platform in underground stations. This is another reason for attempting to move a burning train to the next station.

Emergency Plans and Drills

All of the systems visited said they have emergency plans for fires and/or emergency evacuation of the rail transit system. They have coordinated these plans with appropriate employees and local agencies. Most of the systems said they hold practice drills on a regular basis.

Conclusion

To compensate for the reduction in train crew size with one-person operation, a variety of actions can be taken to reduce the probability of a fire occurring and minimize the resulting damage and/or injuries should one occur. Seven possible actions to be taken have been identified and are presented in the preceding paragraphs.

Emergency Evacuation

Most of the older U.S. two-person train operation systems cited emergency evacuation of trains between stations as a problem for one-person operation. This is particularly true in tunnels with fire and smoke and for long crush-loaded trains with up to 2,000 passengers. In such situations, most people interviewed agreed that two crew members are better than one but they differed in their opinion as to the degree of importance of the second crew member.

Most of the management personnel at the one-person operation systems visited thought the presence of a second crew member would be only marginally beneficial. Many said that one additional person would not make that much difference. What is required is fast response by many specially trained people to assist in the evacuation. One interviewee said that firemen are experienced in evacuation particularly under conditions with fire and smoke; conductors are not. Another said that his system is training all employees how to assist in emergency evacuation procedures so that if they are riding on a train that is being evacuated they can assist the operator. Management and union people at two-person operation systems generally attached more importance to the presence of a second crew member during emergency evacuation.

With respect to the number of passengers to be evacuated per train crew member, it is interesting to note that NYCTA with its 600-ft long trains (see Table 3) is presently operating in old underwater tunnels with up to 1,000 passengers per train crew member. This is essentially as high a ratio of passengers per train crew member as would be encountered by any of the other five U.S. two-person operation systems if they converted their *present* 300- to 400-ft long trains to one-person operation.

A variety of procedures, equipment, and facilities are used at the systems visited to reduce the likelihood of emergency evacuation of passengers between stations and to prevent injuries should such evacuation be necessary including:

1. Minimization of train and facility breakdowns through improved reliability.
2. Provision of a passenger emergency stop or alert system that will permit the train to proceed to the next station before stopping.
3. Supplementation of single crew member with a second crew member or wayside personnel at certain critical locations during heavy train loading conditions.
4. Provisions for moving train to next station or transferring passengers to rescue train.
5. Fire hardened cars and tunnels.
6. Evacuation route for walking out passengers between stations as a last resort.
7. Comprehensive emergency evacuation and fire fighting plans and practice drills.
8. Good communications between the train crew, passengers, central control, and emergency personnel.

Item 2 is discussed in the Train Control section. Items 5 and 7 are discussed in the preceding section. The other five items are briefly discussed in the following paragraphs.

System Reliability

The most obvious way to reduce the incidence of evacuation of passengers between stations is to reduce the frequency of train, power supply, signal, and track failures—in other words, improved system reliability. This can be accomplished by use of equipment and facilities in good operating condition and improved preventive maintenance. As discussed in the Timing of Conversion section, particularly opportune times for conversion to one-person operation are the opening of a new line, arrival of new or rehabilitated rolling stock, or rehabilitation or upgrading of facilities. All of these actions tend to result in improved system reliability.

Supplementation of Crew at Critical Locations

Rather than have a second train crew member on-board all trains at all times, it may be much more cost effective at some systems to operate with one crew member most of the time at most locations. A second crew member or special wayside personnel could be added at certain critical locations and heavy train loading conditions. Examples of those types of crew supplementation are currently in use at BART and NYCTA. BART operates with one-person crews but supplements that crew member with a second crew member on trains passing through the Transbay Tubes and Berkeley Hills Tunnel during peak commute hours in the direction of the heavy commute. NYCTA stations a "tunnel coverage supervisor" on the downstream side of the main flow of passengers for tunnels under the East and Harlem Rivers during the a.m. and p.m. traffic peaks. Their function is to provide assistance in the event a train breaks down in the tunnel and/or an emergency situation develops.

Movement of Train to Next Station

All of the systems visited view evacuation of passengers between stations as a last resort, particularly in tunnels with fire or smoke. A number of interviewers commented that the safest place for passengers is "on the train". Thus, before passengers are taken off trains between stations and walked out to stations or emergency exists, every effort is made to move the train to the next station or transfer the passengers to a "rescue train".

With respect to moving the train to the next station, if there is a failure in the lead car that prevents the train from being moved, most of the systems have provisions for manually operating the train from one of the cabs further back in the train. However, before the train can be moved, a second person must arrive on the scene to serve as flagman in the first car. Also, car brakes and/or propulsion systems can be cut out on individual cars. If necessary, passengers can be moved from one car to another through the car end doors and failed cars uncoupled to permit moving of the train.

If the train cannot be moved under its own power, a second alternative is to push it with another train or transfer the passengers to a "rescue train". Most of the systems visited prefer that the "rescue train" be on the same track as the disabled train and the passengers transferred through the car end doors. However, the rescue train could be on an adjacent track with passengers transferred through the car side doors across planks placed between the doorways of adjacent cars.

Evacuation Route

As a last resort, passengers are evacuated between stations by walking along the guideway to the nearest station or emergency exit. Before walking out passengers, third rail power is cut either remotely on orders from Central Control or locally by the train crew.

All of the systems visited have emergency "walkway" provisions along their entire length. However, the extent and safety of those provisions vary greatly from property to property. Some tunnels including those at PATH, SEPTA, Berlin, London deep tunnels, and Stockholm do not have *separate* walkways, and passengers must walk along the track itself. The other systems have walkways along the side of the track. Those at CTA, NYCTA, BART, MARTA, WMATA, and Lille are located at car floor height. The others are at track level. Almost all of the elevated portions of track have walkways located along the side or between adjacent tracks at essentially track height.

All of the tunnel lighting is on a separate circuit from the power rail and most of the systems have provisions for emergency lighting. A few systems have signs indicating the direction and distance to the nearest station or emergency exit.

Fortunately, the need to evacuate passengers by walking them out along the guideway between stations is an infrequent occurrence. Only representatives at CTA, MBTA, NYCTA, and Paris estimated frequencies greater than once per year for such evacuations.

Communications

Good communications between the train-crew, central control, passengers, and emergency personnel are essential to an

orderly evacuation of passengers from trains between station. The train operator must notify central control of the problem and keep it informed of progress. In addition, the passengers must be kept informed as to what is going on to keep them from panicking and instructed as to what they are to do during the evacuation. Operating rules require that the train crew not evacuate passengers from trains unless authorized to do so by central control if communication is possible.

With two-person train crews, one of the crew members can stay at a radio location and maintain contact with central control and talk to the passengers over the car PA system while the second crew member opens doors, puts ladders in place, and leads the evacuation. This is not possible with one-person operation. However, the use of a portable two-way radio by the single crew member can keep him in contact with central control when he leaves the cab. The ability to connect central control to the cars PA system can also be used to keep passengers informed when the train operator leaves the cab. In addition to the train radio and PA systems, many systems also have telephones or telephone jacks for communication with central control located at regular intervals along the tracks.

Conclusion

If, as a last resort, it is necessary to evacuate passengers from trains between stations, two crew members are better than one, but many believe only moderately so. They believe that what is required in such situations is fast response by many specially trained people to assist in the evacuation.

In addition, to compensate for the reduction in train crew size with one-person operation, a variety of actions can be taken to reduce the likelihood of emergency evacuation of passengers between stations and to prevent injuries should such evacuation be necessary. Eight such actions have been identified and are presented in the preceding paragraphs.

Security

Most of the systems visited agreed that security (i.e., crime and vandalism) could be negatively affected by conversion from two- to one-person train operation. However, only the management interviewees at CTA, NYCTA, and PATH cited security as a *major* issue or problem for such conversion. The union officials interviewed at CTA, MBTA, and BART also cited it as a major issue.

Almost all of the persons interviewed believe that to maintain the same level of security after conversion to one-person operation as before, additional police officers would be required. However, the required increase in police officers would be substantially less than the reduction in conductor positions, i.e., one police officer can provide substantially more security to the system than one train conductor.

Specific issues or problems related to security with one-person train operation include:

1. What will be the effect on actual and perceived security?
2. Which has the greater affect on security, one conductor or one police officer?
3. What type of police is preferred, transit or city police?
4. What devices are available to assist in improving security?
5. What will be the impact on graffiti?
6. What has been the security experience of systems that have recently reduced train crew size?

The findings with respect to these issues are presented in the following paragraphs.

Actual and Perceived Security

Removal of one crew member from trains removes one set of eyes and an authority figure from the train. This may result in a reduction in both actual and perceived security on the train and on the station platforms, which are visible to crew members on the train. As discussed above, management or union interviewees at four of the older U.S. systems with two-person operation cited a possible reduction in security as a major issue for one-person operation. None of the interviewees at the U.S. and European one-person operation systems visited, except a union official at BART, cited this as a major problem. Many believe that the contribution of the conductor to actual security is relatively small and could be compensated for by the addition of significantly fewer roving transit police. The contribution of the conductor to passenger perceived security is generally thought to be greater than to actual security.

A number of interviewees said that at night, passengers, particularly elderly or female passengers, seek out the car the conductor is in to ride in. The passenger feels safer when the conductor is visible and present. Others said that apprehensive passengers can ride in the first car near the train operator and that frequency of train operation is important for increasing passenger perceived security.

Measures suggested by interviewees for minimizing any possible reduction in actual and perceived security with one-person operation include:

- Increased patrols by transit police.
- More frequent service by shorter one-person operation trains.
- Use of transparent enclosures and mirrors to permit the train operator to see the interior of the first car and for passengers in that car to see the operator.
- Passenger intercom or emergency alert on cars for communication or alerting of the train operator.
- Passenger intercom on telephone on station platforms for communication with central control and possibly police.
- CCTV on station platforms for monitoring by remote security personnel and/or more careful observation of the station platform by the train operator particularly at night.

Relative Effectiveness of Conductor Versus Police Officer

Almost all of the interviewees believe that a certified police officer is much more effective in providing security than a single conductor. A few believe he is only marginally more effective. Train crew members are instructed not to physically apprehend criminals or vandals. Their security role is to observe, report what they see and hear, hold trains out of stations or keep doors closed until police arrive, give verbal warnings, and present an

authority figure on the train to deter crime and vandalism. Certified police officers are uniformed, armed, and can make arrests. Also, a police officer can roam through the train, whereas the conductor is assigned to a specific location on the train.

Certified police officers are also considered to be significantly more effective in providing security than uniformed noncertified security guards. Such security personnel are used by some systems to patrol parking lots, guard administrative and maintenance facilities, and at some European systems to accompany certified police officers. However, in the United States certified police officers are strongly preferred for general transit system security duty.

In almost all cases, it is preferred that the police officer be in uniform and highly visible as a deterrent to crime and vandalism. Some plain clothes officers are used but the majority are in uniform.

One interviewee said that no system is able to achieve as much security as it would like and that two-person train operation does not guarantee security on trains. For example, even though NYCTA has two-person train operation, it attempts to assign a police officer to every train between 8:00 p.m. and 4:00 a.m. This illustrates the fact that if a system has a security problem, it may have to resort to a high concentration of police officers regardless of whether it has one- or two-person operation.

Transit Versus City Police

All of the U.S. systems visited, except Chicago CTA, have their own Transit Police Force. CTA is patrolled by Chicago City Police officers. However, those police officers belong to a special Rapid Transit Unit assigned full-time to transit duty and have no other responsibilities.

In Europe all of the systems visited, except Hamburg and London, are patrolled by city police officers who are assigned full-time to transit duty. At Hamburg, non-police security personnel are used with some police dogs. The Hamburg City Police only provide assistance on an as required basis. England has a nationwide police agency that serves all modes of transportation throughout England. A division of that agency is assigned full-time to London. While a few Berlin City Police officers are assigned full-time to Berlin, they are supplemented by non-police security personnel. The system is patrolled by teams of three consisting of one city police officer and two non-police security personnel.

All of the U.S. systems with their own Transit Police Force strongly support that arrangement. They believe that city police departments have too many other responsibilities and priorities to do an effective job of patrolling the transit system. Also, transit police officers can be specially trained for transit service. CTA and the European systems with special units of the city police assigned full-time to transit duty generally believe that arrangement is acceptable. One problem with this latter arrangement was raised by a Paris interviewee, who said that Paris wants more police officers but the Paris Police Department will not assign them any more. All of the interviewees, except those at Hamburg, agreed that use of regular city police officers who are not assigned full-time to transit duty and who have other responsibilities is an unacceptable arrangement.

Devices to Enhance Security

The principal devices used to enhance security are communications equipment and closed circuit television (CCTV). The communications equipment includes:

- Two-way radios for communication between train operators and central control; police officers and police control center; and between police officers. The principal mode of communication between central control and the police control center is direct line telephone.
- Passenger intercom or emergency alert system on cars for communication with or alerting of the train operator.
- Passenger intercom or telephone on station platforms and/or in fare collection area for communication with central control and in a few cases the police.

All of these communication devices, except the police officers' two-way radios, are discussed in the Communications section. A summary of the communication devices presently at or planned for the future at each of the properties visited is given in that section. In addition, police officers are generally equipped with portable two-way radios.

The use of CCTV for train door control is discussed in the Car Side Door Control section. A summary of its use for station and/or platform security purposes is presented here in Table 9. Note that in the United States, all of the newer one-person operation systems, except BART, make extensive use of CCTV for station security purposes. Of the older two-person operation systems, only PATH presently makes general use of CCTV for that purpose. MBTA plans to expand its use in the future. Of the four U.S. systems presently using CCTV for station security purposes, three (PATH, MARTA, and PATCO) have unmanned stations.

While many of the European systems visited make extensive use of CCTV for controlling car side doors, it is used to a much lesser extent for security purposes. Only Lille uses CCTV system-wide for station security purposes and that system also has unmanned stations.

None of the systems visited use CCTV on-board trains for security. Those with passenger intercoms or emergency alert systems on trains for communication with or alerting of the train operator are listed in Table 8.

Graffiti

Of the systems visited, only NYCTA presently has a visible graffiti problem, and NYCTA is a two-person train operation system. Thus, the presence or absence of graffiti cannot be directly linked to whether or not the system has one or two-person operation. A number of interviewees said that to eliminate graffiti, a system must assign a high priority to its elimination and remove it from cars as soon as it appears. Both cars and stations should be kept free of litter. Also, a system must aggressively pursue graffiti writers for arrest, conviction, and fines. Every effort must be made to get the police, courts, media, and public involved in its eradication. Systems, such as SEPTA, have successfully employed such an approach to reduce the graffiti problem. NYCTA personnel said they are now embarking on such a program.

Security at Recently Converted Systems

Three of the systems visited have recently undergone or are undergoing a reduction in train crew size. Those are MBTA, SEPTA, and London. None of those systems reported a reduction in security as a result of the reduction in train crew size. For example:

- *MBTA*. Management reported that security was not negatively affected by the conversion from three- to two-person operation in November 1981. The number of guards was reduced by 66 but 39 MBTA police officers were added. Crime is at the lowest level in 15 years and is steadily decreasing. There was no discernable reduction in ridership at night.
- *SEPTA*. In May 1981, SEPTA introduced its own Transit Police Force. Since that time, crime and vandalism have been reduced considerably. In October 1983 and September 1984, SEPTA introduced one-person operation for two limited services. SEPTA management expressed no particular problem with security on those one-person operation trains. SEPTA recently installed passenger emergency alarms to the operator on trains and two-way intercoms to central control on station platforms.
- *London*. In the fall of 1984, London converted the Hammersmith & City and Circle Lines to one-person operation. Management reported that they have not experienced a reduction in security on those lines since the conversion.

Conclusion

Most of the interviewees believe that any reduction in security related to removal of the conductor from trains for one-person operation could be compensated for by the addition of significantly fewer roving police officers than the corresponding reduction in conductor positions. Certified police officers are preferred to noncertified security guards, and in the United States, transit police are generally preferred to local police.

Other measures for minimizing any possible reduction in actual and perceived security with one-person operation include:

- More frequent service by shorter one-person operation trains.
- Use of transparent enclosures and mirrors to permit the train operator to see the interior of the first car and for passengers in that car to see the operator.
- Passenger intercom or emergency alert on cars for communication with or alerting of the train operator.
- Passenger intercom or telephone on station platforms for communication with central control and possibly police.
- CCTV on station platforms for monitoring by remote security personnel and/or more careful observation of station platforms by the train operator particularly at night.

Operational Performance

Most of the older U.S. two-person train operation systems are concerned that conversion to one-person operation may increase their required run time from terminal to terminal and decrease their percent on-time performance. The former problem is primarily associated with possible increases in station dwell time, the latter with equipment failures and recovery therefrom.

Table 9. Summary of use of closed circuit television (CCTV) for station and/or platform security.

System	Extensive Use of CCTV for Station Security	Comments
CTA	No	City conducted limited experiment but that work has been discontinued. No plans to install.
GCRTA	No	No plans to install.
MBTA	No-Present Yes-Future	Experimental at four stations. Plan to install at all stations at specific area on platform with 2-way communications.
NYCTA	No	Experimental at four stations. No plans to use much CCTV for security. Only use for special places and circumstances.
PATH	Yes	Used at station fare collection areas, escalators, elevators, and few platforms. Sixty cameras total.
SEPTA	No	City conducting pilot program at five stations. Platform cameras at three of those stations.
BART	No	Few station platforms are monitored by police.
MARTA	Yes	Extensive use on station platforms, in fare collection areas, and other station locations. Monitored at five zone centers.
PATCO	Yes	Used in all station fare collection areas. Two stations in Philadelphia have cameras on platforms. Monitored at central control.
WMATA	Yes	Extensive use on station platforms, in fare collection areas, and other station locations. Monitored by station attendant in kiosk at each station.
Berlin	Yes-Line 4 No-Other Lines	Extensive use for automated Line 4. For rest of system, CCTV is used primarily for train dispatching. Train dispatcher is located on platform.
Hamburg	Yes-PUSH No-Other Lines	Extensive use for automated PUSH system. For rest of system, CCTV is used primarily for train dispatching. Train dispatcher is located on platform.
London	No	Limited use for security. Used for door control at curved platforms.
Paris	No	Not used for security. Extensive use for train door control.
Stockholm	No	Primarily used for door control. A few stations have CCTV monitored by police. In Sweden use of CCTV for monitoring is discouraged because of privacy considerations.
Lille	Yes	Extensive use on station platforms, fare collection areas, and other station locations. Lille has unmanned trains and stations.

Station Dwell Time

Because it is so closely related to car side door control, the possible impact of one-person operation on station dwell time was discussed earlier, immediately after the discussion of car side door control. In that section it was concluded that the potential increase in station dwell time with one-person operation can be eliminated essentially through use of automatic train control; mirrors and/or CCTV to enable the operator to observe the doors on either side of the train without leaving the console; or having all of the platforms on the console side of

the train. If none of those solutions is practical, the increase in station dwell time could be as high as 16 sec at stations with platforms on the opposite side of the train from the operator console.

A SEPTA representative stated that if the Broad Street Local service were converted to one-person operation, SEPTA estimates that the round-trip run time would be increased by 5 min. This would require an extra train set to maintain the same headway as with the present two-person operation. To reduce the increase in station dwell time, it has been suggested that an additional door-open button be included on the operator console so the doors on the opposite side of the train can be opened before the operator walks across the car. (CTA has included such a door open switch in the specifications for new railcars.)

Equipment Failures and Recovery Therefrom

The issue with respect to equipment failure and recovery therefrom is that with one-person operation there is one less crew member to troubleshoot and/or override malfunctioning equipment. Such tasks include:

- Freeing stuck doors and cutting out failed doors and brakes.
- Guarding stuck doors.
- Resetting passenger emergency brake devices.
- Detecting and reporting car defects.
- Occasionally keying-by or tying down a brake trip arm at wayside signals.

If the time to perform these functions is increased with one-person operation, an unacceptable level of train delays may result.

Such problems have been solved at present one-person operation systems but they are a major concern for some of the older systems with less reliable equipment and facilities. The principal approach for resolving this problem is improved car and wayside equipment reliability and reduction of the time required to troubleshoot or cut out malfunctioning equipment.

Of the newer one-person operation U.S. systems, BART, PATCO, and WMATA reported typical on-time performance levels of 95, 98, and 98 percent of trains within scheduled run time plus 5 min, respectively. Of the older two-person operation U.S. systems, NYCTA and PATH reported typical levels of 88 and 95 percent, respectively. (PATH defines on-time performance as percent trains within scheduled run time plus 3 min.) SEPTA reported that the on-time performance of the Broad Street Express service is essentially unchanged from what it was prior to its conversion to one-person operation. That service consists of short runs and uses new rolling stock.

All of the European systems visited said that they did not experience any major change in on-time performance as a result of conversion to one-person operation. London encountered some delays to passengers during the first few weeks of the conversion of the Hammersmith & City and Circle Lines to one-person operation but now there is no difference in the running times and no delay for the passengers.

To minimize the frequency of equipment malfunctions, equipment and facilities in good operating condition and improved preventive maintenance are required. As previously mentioned, particularly opportune times for conversion to one-person operation are the opening of a new line, arrival of new or rehabilitated rolling stock, or rehabilitation of facilities. All of these actions tend to result in improved system reliability. An MBTA representative said that conversion to one-person operation would require a complete revision of their maintenance policies, procedures, and level of effort, particularly for the Red Line.

Many of the systems visited specifically mentioned the need for good car side door reliability. This is illustrated by the fact that at NYCTA, 10-car trains have up to 160 door panels per train. The door panels are interlocked with the train propulsion system such that if any one panel fails to close or its interlocking switch fails, the train cannot be started until the door is closed or locked out.

For above-ground lines, ice and snow preventing doors from operating properly in the winter are of particular concern. Some systems, such as PATCO, temporarily reassign car washers and some station and operations people to the platforms with snow brooms to free up doors. The new Tokyu cars at GCRTA will have doors in pockets with heated gliders to prevent fouling by ice or snow.

Provision of a passenger intercom to permit communication with the train operator or a passenger emergency alert device could eliminate the necessity of resetting passenger emergency brake devices. Also, with such systems, passengers could alert the train operator to severe car defects.

A number of the systems visited stated that requirements for the single operator to leave the train and go to track level during operation should be minimized. For example, door and brake cutouts should be operable from within the cars. Also, it should not be necessary for the train operator to leave the cab to occasionally key-by or tie down a brake trip arm at wayside signals.

Of the systems visited, only PATH and MBTA (for the Blue and Orange lines) said that it was necessary for a train crew member to go to track side to key-by or tie down a brake trip arm at wayside signals. All of the other systems said that they have provisions for performing this function from the train cab. This is accomplished through use of magnetic rather than mechanical brake trips or use of mechanical devices such as levers, pull cords, or sticks to permit operation of the trips by the train operator from the cab side window.

Conclusion

Specific findings with respect to possible increase in station dwell time with one-person operation and possible approaches for eliminating or minimizing such increases are listed in the Station Dwell Time section. If in the extreme case round-trip run time is increased to the extent that an additional train set is required to maintain the same headways as with two-person operation, the cost of procuring and operating that additional train set must be considered as offsetting a portion of the labor savings with one-person operation.

To maintain percent on-time performance with one-person operation, improved car and wayside equipment reliability and reduction of the time to troubleshoot or cut out malfunctioning equipment are required. To improve reliability, equipment and facilities in good operating condition and improved preventive maintenance are required. This is particularly true for car side doors. Requirements for the single train operator to leave the train and go to track side during operation should be minimized. For example, door and brake contacts should be operable from

within the cars, and it should not be necessary for the train operator to leave the cab to key-by or tie down a brake trip arm at wayside signals. Also, provision of a passenger intercom or emergency alert system would provide passengers with a means of alerting the train operator to severe car defects and could eliminate the necessity of resetting passenger emergency brake devices.

On-Board Fare Collection

Of the 16 systems visited, only CTA, GCRTA, and SEPTA have on-board fare collection and that essentially is only done in off-peak hours. (NYCTA has on-board fare collection for two special services but they are a very small part of its operation.) Since the conductor assists in on-board fare collection, fare collection is an issue or problem for conversion to a one-person operation at those three properties. It is not an issue or problem for the other systems visited.

CTA (Chicago)

CTA operates single-car trains and 3-section articulated cars on its Skokie Line and single-cars at night on its Evanston Line. Those single- and articulated-car trains are operated by one crew member. At night on its other lines, it operates 1-car trains with two crew members. During the weekday base period, CTA has ticket agents at most stations. At nights and on weekends, the majority of stations are unmanned and fares are collected on-board by the conductor.

On-board fare collection is performed only on single- and 2-car trains with the exception of certain stations on the Lake Street route, where special platform barriers allow on-board fare collection on longer trains.

GCRTA (Cleveland)

GCRTA operates 2-, 3-, and 4-car trains during peak periods, 2-car trains between the a.m. and p.m. peaks, and single-car trains after 6:00 p.m. and in the early morning. The single-car trains are operated by a single crew member. All other trains have two crew members. During the peak periods, GCRTA has ticket agents at each station. Between the morning and afternoon peaks, in the evening after 6:00 p.m., and in the early morning before 6:00 a.m., the stations are unmanned and fares are collected on board the trains.

On the 2-car trains operated between the a.m. and p.m. peaks, the train operator collects fares on the first car and the conductor collects them on the second car. On the single-car trains operated after 6:00 p.m. and in the early morning, the single train operator collects the fares.

SEPTA (Philadelphia)

On its Ridge Avenue Spur, SEPTA operates 2-car trains Monday through Saturday. No service is provided on Sundays. Those 2-car trains have a single train operator. There is no ticket agent at the Chinatown station, except 3:00 to 6:00 p.m. Monday through Friday. When the ticket agent is not on duty at that station, the train operator collects fares on 2-car trains.

On the Market-Frankford Line, 6-car trains are operated during the day and 3-car trains are operated at night. All trains have two crew members. During the day and early evening, there are ticket agents at each station. During the late night and early morning hours, 75 percent of the stations are unattended and the conductor collects fares through a cab window. The doors are not opened until after the boarding passengers have paid their fares. An exact-fare system is used.

Fare Collection at Other Systems

In the United States, all of the newer one-person operation systems, i.e., BART, MARTA, PATCO, and WMATA, have automatic fare collection in the stations. BART and WMATA have very extensive systems with provisions for variations in fares. MARTA and PATCO have less extensive systems. MARTA's system accepts only exact change, weekly or monthly passes, or special transfers from buses. Two stations have change machines; the others do not. MARTA and PATCO stations are unmanned. BART and WMATA have a station attendant in the station fare collection area but they do not collect fares or make change.

All of the older U.S. two-person operation systems, except PATH, have ticket agents in the stations. PATH has automatic fare collection and unmanned stations. The turnstiles accept exact fare only and bill changers are available in the area.

In Europe, most of the systems visited have various forms of self-service fare collection. That is, the passenger determines and pays the fare at automatic ticket dispensing machines. The ticket is punched and validated at another machine. Passengers are required to present their ticket to fare inspectors who perform spot checks on trains. London, Paris, and Stockholm also have ticket agents at stations; Berlin, Hamburg, and Lille do not.

Conclusion

On-board fare collection is an issue or problem for conversion to one-person operation at CTA, GCRTA, and SEPTA. The problem primarily exists for conversion to one-person operation of 2-car trains at CTA and GCRTA, and 3-car trains at SEPTA. On-board fare collection is already implemented at all three properties for one-person single-car trains and at SEPTA for one-person 2-car trains. Possible solutions to the problem include:

- Collection of fares from boarding passengers by the train operator through a cab window before opening train doors. This is essentially the method currently being used at SEPTA for 3-car trains, except the conductor rather than the train operator collects the fare. With full-width or convertible full-width cabs, the operator will have access to cab windows on both sides of the train so he can collect fares at platforms on either side of the train. Possibly exact-fare could be required to speed up the boarding process.
- Operation of single-car trains with one crew member at shorter headways than current 2- or 3-car trains with two crew members.
- Substitution of a single longer articulated car with one crew member for present 2- and 3-car trains with the operator collecting fares as for current single-car trains.

Table 10. Summary of heavy-rail rapid-transit employees at systems visited.

System	Heavy-Rail Rapid-Transit Mode Employees: Total Employees	Train Operators	Train Conductors	Conductors as % of Total Employees	Transit Police Department[b]
CTA	4,039[a]	400	400	9.9	287[c]
GCRTA	418[a]	39	39	9.3	36
MBTA	1,481	205	205	13.8	105
NYCTA	27,552	3,357	3,151	11.4	3,600
PATH	1,046	120	137	13.1	87
SEPTA	1,876[a]	256[a]	256[a]	13.6	133
BART	1,931[a]	238	0	0	138
MARTA	511[a]	106	0	0	96
PATCO	315	50	0	0	25
WMATA	2,653[a]	308	0	0	321
Berlin	5,000	780	1,000[e]	20[e]	15[c] +30[d]
Hamburg	n.d.[f]	320	360[e]	n.d.	35[d]
London	23,600	2,000	2,000	8.4	300
Paris	11,200	2,685	0	0	350[c]
Stockholm	n.d.	n.d.	n.d.	n.d.	140[c]
Lille	170	0	0	0	40[c]

Source: Data and estimates provided by systems visited except as noted in (a).

(a) Jacobs, M., O'Connor, R., Chen, S., et al., "National Urban Mass Transportation Statistics, FY 1982 Section 15 Annual Report". UMTA Report UMTA-MA-06-0107-84-1 (November, 1983).
(b) Not included in total employees.
(c) City Police
(d) Non-police security personnel
(e) Platform train dispatchers
(f) n.d. - no data

- Installation of some type of "self-service" fare collection system for night time use with a limited number of exact fares and spot checks for validated tickets.
- Installation of a limited capability automatic fare collection system for night time use only (e.g., similar to those at PATH or MARTA).
- Installation of a more extensive automatic fare collection system for use all day long.
- Operation with a second person (fare collector) on-board train during the off hours.

HUMAN RESOURCE AND INSTITUTIONAL ISSUES

Changes in Work Force

Transit is a labor intensive industry. Labor salaries and related fringe benefits are the major cost elements in most transit system budgets ranging from 50 to 75 percent of the total operating costs. The principal motivation for converting two-person train operation systems to one-person operation is to provide more cost-effective operation of heavy-rail rapid-transit trains by reducing the number of employees required to deliver a given level of service or by increasing the level of service without increasing the number of required employees.

Table 10 presents a summary of the number of heavy-rail rapid-transit employees at the systems visited. Most of the systems visited provide bus and/or other modes of transit in addition to heavy-rail rapid-transit. The employees listed in Table 10 are applicable to the heavy-rail mode only.

As shown in Table 10 for U.S. two-person operation systems, approximately 9 to 14 percent of the heavy-rail employees are classified as train conductors. This represents the maximum possible percentage reduction in total system employees through conversion to one-person operation assuming a system-wide conversion; all of the conductors are eliminated; no additional employees are added in other job classifications; and the present level of service is maintained.

It is unlikely that any eventual reduction in staff as a result of conversion to one-person operation would be so large. Essentially all of the management and union people interviewed believe that in the event of such conversion, additional employees would be required in the following areas:

- Security/police department.
- Maintenance.
- Ad hoc platform attendants (i.e., at busy stations during peak periods).
- Supplemental crew members or wayside coverage persons at critical locations during peak commute hours.

Also, if service is increased by operating more frequent one-person trains, additional train operators will be required.

Transit System Management Position

Two major issues related to conversion to one-person train operation are: (1) What will become of crew members displaced as a result of such conversion, i.e., will they be laid off or transferred to other jobs? (2) What will the labor union's position be? These issues are addressed in this and the following two sections.

With respect to the first issue, the personnel and labor relations management people interviewed at all of the systems visited were unanimous in their opinion that crew members displaced as a result of conversion to one-person train operation would not be laid off. They would either be used to improve service by running shorter, more frequent trains, assigned to other job classifications, or absorbed through normal attrition. They stated that it is not transit system practice to lay off staff members whose jobs are eliminated through technological advances or procedural changes. This practice is a result of a combination of: (1) a general transit system philosophy to minimize lay-offs; (2) protection of interests of transit employees under Section 13(c) of the Urban Mass Transportation Act of 1964, as amended; (3) historical management-union working agreements; and (4) in one case, a no-lay-off clause in the union contract. Management would work closely with the union and make every effort to place surplus crew members in comparable positions.

Examples of past actions illustrating this no-lay-off practice along with concessions that are sometimes negotiated for conversion to one-person operation are presented in the following paragraphs.

CTA (Chicago). In the early 1950s, train crews were reduced from five to two persons on 8-car trains. Surplus crew members were absorbed through attrition or transferred to other positions.

GCRTA (Cleveland). In 1981–1982, GCRTA replaced the older cars used on their light-rail lines with new Breda articulated cars. A single articulated car, which is 78 ft long, replaced 2-car trains of older shorter cars. One person operates a single

articulated car, while the older 2-car trains had two crew members. Surplus personnel were re-assigned to other positions, primarily to fare booths.

MBTA (Boston). After several years of unsuccessful attempts by management to reduce on-board personnel through collective bargaining and legislated means, in December 1980 a law known as the "management rights law," Chapter 581 of the Acts of 1980, was enacted in Massachusetts. Among its provisions was the repeal of a 1935 statute that required that there be one "guard" for each two cars on trains of two cars or more. After some legal obstacles were cleared, in November 1981 MBTA reduced train crew size from three to two persons on 4-car trains. Some 66 less "guard" positions were called for in train crew requirements. Since MBTA had been undergoing severe financial restraints, which in fact was the catalyst that precipitated the passage of the reform legislation after the system had closed down for one day, a furlough was implemented for those affected by the reduction. However, within a 2-month period all the furloughed personnel had been recalled to active status. Some returned to "guard" positions that had been vacated by attrition, while others were trained for comparable positions. It was the distinct purpose of the management to be the least disruptive of the workforce as possible and except for the severe existing financial problems it would have been likely that no lay-offs would have occurred at all.

NYCTA (New York City). In 1948 an arbitrator authorized the Transit Authority to reduce from two to one conductor on each train. There was no loss of employment. The surplus people were transferred to other positions. More recently there was a reduction in number of platform conductors without terminations.

PATH (New York-New Jersey). Over the period 1971–1973, PATH removed more than 100 people from stations with the institution of "exact fare" on the system. Those employees were placed in other jobs or absorbed by attrition. A few chose to take severance pay. Also, 67 flagman-collector positions were eliminated when PATH assumed total responsibility for service that it formerly operated jointly with the Pennsylvania Railroad between Newark and Journal Square. The surplus people were absorbed without terminations.

SEPTA (Philadelphia). SEPTA was in the process of reducing the train crew size from two- to one-person operation on its Broad Street Subway "express service" at the time of the study team's visit. This action followed the successful implementation of one-person operation with the reopening of its Ridge Avenue Spur Line. That line had been shut down for 2 years. No personnel were adversely affected by the reopening of the Ridge Avenue Spur Line because it was a restoration of service. Management representatives said that all of the conductors displaced by conversion of the Broad Street Express service to one-person operation would be used to increase service, by dropping the headway between trains, or transferred to other jobs.

Hamburg. In 1955, the train crew was reduced from two to one person. Surplus crew members were assigned to other jobs and absorbed through normal attrition. It was necessary to increase the wages of operators of one-person operation trains.

London. London is presently performing a staged (one line at a time) conversion to one-person operation. Displaced conductors are given the opportunity to become train operators or are transferred to a line of their choice that continues to have two-person operation. London pays a premium of 2 British pounds per week to operators of one-person operation trains with manual train control. No premium is paid to operators of one-person operation trains with automatic train control, i.e., the Victoria Line. London is also considering reducing the work week by 2 or 3 hours for operators of one-person operation manually controlled trains.

Paris. Paris converted from manual to automatic train control over a 15-year period, 1963 to 1978. As the trains were converted from manual to automatic control, the crew was also reduced from two- to one-person operation. The conversion to one-person operation resulted in the need to reduce 1,200 guard positions. Those who could qualify as operators were so trained. Those who could not were transferred to other positions such as ticket collectors. A "hiring freeze" in operating positions was implemented during this period. The wages of operators of one-person operation trains were increased by 10 percent, and incentives of several thousand French francs were paid to guards who had to change jobs.

Stockholm. Stockholm converted from two- to one-person operation during the 1970s. The process extended over almost a decade so attrition solved the problem of excess employees. All changes in jobs were negotiated with the union. Operators of one-person operation trains had their work day reduced from 8½ to 7⅓ hours at the same pay.

Based on the above examples and discussions with transit management representatives, it is concluded that in the event of conversion to one-person operation, transit managers would elect to achieve savings from reduced personnel needs over an elongated period of time that would be necessary to reduce the force by attrition.

Transit Labor Contract Provisions

A review of the various labor contracts gathered during the study revealed no obvious contractual bar to implementing one-person train operation. Four contracts contain strong management rights provisions, one contains a no-lay-off provision for employees with over one year of service, and one contains protective reduction in force provisions. Provisions such as the latter two would postpone a reduction in number of system employees but not necessarily the implementation of one-person operation.

Systems with strong management rights, no-lay-off provisions or protective reduction in force and/or seniority clauses in their labor contract include:

- *GCRTA.* There is a single seniority list for heavy-rail train operators and conductors and bus drivers. Train operators and conductors come from the bus driver ranks and can "bump back" into that position.
- *MBTA.* The Labor Contract contains a strong management rights clause that is reinforced by state law.
- *NYCTA.* The Labor Contract has a strong management rights clause. In addition, the parties have executed a Memorandum of Understanding that is addended to the Contract and gives the Authority the right to transfer hourly paid employees to other duties but with no loss in pay and with retraining.
- *PATH.* The Labor Contract with the Brotherhood of Locomotive Engineers has a clause in the "Miscellaneous" provisions that includes management's right to "introduce technological improvements." In the "Miscellaneous" provisions of the Contract with the United Transportation Union, which represents the conductors, it specifies "PATH shall have

the right to introduce technological improvements by way of automation, mechanization, ..."

- *SEPTA.* The Labor Contract has a no-lay-off clause. Employees represented by the union who have accrued one year seniority will not be laid off.
- *MARTA.* The Labor Contract has a strong management rights clause. Also, there is a single seniority list for heavy-rail train operators and bus drivers.
- *PATCO.* The Labor Contract has a strong management rights clause which states that the union will not oppose the operation of the system as it was planned.
- *WMATA.* The Labor Contract has a detailed procedure for a reduction in force which provides a great deal of protection for surplus employees.

Transit Labor Union Position

Historically, the transit industry has been highly unionized. The operating employees at the systems visited are represented by the following unions:

- *Amalgamated Transit Union (ATU)*—CTA, Local 308; GCRTA, Local 268; MBTA, Local 589; BART, Local 1555; MARTA, Local 732; and WMATA, Local 689.
- *Transportation Workers Union (TWU)*—NYCTA, Local 100; and SEPTA, Local 234.
- *International Brotherhood of Teamsters, Chauffeurs, Warehousemen and Helpers of America (IBT)*—PATCO, Local 676.
- *Brotherhood of Locomotive Engineers (BLE)*—PATH (Train Operators).
- *United Transportation Union (UTU)*—PATH (Train Conductors).
- *Union of Public Services, Transport, and Traffic Employees (OTV)*—Berlin and Hamburg.
- *National Union of Railwaymen (NUR)*—London.
- *Swedish Kummunal Works (SKW)*—Stockholm.

In the United States, the two dominant unions are the ATU and the TWU which, together, represent 90 percent of the operating employees. Typically the ATU restricts its membership to transit workers, whereas the TWU also represents people in other forms of transportation including the airlines. An important difference between the two is their philosophy for resolving disputes. The ATU favors arbitration, whereas the TWU has taken a more aggressive role.

In America, the term "trade union" and "labor movement" are synonymous. In Europe, trade unions are only one element in a variety of organizations which together form the labor movement. Also, Europeans see accommodation or co-management as an acceptable relationship between management and unions, while in the United States, a more adversarial relationship exists.

All the union representatives of the older U.S. two-person train operation systems interviewed said that they were opposed to conversion of multiple-unit trains to one-person operation. The principal reasons they gave for their opposition were safety and security, particularly door safety and train evacuation between stations in tunnels with fire. They generally agreed that although it may be possible to design new systems for one-person operation, old systems have too many problems with antiquated structures and tunnels, curved crowded station platforms, and old rolling stock to convert to one-person operation. A few stated that they would be required to resist such conversion to fairly represent their membership.

When asked what actions would be taken if the union was faced with the possibility of a reduction from two- to one-person operation, the union officials at one transit agency replied that many actions could be taken such as contractual trade-offs, negotiations, or arbitration. They also indicated there are other avenues, such as going to the community or the press and possibly the courts.

In the United States, all of the one-person multiple-unit train operation systems, except SEPTA, were conceived and designed for one-person train operation and have operated in that mode from the first day of revenue service. They had no history of two-person operation and did not encounter major labor opposition to one-person operation. However, when interviewed, union officials at BART and PATCO expressed some opposition to one-person operation. At BART, the union is opposed to removal of the second crew member at certain critical locations and heavy train loading conditions, i.e., the Transbay Tubes and Berkeley Hills Tunnel during peak commute hours. At PATCO, the union is opposed to one-person operation of 8-car trains.

In Europe, all of the systems visited, except Lille which is unmanned, have been, or are in the process of being, converted to one-person operation. All of the systems, except Berlin, encountered strong union opposition to the conversion. Little labor opposition was encountered at Berlin because there was a labor shortage at the time of the conversion (mid-1960s). Berlin, Hamburg, and Paris representatives stated that labor opposition to conversion to one-person operation tends to be greater in periods of general unemployment than in periods of full employment.

Recent union actions taken at MBTA, SEPTA, and London in response to reductions in the number of crew members on trains are indicative of the unions' position. Those actions are briefly summarized in the following.

- *MBTA.* After enactment of Chapter 581 of the Acts of 1980 by the Massachusetts legislature, MBTA immediately attempted to reduce the number of guards from two to one on 4-car trains. Local 589 of the ATU protested this action and, on January 7, 1981, obtained a preliminary injunction from the Massachusetts Superior Court enjoining the MBTA from "failing to post less than one guard for each two cars on trains of two cars or more." That injunction was later vacated (*2*) and, commencing November 1981, only one guard was assigned to a 4-car train. The union again attempted to overcome the reduction in guards by pursuing the matter in arbitration in late 1982 on the premise that the safety and security of the riding public as well as the remaining guard were now in jeopardy. In an Award dated December 17, 1983 (*3*), the grievance was denied.
- *SEPTA.* When SEPTA first announced its intent to operate one-person 2-car trains on the Ridge Avenue Spur, Local 234 of the TWU protested this action and advanced the issue to arbitration. In an Award dated October 21, 1983 (*4*), the union's request that SEPTA be ordered to cease the operation of one-person 2-car trains on the Ridge Avenue Spur was denied. In February 1984, SEPTA attempted to initiate one-person operation of 5-car "Express" trains on its Broad Street Subway. The union obtained a Court restraining order to prevent such operation and the issue was advanced to arbitration. Arbitration followed with an Interim Award recognizing SEPTA's right to

implement a one-person operation of the Broad Street Express service after August 5, 1984. However, the Board of Arbitration retained jurisdiction for the consideration of assertions by the union of additional instances which reflect on the safety of the operation. In an Award dated August 24, 1985 (*5*), the Board of Arbitration recognized SEPTA's right to implement one-person operation of the 5-car trains used for the Broad Street Express service. The arbitrator continues to retain jurisdiction in the issue and will monitor safety reports.

- *London.* While London's Victoria Line, which began service in 1968, has always had one-person operation, London has only recently (fall 1984) converted some of its older two-person operation lines to one-person operation after negotiating with the union on this issue over a period of 14 years. As recently as May 1985, union leaders called a strike to protest such conversion but the strike was unsuccessful and lasted only one day.

Based on the above examples and discussions with union officials, it is concluded that labor will likely oppose any action to convert two-person multiple-unit train operation to one-person operation. They have, in the past, resisted elimination of whole job classifications, and it is believed they will continue to take that position. Opposition could range anywhere from filing a grievance to court action to a strike.

Transit Labor-Related Regulations/Codes/Laws

Four labor-related regulations and laws bearing on conversion from two- to one-person train operation were identified.

1. Section 13(c) of the Urban Mass Transportation Act of 1964, as amended.
2. Civil Service Rules and Regulations.
3. Railway Labor Act.
4. Massachusetts State Law, Chapter 581 of the Acts of 1980.

The first regulation applies to all of the U.S. systems. The second to GCRTA and NYCTA only, the third to PATH only, and the fourth to MBTA only.

Section 13(c)—Urban Mass Transportation Act

Section 13(c) of the Urban Mass Transportation Act of 1964, as amended, provides for the protection of employees when a mass transit system is acquired or improved by states or local public bodies with the use of federal funds. It provides that "fair and equitable" arrangements be made to protect the interests of employees affected by the federal grant. The protective arrangements must include, but are not limited to, provisions that:

1. Preserve rights, privileges, and benefits (including continuation of pension rights and benefits) under existing collective bargaining agreements.
2. Continue collective bargaining rights.
3. Protect individual employees against a worsening of their position with respect to their employment.
4. Assure employment to employees of acquired mass transportation systems and priority re-employment of employees terminated or laid off.
5. Provide paid training or retraining programs.

As a condition for receiving federal financial assistance under the Act, the Secretary of Labor must certify that the provisions of 13(c) have been complied with by grant applicants. So-called "13(c) agreements" negotiated between the transit union involved and management representatives have become the vehicle for providing protective labor arrangements.

A technological advancement such as conversion to one-person operation was perhaps among the anticipated developments for which federal funds would be used when the Congress enacted the Urban Mass Transportation Act in 1964. It is clear that automation was considered in the legislative history of the Act when Senator Harrison Williams promised that the objectives of labor would be seriously considered . . . "to protect rights of employees displaced through automation" (*6*).

None of the U.S. personnel and labor relations management people interviewed believe that 13(c) would prevent conversion to one person operation. They said that most of the 13(c) actions to date at their properties were related to start-up or expansion of services. At those times, it was often necessary to absorb workers from acquired bus companies or bus and rail companies whose routes or lines they duplicated. They could not recall any instances where 13(c) considerations had been a major problem in implementation of a technological or procedural change in system operations. The unions have from time to time delayed in signing-off on a federal grant application but the problem has always been resolved. Also, 13(c) considerations did not prevent SEPTA from converting its Ridge Avenue Spur and Broad Street Express service from two- to one-person operation.

None of the U.S. union officials interviewed cited 13(c) as a major issue for conversion to one-person operation. However, as discussed in the Transit Labor Union Position section, the unions are strongly opposed to such conversion for multiple-unit trains. The major issue that arises then is how much cooperation would management receive from the union in preparing a federal grant application for funds to support a conversion to one-person operation.

Negotiations between the union and management would be conducted under the guidelines of the Department of Labor. The Secretary of Labor monitors progress of such negotiations, and in cases where negotiations break down incorporates into the time schedule dates by which the Secretary will take alternative action. If during the process of an application the Secretary finds that the parties are unable to reach agreement, he will review the positions of the parties to determine appropriate action. Such action may include the Secretary's determination of the terms and conditions on which certification will be based or refusal to certify for specified reasons. Over the years the Department of Labor's role has been to assist the parties to reach voluntary agreement rather than to impose specific terms and conditions. Only on a few rare occasions has the Secretary exercised his authority to establish the terms.

If the union were to agree to protective arrangements as part of the grant application, the 13(c) agreement itself provides a grievance procedure with arbitration provisions. In case a dispute arising out of the project occurred, the union would have recourse within the agreement. The Amalgamated Transit Union (ATU) has accepted automation provided that employment rights of transit workers are protected by written guarantees (*7*). Failing satisfactory resolution through the arbitration process, there is the judicial route through the federal court system.

Civil Service

Employees at GCRTA and NYCTA come under Civil Service Rules and Regulations that provide additional protection for employees from termination of their employment. Civil Service Laws were enacted at both federal and state levels to protect civil employees from abrupt dismissal because they are not a member of or did not support the political party in power.

In the matter of termination of employment an elaborate appeal process is available in most instances to the affected employee. Many governmental agencies do not wish to devote the resources required to contest the process and elect to settle for alternate solutions to excess work force such as attrition.

Railway Labor Act

PATH is a somewhat unique entity in that it is considered a railroad operation rather than a heavy-rail rapid-transit operation. It is subject to the rules of the Federal Railroad Administration and Interstate Commerce Commission. Its labor management relations are subject to the Railway Labor Act (RLA). Consequently, the process for reducing its on-board train complement would be cumbersome. Under the RLA provisions, the union involved with the job classification in effect "owns" the work. Unless the union chooses to negotiate away its jurisdiction, it could be necessary to "buy out" the conductor job. Additionally, if any part of the work in question remains, it cannot be transferred to another classification under the RLA.

Massachusetts State Law

In Massachusetts, Chapter 581 of the Acts of 1980 designates certain matters as inherent management rights and prohibits the MBTA from bargaining collectively with labor organizations representing its employees over any of them. Pertinent to this study would be the inherent right of management "to determine levels of staffing and training" and "to classify the various positions of the authority and ascribe duties and standards of productivity there of".

Transit Safety-Related Regulations/Codes/Laws

Presently, there are no federal, state, or local regulations or laws banning one-person operation of rapid-transit trains at any of the systems visited. One minor exception to this exists for BART. During peak commute hours, the California Public Utilities Commission (CPUC) requires BART to have a second crew member on-board trains running through the Transbay Tubes and Berkeley Hills Tunnel in the direction of the heavy commute. Shortly after the Transbay Tube train fire on January 17, 1979, the CPUC required a second crew member on all trains passing through the tube, but now this is only required during the rush hours. BART has fire hardened its cars and is currently attempting to have the requirement for a second crew member removed from all trains.

Prior to December 1980, Massachusetts State Law G.L.c. 161, S. 91A had required that a guard be assigned to each two cars of passenger trains consisting of more than one car. In December 1980, Chapter 581 of the Acts of 1980 became law in Massachusetts and repealed G.L.c. 161, S. 91A. Massachusetts was unique in that a given size train crew was specifically required by State Law. That law has now been repealed and to our knowledge, no laws or regulations requiring a specific number of persons in a rapid-transit train crew currently exist anywhere in the United States, except as noted for BART.

PATH falls under Federal Railroad Administration (FRA) rules. Those rules require that train operators not work more than 12 hours in a 24-hour period but do not require two-person crews for rapid-transit trains.

Most of the U.S. systems visited said that they do not fall under the jurisdiction of any federal, state, or local safety regulatory agency. Exceptions to this include the following:

- BART, which is regulated by the CPUC.
- MBTA, which is subject to statutes of the Massachusetts State Legislature and to the Massachusetts Department of Public Utilities on matters of safety.
- PATH, which is regulated by the FRA.

In Europe, all of the rail transit systems visited are subject to federal safety regulations and laws. None of those regulations ban one-person train operation.

In Germany, a federal regulation called the "BOSTRAB" requires one crew member on all transit trains. The BOSTRAB is currently being revised, and it is anticipated that the revised version will permit unmanned operation if appropriate technical provisions are made. There is also a recently passed federal regulation that requires future transit trains to proceed to the next station before stopping after a passenger emergency device is activated.

In France, the Ministry of Transport has recently passed a regulation permitting operation of unmanned transit trains such as the Lille system. It has also passed a regulation that requires future transit trains to proceed to the next station before stopping after a passenger emergency device is activated.

In Sweden, the Department of Transportation has a regulation that can be interpreted as requiring at least one crew member on rapid-transit trains. In England, there is a federal regulation requiring that all car end doors be unlocked at all times.

Timing of Conversion

Many of the system management people interviewed stated that "timing" is an important issue for conversion to or implementation of one-person train operation. Timing is important from both a technological and a labor-management viewpoint. The suggested times for such conversion in descending order of preference are:

- Beginning of system operations.
- Opening of a new line.
- Reopening of a closed line.
- Arrival of new and rehabilitated rolling stock, resignalling or conversion to automatic train control, or rehabilitation of facilities.
- Time of labor shortage or financial difficulties.
- During negotiations for a new labor contract.

The most opportune time to implement one-person operation from both a technological and labor-management viewpoint would be at the time of establishment of a transit system. Most likely federal funds would be used, and therefore the 13(c)

agreement would be in place for labor protection; there would be few constraints, particularly with no employees to be laid-off or attrition required. The system would be envisioned from the start as a one-person operation and designed as such. All of the existing one-person operation systems in the United States, except SEPTA, began operation as one-person systems.

The second most opportune time for installing one-person operation would be in connection with the opening of a new line. Again, most likely the 13(c) considerations would be in place because of the use of federal monies. Again there would be no layoffs or attrition with which to contend, but some existing transit employees could be affected and there would be precedent at the transit agency for two-person operation. As an example of this type of timing, CTA is planning a new route to the southwest side of Chicago. Provisions are being made in the design of the new route and equipment to provide management with the option of one-person train operation.

The third most opportune time for conversion would be when reopening a line that had been closed down or out of service for an extended period of time. SEPTA's reopening of the Ridge Avenue Spur with one-person operation of 2-car trains is an example of this type of timing. Also, portions of PATCO's line in Philadelphia include refurbished Philadelphia Transportation Company rapid transit facilities.

The fourth most opportune time for conversion is the arrival of new or rehabilitated rolling stock, resignalling or conversion to automatic train control, or rehabilitation of facilities. Examples of this timing include: (1) SEPTA's conversion of its Broad Street Express service to one-person operation using new Kawasaki cars equipped for one-person operation; (2) the potential for one-person operation at GCRTA after it is resignalled for all right-hand running; and (3) Paris's conversion to one-person operation as it was being converted to automatic train control.

Other opportune times for conversion include periods of low unemployment or when the transit system is undergoing severe financial difficulties. Berlin and MBTA are examples of conversion under those conditions, respectively. Berlin converted to one-person operation 20 years ago during a period of low unemployment in Germany. Little labor opposition was encountered. In November 1980, MBTA overran its budget for the second consecutive year. Because of that, a one-day shutdown of the system took place. To provide funds that were necessary to keep the MBTA operating until the end of 1980, the Massachusetts Legislature was reconvened in a special session and enacted Chapter 581. Not only did that law provide the needed funds, it also repealed the "guard law" enabling MBTA to reduce the number of guards from two to one on 4-car trains.

Finally, a few system management people stated that they would not "break a contract" to convert to one-person operation. Rather they would include this issue with others to be negotiated at the time the labor agreement is open for changes at the end of its term. At the time of contract negotiations there would be give-and-take and trade-offs on many items.

FRAMEWORK FOR ECONOMIC ASSESSMENT

None of the systems visited indicated that a formal cost analysis of one- versus two-person train operation had been made. London managers stated that they have made an economic study of unmanned versus one-person operation and concluded that unmanned operation would be more expensive than one-person operation, primarily because of the need to retrofit their system with an automatic train control system and maintenance of that system. However, for one- versus two-person train operation, they have more or less taken for granted that conversion costs for one-person operation would be minor relative to savings in wages. All of the systems that began service with or have converted to one-person operation appear to have made the same assumption. None of those one-person operation systems expressed an interest in converting or returning to two-person operation for either technical or economic reasons.

One of the objectives of this study was to develop a framework for an economic assessment of the effects of implementing one-person operation. The results of that effort are presented in this section. Measures of investment worth are discussed first, followed by identification of cost elements that must be considered in a site-specific economic analysis and plan.

Measures of Investment Worth

A variety of methods are used by industry and government for making capital investment decisions including, among others, net present value and payback period. The net present value of an investment is the net present value of the expected cash flows associated with the investment over the life of the investment. The payback period is the period of time required to recover the initial investment. The latter measure of investment worth has many limitations but may have limited application for this analysis.

The basic mathematical relationship for the net present value of an investment is (*8*, p. 45):

$$V = \sum_{t=0}^{n} X_t (1 + i)^{-t} \qquad (1)$$

where:

V = net present value of the investment, \$;
X_t = cash flow of period t, \$;
i = time value of money adjusted for general inflation, or discount rate, %/100;
t = specific time period, year 0, 1, 2, . . . n; and
n = life of investment, years.

The term $(1 + i)^{-t}$ is sometimes called the "present-value factor" or "present-worth factor". It can be used to calculate the present value of \$1.00 at some future time period t when assuming a discount rate i.

Figure 1 shows a comparison of the net present value method for measuring investment worth with life-cycle cost and payback period methods. For illustrative purposes, assume:

1. Investment A represents the operating and maintenance costs for an existing specific system, line, or service with two-person train operation.
2. Investment B represents the cost of converting that system, line, or service from two- to one-person operation and the annual operating and maintenance costs for one-person operation.
3. The net difference of Investment A minus Investment B represents the cost of conversion plus the annual savings (or loss) in operating and maintenance costs for one-person operation relative to two-person operation.

Initial and Annual Costs for Hypothetical Investment Alternatives A and B

Investment Alternative	Initial Cost, $	Annual Costs, $ Year 1	Year 2	Year 3	Year 4	Year 5
A	0	200	200	200	200	200
B	400	150	50	150	50	100
Net Difference A-B	-400	+50	+150	+50	+150	+100

Preferred Investment as Determined by Alternative Measures of Investment Worth

Measures of Investment Worth	Investment Alternative A	B	A-B	Preferred Investment
Payback Period(1), years	-	-	4	B
Life-Cycle Cost(2), $	1,000	900	+100	B
Net Present Value(3), $				
0% discount rate	-	-	+100	B
5% discount rate	-	-	+29	B
10% discount rate	-	-	-29	A

(1) Payback Period = Period of time required to recover initial investment.

(2) Life-Cycle Cost = Sum of costs over life cycle.

(3) Net Present Value = $\sum_{t=0}^{5}$ (Net Costs A-B)$_t(1+i)^{-t}$, where: t = year from 0 to 5 and i = 0, 0.05, or 0.10.

Figure 1. Comparison of measures of investment worth.

The accept or reject criteria used for determining the preferred investment alternative for the three measures of investment worth illustrated are:

1. Payback period—Accept investments with a payback period shorter than the life of the investment.
2. Life-cycle cost—Accept the investment with the lower life-cycle cost.
3. Net present value—Accept investments with a positive net present value.

Figure 1 shows that when using the net present value measure of investment worth with a 10 percent discount rate, hypothetical Investment A is ranked above Investment B. All of the other measures illustrated result in a ranking of Investment B above Investment A. The reason for this is as the discount rate increases the present value of future savings is reduced relative to the value of the initial investment.

Note that essentially the same results are obtained with the life-cycle cost method and net present value method when a zero percent discount rate is assumed. It can be shown that a "discounted life-cycle cost" procedure would give the same results as the net present value method as long as the same discount rate is used for both. The advantage of the net present value method for measuring the investment worth of converting a specific system, line, or service from two- to one-person operation is it only requires that the difference in costs between the two modes of operation be estimated. It does not require that all the costs for both modes of operation be estimated as would be the case for a "discounted life-cycle cost" approach.

One of the qualifications on the payback period method of measuring investment worth is that the payback period must be less than the life of the investment. This is sometimes overlooked by those using this method. Also, it does not consider either the future of the investment after the payout period or the time value of money. For example, again referring to Figure 1, the payback period for the initial cost of Investment Alternative B is 4 years. Since the life of the investment is 5 years, the 4-year payback period is a valid measure of the investment worth—but only if a zero percent discount rate is assumed. If a 10 percent discount rate is assumed, the present value of savings over the 5-year life of the investment would be less than its initial cost of $400 and the investment would never be paid off.

However, the use of some type of payback period approach may have limited application for this analysis. For example, it is possible to determine a theoretically correct maximum acceptable payback period if the following conditions apply:

1. The conversion from two- to one-person operation consists of one or two periods of cash outlays followed by one or more periods of cash savings.
2. The savings per period are essentially constant from year to year.
3. The life of this investment is known.

The basic mathematical relationships for this maximum acceptable payback period are:

$$\text{Payback period} = \frac{\text{Cost of investment}}{\text{Savings per year}}$$

Assuming constant annual savings,

$$MPP = \frac{1-(1+i)^{-n}}{i} \text{ (Ref. 8, p. 43)} \qquad (2)$$

where:
MPP = maximum acceptable payback period;
n = life of investment, years; and
i = discount rate, $/100.

The term $[(1-(1+i)^{-n})/(i)]$ is equal to the present value of an annuity of $1.00 per period for n periods (the life of the investment) discounted at a rate i per period.

Values of the maximum acceptable payback period for selected values of investment life and discount rate are:

Maximum Acceptable Payback Period, years

Discount Rate, %	Investment Life, years: 5	10	20
0	5	10	20
5	4.3	7.7	12.5
10	3.8	5.1	8.5

In conclusion, of the measures of investment worth considered, the net present value method is generally applicable and may be used for comprehensive detailed analyses of the economic worth of conversion of specific systems, lines, or services from two- to one-person operation. A "discounted life-cycle cost" procedure would give the same results as the net present value

procedure but requires the estimation of all of the costs for both two- and one-person operation, whereas the net present value method only requires the estimation of differences between the two modes of operation. For this reason the net present value method is preferred.

Where the major costs of conversion essentially all occur at the beginning of the conversion period and the savings (or losses) in operating and maintenance costs between the two modes of operation are essentially constant from year to year, the "maximum acceptable payback period" approach described in the latter portion of this section may be used. This more cursory approach can give an early "first-cut" indication of the economic worth of such conversions.

The remainder of this section is devoted to the identification and definition of cost elements that must be estimated regardless of the specific measure of investment worth chosen. In general, those cost elements are related to the differences in costs between continued two-person operation and conversion to one-person operation. Selection of a specific discount rate (whether it be zero or some other rate) and life of the investment to be used in economic analyses must be made by the specific agency making the analyses to be consistent with the practices and policies of that agency. Likewise, other measures of economic worth may be chosen so as to be compatible with other economic analyses at the agency. If a discount factor other than zero is chosen, it is important to remember that both the timing and magnitude of costs must be estimated.

If potential savings in costs with one-person operation are to be used to improve service at a fixed cost rather than to maintain present service with a reduction in costs, it may be desirable to first calculate potential savings at the present level of service and then estimate how much additional service can be purchased with the savings.

Cost Elements

Costs are basically of three types: (1) initial, investment, or capital costs; (2) operating and maintenance costs; and (3) salvage value.

Investment or capital costs are usually nonrecurring during the life of the item and include all of the costs required to get an item or system ready for service, e.g., the basic parts or component costs, installation costs, and any special supporting equipment costs. Operating and maintenance costs are recurring costs that are necessary to operate and maintain an item or system over its useful life. Salvage value includes the market, trade-in, or scrap value of an item at the time of disposal minus the cost of removal and disposal.

For purposes of making an economic assessment of the investment worth of converting a specific system, line, or service from two- to one-person operation, investment or capital costs are defined as all of the costs required to convert that specific system, line, or service from two- to one-person operation. Likewise the future savings (or losses) resulting from that investment are defined as the sum of the differences in operating and maintenance costs between the two- and one-person operation versions of that specific system, line, or service over its useful life.

Substituting the above definitions in Eq. 1 gives the basic mathematical relationship for the net present value, V, of an investment for converting a specific system, line, or service from two- to one-person operation, i.e.,

$$V = \sum_{t=0}^{n} \left[-C_{1_t} + \left(O\&M_{2_t} - O\&M_{1_t}\right)\right] \cdot (1+i)^{-t} + S_1 \cdot (1+i)^{-n} \qquad (3)$$

where:

i, t, and n are as previously defined;

C_{1_t} = capital costs required to convert a specific system, line, or service from two- to one-person operation during period t, \$;

$O\&M_{1_t}$ = operating and maintenance costs for the one-person operation version of the specific system, line, or service in question during period t, \$;

$O\&M_{2_t}$ = operating and maintenance costs for the two-person operation version of the specific system, line, or service in question during period t, \$; and

S_1 = salvage value of the capital cost items included in $\sum_{t=0}^{n} C_{1_t}$, \$.

Note that:

1. Equation 3 applies to a situation where a two-person operation system already exists and no additional capital costs are required for continued two-person operation, i.e., $C_{2_t} = 0$ for all time periods. C_{1_t} includes only the capital costs required to modify the existing cars and facilities for conversion to one-person operation.
2. Where a new line or cars or overall rehabilitation of cars or facilities are being evaluated, the term $-C_{1_t}$ in Eq. 3 is replaced by the term $-(C_{1_t} - C_{2_t})$. This latter term is defined as the additional or "marginal" capital costs for the one-person version that are over and above those required for the two-person operation version during period t.
3. If the salvage value, S_1, is small relative to the sum of the investment or capital costs and if the assumed life n of the equipment is long, the present worth of the salvage value will be small and the last term in Eq. 3 may be ignored for less comprehensive analyses.

In the remainder of this section, the term "system" is used to represent any specific rapid-transit system, line, or service to be analyzed.

Capital Cost Elements

As stated, for purposes of this economic assessment procedure, capital costs are defined as only those capital costs required to convert a specific system from two- to one-person operation or the "marginal" costs between one- and two-person operation. Specific capital cost elements that must be considered include:

1. *Changes to Cars and Car Equipment*

- Relocation of side door controls.
- Changes to operator's cab configuration and equipment. Possible elimination of conductor's cab or station.
- Changes to doors, door operators, and/or train-lined interlocking system to improve reliability.
- Possible addition of sensitive door edges and/or warning chimes that doors are about to close.
- Possible relocation of door and brake cut outs to car interior.
- Addition of portable two-way radio for train operator.
- Addition of passenger intercom or emergency alert system.

- Possible upgrading of PA system.
- Possible changes to passenger emergency stop system to make it active at or near station platforms only.
- Possible reduction of gaps between cars or installation of barriers between the outer edges of adjacent cars to prevent passengers from falling off station platform between cars.
- Possible changes to end door locking devices and/or between car passageways to improve between car safety.
- Additional fire hardening of cars over and above what would be done for two-person operation.
- Addition of fire extinguishers accessible to passengers.
- Changes to on-board fare collection equipment.
- Cost of additional train set(s) to maintain headways if increase in station dwell time is excessive.

2. *Changes to Facilities and Station and Wayside Equipment*
- Straightening and/or removal of obstacles near edge of station platforms.
- Changes in lighting along edge of station platforms.
- Addition of closed circuit television (CCTV) and/or mirrors or other means to assist train operator in observing the train doors, particularly at curved platforms.
- Possible addition of a passenger activated emergency stop device on station platforms.
- Addition of two-way intercom or telephone on station platform for communication between passengers and central control and possibly police.
- Possible addition of CCTV on station platforms for security purposes.
- Additional fire hardening of tunnels over and above what would be done for two-person operation.
- Additional provision for a safe passenger evacuation route between stations over and above what would be provided for two-person operation.
- Addition of provisions for keying-by a brake trip arm at wayside signals from the cab window.
- Changes to station fare collection equipment over and above what would be provided for two-person operation.
- Possible increases in number of police cars and portable radios.

3. *Severance Pay, Job Buy Out, or No Loss of Pay*
- In some cases, where employees elect to leave rather than transfer to other jobs, it may be necessary to pay them severance pay. In the case of PATH, which is subject to the Railway Labor Act, it may be necessary to "buy-out" the conductor job from the union. Also, in some cases, such as at NYCTA, the Authority has the right to transfer hourly paid employees to other duties but with no loss in pay. For this latter case, any *additional* pay required for a lesser paying job would be considered an additional cost for conversion to one-person operation subject to reduction over time in accordance with the system's employee attrition rate experience. In an evolutionary type conversion, i.e., one service or line converted at a time, severance pay and no loss of pay costs may be avoided by transferring people to the same job on other lines or services with reduction of staff occurring through normal attrition over time. In the case of a new reopening of a closed line or service, all three of these costs may be avoided.

In estimating the costs associated with each of these capital cost elements, it must be rememberd that capital cost includes all system design, construction, installation, and checkout costs as well as equipment costs. Also, the concept of "marginal" cost must be rigorously applied. Only costs over and above what would be provided for two-person operation should be included. For example, MBTA and PATH presently have major tunnel rehabilitation projects underway including the ventilation and standpipe systems. That work is being done irrespective of whether the trains have two- or one-person operation and is not an appropriate marginal cost for one-person operation.

Also, if a property is considering installing CCTV in stations to enhance security regardless of whether they have one- or two-person train operation, that is not an appropriate marginal cost for one-person operation. In fact, a decision to install CCTV in stations for security purposes may be influenced more by whether the stations are manned or unmanned than whether the trains have one- or two-person operation.

In the case where a two-person operation system already exists and no additional capital costs are required for continued two-person operation, identification of the costs required to modify or retrofit the existing cars and facilities for conversion to one-person operation should be fairly straightforward. However, where a new line or cars or overall rehabilitation of cars or facilities are being evaluated, it may be more difficult to identify the marginal costs associated with one-person operation. In fact, in some instances and for some cost elements there may be little or no difference in the capital cost of the one- and two-person operation versions.

For example, as discussed in the Car Side Door Control section, CTA has been evaluating alternative design options as part of the development process for their next railcar specification. Preliminary studies indicate that if the design features they consider required for one-person operation are incorporated in the original design of the car, there should be no increase in the price of the car, except possibly a $1,000 per car increase for addition of a passenger intercom.

CTA also estimated that with convertible full-width cabs, the net effect on seating capacity will be an increase of approximately six passenger seats per 8-car train. That increase in passenger seats results from the fact that more seats are gained by elimination of the conductor stations than are lost by substituting convertible full-width cabs for operator corner cabs. If in this instance car costs are compared on a per-seat rather than per-car basis, the cost of the one-person operation version of the car is less than the two-person operation version even after addition of the passenger intercom to the one-person operation version.

One major consideration in estimating differences in car or train capital costs between one- and two-person operation versions of a system is the impact of possible increases in station dwell time with one-person operation, i.e., the last cost element listed above under Changes to Cars and Car Equipment. One possible method for incorporating this impact in a cost comparison of one- and two-person operation versions of a given system is to assume the same headway for both versions and calculate the theoretical number of any additional cars or train sets required to maintain that level of service with one-person operation.

For example, as a hypothetical worst case condition, the following conditions are assumed:

- Line has 20 stations. Half of the station platforms are on

the left side of train, the other half on the right side.
- For two-person operation, round-trip time is 1 hour (60 min) and headway is 5 min.
- Station dwell time for one-person operation is increased 15 sec at platforms on opposite side of train from operator console and 0 sec at platforms on the same side as operator console.
- All other running times and station dwell times are the same for both one- and two-person operation.

For these assumed conditions, the total round-trip time for one-person operation would be increased from 60 to 65 min (i.e., 60 min + (20 stations per direction × 2 directions per round trip × ½ platforms on opposite side of train from operator console × ¼ min increase in station dwell time per platform on opposite side of train from operator console)). To maintain a 5-min headway, 13 one-person operation train sets would be required (65 min round-trip time ÷ 5 min headway), whereas only 12 train sets would be required for two-person operation. This results in an 8.3 percent increase in total train or car costs for one-person operation.

The foregoing hypothetical example illustrates the potential for high costs associated with possible increases in station dwell time with one-person operation. Such increases in station dwell time may be reduced through application of one or more of the methods listed in the Station Dwell Time section.

Operating and Maintenance Cost Elements

As stated, for purposes of this economic assessment procedure, savings (or/losses) in operating and maintenance costs are defined as the sum of the differences in operating and maintenance costs between the two- and one-person operation versions of the specific system being analyzed. Specific operating and maintenance cost elements that must be considered include:

1. *Changes in Work Force*
- Reduction in number of conductors.
- Possible increases in the number of:
  - Train operators for any additional trains required to maintain headways if increase in station dwell time is excessive.
  - Supplemental crew members or wayside coverage persons at critical locations during peak commute hours.
  - Ad hoc platform attendants at specific high volume stations during peak commute hours.
  - Yard hostlers to make up and inspect trains.
  - Car and wayside maintenance staff required for improved preventive maintenance and to maintain any additional equipment and facilities, such as the additional equipment and facilities listed earlier under capital cost elements.
  - Person at central control to monitor passenger intercom or telephone on station platforms.
  - Policemen.
  - Other security personnel to monitor CCTV on station platforms.

2. *Changes in Wage Rates and/or Work Hours*
- In Europe, many of the systems visited experienced an increase in train operator wage rates and/or reduction in work hours as a result of conversion from two- to one-person operation. In the United States, neither MBTA, which reduced the train crew from three to two persons in 1981, nor SEPTA, which reduced the crew from two- to one-person for some services in 1983 and 1984, experienced either of these cost increases.

3. *Changes in Parts, Materials, and Electric Power Costs*
- Additional parts and material costs required for improved preventive maintenance and to maintain any additional equipment and facilities.
- Additional electric power consumed by any additional trains required to maintain headway if increase in station dwell time is excessive.
- Additional electric power consumed by any additional equipment, such as CCTV and lighting along edge of platforms.
- Additional fuel for police cars.

As for capital costs, in estimating the savings (losses) in operating and maintenance costs, the concept of marginal costs must be rigorously applied. Only costs over or under what would be required for two-person operation are included.

In estimating the impact of possible increased station dwell time on operating and maintenance costs, an approach similar to that discussed for capital costs may be used. That is, the same headway for both one- and two-person operation versions of the system is assumed and the theoretical number of any additional train sets required to maintain that level of service with one-person operation is determined. The additional operator, maintenance, and electric power costs required to operate any additional train sets can then be estimated.

Increased maintenance costs are of two types. The first type is related to any increase in required preventive maintenance to car and wayside equipment to maintain on-time performance with one-person operation. The second type is related to maintaining any additional equipment and facilities added to the system and required for one-person operation only.

In estimating the total difference in operating and maintenance costs between two- and one-person operation, it is necessary to estimate possible changes in labor hours, labor rate, and/or parts and materials cost for each job classification or cost category affected. As a minimum, all of the job classifications and cost categories listed under (1) Changes to Work Force and (2) Changes in Parts, Materials and Electric Power Costs must be considered.

For example, the cost of any specific operating and maintenance cost category may be defined as:

$$O\&M_j = M_j + (L_j \cdot R_j) \qquad (4)$$

where:

$O\&M_j$ = cost of operating and maintenance cost category j, \$;

M_j = parts and materials costs associated with operating and maintenance cost category j, \$;

L_j = direct labor hours associated with operating and maintenance cost category j, hr;

R_j = labor rate including fringe benefits and burden associated with operating and maintenance cost category j, \$/hr.

Equation 4 applies equally to:

1. Cost categories, such as maintenance costs, where there may be both parts and labor related costs.
2. Cost categories, such as train operator and conductor costs, where there may be labor related costs but essentially no material cost, i.e., $M_j = 0$.
3. Cost categories, such as electric energy cost, where there may be material costs but essentially no labor costs, i.e., $L_j = 0$.

The labor rate, R_j, includes provision for all direct labor costs including fringe benefits, supervisor costs, and all other indirect or burden costs associated with operating and maintenance cost category j. The labor rate may vary from cost category to cost category. For example, the labor rate for train operators may be different from that for maintenance persons or police officers.

Substituting Eq. 4 for the operating and maintenance cost portion of Eq. 3 gives the basic mathematical relationship for the net present value, ($V_{o\&m}$), of the difference in operating and maintenance costs for a specific system converted from two- or one-person operation, i.e.,

$$\begin{aligned} V_{o\&m} &= \sum_{t=0}^{n} \left(O\&M_{2_t} - O\&M_{1_t}\right) \cdot (1+i)^{-t} \\ &= \sum_{t=0}^{n} \sum_{j=1}^{m} \left(O\&M_{2_{j,t}} - O\&M_{1_{j,t}}\right) \cdot (1+i)^{-t} \\ &= \sum_{t=0}^{n} \sum_{j=1}^{m} \left[\left(M_{2_{j,t}} + \left(L_{2_{j,t}} \cdot R_{2_{j,t}}\right)\right)\right. \\ &\quad \left. -\left(M_{1_{j,t}} + \left(L_{1_{j,t}} \cdot R_{1_{j,t}}\right)\right)\right] \cdot (1+i)^{-t} \end{aligned} \tag{5}$$

where:

i, t, n, $O\&M_{2_t}$, and $O\&M_{1_t}$ are as previously defined;

$M_{1_{j,t}}$ = parts and materials cost for the one-person operation version of cost category j during period t, \$;

$M_{2_{j,t}}$ = same as above except for two-person operation version, \$;

$L_{1_{j,t}}$ = direct labor hours for the one-person operation version of cost category j during period t, hr;

$L_{2_{j,t}}$ = same as above except for two-person operation version, hr;

$R_{1_{j,t}}$ = labor rate for the one-person operation version of cost category j during period t, \$/hr;

$R_{2_{j,t}}$ = same as above except for two-person operation version, \$/hr;

j = specific cost category or job classification, category 1, 2, 3 . . . m; and

m = number of specific operating and maintenance cost categories.

Equation 5 is a general equation and includes provisions for variation of material cost, direct labor hours, and labor rate for each cost category or job classification, j, during each time period, t, and between the one- and two-person operation versions of the specific system being analyzed. If for less comprehensive analyses it is assumed that the operating and maintenance costs will essentially be the same from year to year, the marginal operating and maintenance costs between two- and one-person operation need only be calculated for one year and assumed to be constant for the other time periods or years.

Also, for a given cost category or job classification, it is likely that the labor rate will be the same for one- and two-person operation versions of the system. The only likely exception to this may be the labor rate for the train operator. If the train operator wage rate is increased and/or the number of working hours is reduced for the same pay for one-person operation, the train operator labor rate must be adjusted upward for one-person operation to reflect these differences.

For those systems that use the conductor position to provide part of the operator's training, some additional or marginal operator training costs will be encountered with one-person operation. For economic analyses those additional costs can be reflected in an increased operator labor (burden) rate for one-person operation.

CHAPTER THREE

INTERPRETATION, APPRAISAL, APPLICATION

All of the older heavy-rail rapid-transit systems in the United States continue to have two-person operation of multiple-unit trains. This includes CTA (Chicago), GCRTA (Cleveland), MBTA (Boston), NYCTA (New York), PATH (New York-New Jersey), and SEPTA (Philadelphia). All of the newer U.S. systems (i.e., systems that began operation on or after 1969)

and many European systems have one-person operation of rapid-transit trains. The objectives of this study were (1) to identify and evaluate the issues or problems (and possible solutions) that must be addressed in contemplating conversion of the older U.S. two-person train operation systems to one-person operation including the identification of those issues unique to particular systems; and (2) to develop a framework for making an economic assessment of the investment worth of converting a specific system line, or service from two- to one-person operation. No recommendations that any specific rapid-transit system be converted from two- to one-person operation were to be made. That decision is left to the individual transit agencies to make after careful analysis of their specific conditions and situation.

Detailed findings related to the foregoing objectives are reported in Chapter Two. The more general findings and their interpretation, appraisal, and application are presented in this chapter. The major technical, operational, human resource, and institutional issues or problems identified are presented first followed by a summary of possible solutions for each of those problems. This is followed by a summary of additional project findings relative to Transit Labor and Safety Related Regulations/Codes/Laws, Timing of Conversion, and Economic Assessment.

Any comments or generalizations made in this chapter apply only to the 16 U.S. and European heavy-rail rapid-transit systems visited during the study. Those systems are listed in the Research Approach section of Chapter One and in Appendix A. For purposes of readability, this proviso is not *always* repeated in the following paragraphs.

ISSUES OR PROBLEMS

Management personnel at all of the U.S. and European heavy-rail rapid-transit systems visited that are presently operating with one-person train crews on multiple-unit trains are satisfied with that mode of operation and have no desire to convert to two-person train operation. They are satisfied with the safety, security, and operational performance of their systems and stated that they have no major or limiting problems in those areas.

With respect to the labor issue, all of the newer systems that began operation from the first day of service with one-person operation of multiple-unit trains did not encounter major labor opposition to one-person operation. All of the older systems, except Berlin, that have converted their entire system or only specific lines or services to one-person operation have encountered strong union opposition to such conversion. To date, union opposition has sometimes delayed but never completely stopped conversion to one-person operation where it has been attempted. Berlin encountered little labor opposition because there was a labor shortage in Germany at the time of its conversion (i.e., mid-1960s).

Three of the six U.S. two-person operation systems visited, CTA, GCRTA and SEPTA, are very interested in conversion to one-person operation of multiple-unit trains. SEPTA has already converted two special services on its Broad Street Line to one-person operation. Management personnel at the other three, MBTA, NYCTA, and PATH, stated that they have no plans or desire for such conversion at this time.

System management and union personnel interviewed at each of the six U.S. two-person operation rapid-transit systems visited were asked their opinion as to the major issues or problems that must be resolved in converting from two- to one-person operation of multiple-unit trains. Their responses are presented in the Overall Judgment of Systems Visited section of Chapter Two. A single composite listing of those individual system responses is presented below. This composite listing is a ranked listing with the issues or problems judged to be most important listed first. The ranking takes into consideration the frequency of citation and relative priority placed on the listed issues or problems by the six systems in question, plus the overall judgment of the research team based on the findings of the total study. In some cases more than one issue or problem is judged to have equivalent rankings and is listed together under a common ranking. For example, car side door safety and union opposition are judged to be the most important issues or problems and are both assigned a ranking of one. The ranked listing of issues and problems follows:

1. Car side door safety and Union opposition.
2. Fire and Emergency evacuation between stations.
3. Reduced train operational performance resulting from increased time to recover from equipment, particularly door, failures, and increased station dwell time.
4. Security including perceived security.
5. Communication between train operator and central control, passengers on train and train operator, and passengers on station platforms and central control and possibly police.
6. One less on-board crew member to provide passenger information and assistance and detect problems.
7. Between car and end door safety.
8. On-board fare collection, Operator training, and Incapacitation of train operator.
9. Increased operator stress and Loss of a position to assign medically disqualified train operators to.

In addition to the foregoing issues and problems, there is some concern that new cars are still being delivered without provisions for future conversion to one-person operation. Also, while in most cases the reduced labor costs associated with one-person train operation should exceed the costs of conversion from two- to one-person operation, some systems are concerned that the costs of improving equipment reliability and upgrading facilities will in some cases offset such savings.

POSSIBLE PROBLEM SOLUTIONS

A detailed discussion of solutions successfully applied by existing one-person operation systems to each of the above issues or problems is presented in Chapter Two. A summary of those solutions is presented in the following paragraphs.

Car Side Door Safety

For new, one-person train operation systems in the United States, satisfactory door operation has been demonstrated for trains up to 700 ft in length. Those systems generally have straight, unobstructed, and relatively uncrowded station platforms. For older systems, with more obstructed and crowded station platforms, satisfactory door operation has been demonstrated with maximum door observation distances up to ap-

proximately 400 ft (e.g., London and PATCO). This latter length is as long or longer than the *present* maximum train lengths at all of the older U.S. two-person operation systems except NYCTA, which operates trains up to 600 ft in length.

Mirrors and closed circuit television (CCTV) are extensively used in Europe to assist the train operator in observing the car side doors at both curved and straight platforms. In the United States, PATCO is experimenting with CCTV for use with 8-car (544-ft long) trains. Mirrors and CCTV are not trouble-free and their use must be carefully tested and evaluated for specific applications.

Other devices used to assist in safe door operation include interlocking of car side doors with train propulsion and/or braking system, sensitive door edges, warning chimes or announcement that doors are about to close, good platform lighting along side of train, and passenger-activated emergency stop devices both on the cars and platforms.

For most two-person train operation systems, the conductor is instructed to continue watching the car side doors after they are closed until the train has moved some specified distance along the platform. However, if the operator of a one-person operation train is instructed to look to the front of the train before train startup or if the console is on the opposite side of the train from the platform and the operator must return to the console before starting the train, he may not be able to observe the doors after train startup.

London has partially solved this problem by permitting the train operator of one-person operation trains to remain at the console and monitor the car side doors via a mirror or mirror and CCTV monitors located on the station platform. For a short distance (a few meters) after train startup, the operator can still see the mirror or CCTV monitors to check the side of the train. Also, most one-person operation systems and a few two-person operation systems (i.e., GCRTA and MBTA) are presently operating without having the train operator or conductor monitor the side doors after train startup. Door interlocks with the propulsion and/or braking system are used by all of the systems that do not continue to observe the car side doors after train startup.

Labor Union Opposition

A summary of union opposition encountered at two-person operation systems and the outcome of that opposition is presented in the Transit Labor Union Position section of Chapter Two. Based on those examples and the project team's discussions with union officials, it is believed that the union will oppose any action to convert two-person multiple-unit train operation to one-person operation. Opposition could range anywhere from filing a grievance, to court action, to a strike. To date, such actions have sometimes delayed the implementation of one-person operation but have not completely stopped such conversion where it has been attempted.

With respect to minimizing any confrontation with the union, labor management people interviewed at all of the systems visited were unanimous in their opinion that crew members displaced as a result of conversion to one-person operation will not be laid off. They will either be used to improve service by running shorter, more frequent trains; assigned to other jobs; or absorbed through normal attrition. Also, most of the labor management and union people interviewed recommended that management work closely with the union in any attempt to implement a conversion to one-person operation.

A review of various labor contracts gathered during the study revealed no obvious contractual bar to implementing one-person train operation.

Fire Prevention and Control

To compensate for the reduction in train crew size with one-person operation, a variety of actions can be taken to reduce the probability of a fire occurring and to minimize the resultant damage and/or injuries should one occur. Those actions include:

- Fire hardening of cars through proper selection of materials and designs.
- Strict enforcement of no smoking rules and frequent removal of paper and trash from cars.
- Provision of passenger intercom or emergency alert system on cars for passengers to alert operator of fire.
- Provision for passenger access to fire extinguishers.
- Fire hardening of tunnels including installation of reversible ventilation system and standpipes.
- Provisions for moving train to next station if at all possible and for evacuation of passengers between stations as a last resort.
- Preparation and coordination of emergency fire and evacuation plans, training, and drills with all affected agencies including transit personnel and police and local fire, police and medical units.

Emergency Evacuation Between Stations

If as a last resort it is necessary to evacuate passengers from a train between stations, most interviewees agreed that two crew members are better than one, but they differed in their opinion as to the degree of importance of the second crew member. Many of the management personnel at the one-person operation systems visited believe the presence of a second crew member would be only marginally beneficial. They believe that what is required is fast response by many specially trained people to assist in the evacuation. Management and union people at two-person operation systems generally attached more importance to the presence of a second crew member during emergency evacuation.

Regardless of the above, a variety of procedures, equipment, and facilities can be used to reduce the likelihood of emergency evacuation of passengers between stations and to prevent injuries should such evacuation be necessary including:

- Minimization of train and facility breakdowns through improved reliability.
- Provision of a passenger emergency stop or alert system that will permit the train to proceed to the next station before stopping.
- Supplementation of the single crew member with a second crew member or wayside personnel at certain critical locations during heavy train loading conditions.
- Provisions for moving the train to the next station or transferring passengers to a rescue train.
- Fire hardened cars and tunnels.

• Evacuation route for walking out passengers between stations as a last resort.

• Comprehensive emergency evacuation and fire fighting plans and practice drills with all affected agencies including transit personnel and police and local fire, police and medical units.

• Good communications between the train crew, passengers, central control, and emergency personnel.

Operational Performance

Most of the older U.S. two-person train operation systems are concerned that conversion to one-person operation may increase their required run time from terminal to terminal and decrease their percent on-time performance. The former problem is primarily associated with possible increases in station dwell time, the latter with equipment failures and recovery therefrom.

Potential increases in station dwell time with one-person operation can essentially be eliminated through use of automatic train control, mirrors and/or CCTV to enable the operator to observe the doors on either side of the train without leaving the console, or having all of the platforms on the console side of the train. If none of those solutions is practical, the increase in station dwell time could be as high as 16 sec at stations with platforms on the opposite side of the train from the operator console.

To reduce this latter increase in station dwell time, careful consideration should be given to the location of the door "open" buttons (possibly they can be located on the console) and cab side window opening/closing provisions. Also, consideration should be given to the human factor aspects of the cab and cab equipment design including experiments with cab mockups before finalizing the cab design for new or retrofitted cars.

To maintain percent on-time performance with one-person operation, improved car and wayside equipment reliability and reduction of the time to troubleshoot or cut out malfunctioning equipment is required. To improve reliability, equipment and facilities in good operating condition and improved preventive maintenance are required. This is particularly true for car side doors. Requirements for the single train operator to leave the train and go to track side during operation should be minimized. For example, door and brake cutouts should be operable from within the cars, and it should not be necessary for the train operator to leave the cab to key-by or tie down a brake trip arm at wayside signals.

Security

Most of the interviewees believe that to maintain the same level of security after conversion to one-person operation as before conversion, additional police officers would be required. However, the required increase in police officers should be substantially less than the reduction in conductor positions. Certified police officers are preferred to noncertified security guards and in the United States transit police are generally preferred to local police.

Other measures for minimizing any possible reduction in actual and perceived security with one-person operation include:

• More frequent service by shorter one-person operation trains.

• Use of transparent enclosures and mirrors to permit the train operator to see the interior of the first car and for passengers in that car to see the operator.

• Passenger intercom or emergency alert on cars for communication or alerting of the train operator.

• Passenger intercom or telephone on station platforms for communication with central control and possibly police.

• CCTV on station platforms for monitoring by remote security personnel and/or more careful observation of the station platforms by the train operator particularly at night.

Communications

Almost all of the persons interviewed believe that good communications are *essential* for successful one-person train operation. Features which provide this include:

• Two-way radio communication between the train operator and central control with portable radios for the operator so he can maintain two-way contact with central control at all times.

• PA system on cars for both train operator and central control announcements.

• Passenger intercom or emergency alert device in all cars for communication between passengers and the train operator.

• PA system on station platforms for both central control and station attendant announcements.

• Two-way intercom or telephone on station platforms and/or in fare collection area for communication between passengers and central control and possibly police. This is particularly important for unattended stations.

Passenger Information and Assistance and Problem Detection

Interviewees at three systems and one union cited loss of the conductor for answering passenger questions, assisting sick or incapacitated passengers, or detecting problems as a problem for one-person operation. This is one of the reasons that many of the interviewees believe a passenger intercom for communication with the train operator is required for one-person operation. In the case of an incapacitated passenger, other passengers must be relied on to report this to the train operator who, in turn, can relay the message to central control. Provision of a passenger intercom or emergency alert system also provides passengers with a means of alerting the train operator to severe car defects, fires, or other problems. In addition, a good set of route, emergency procedure, and other informational signs can be developed and prominently displayed in all cars to provide needed information to the passengers.

Between Car and End Door Safety

Car and/platform modifications may be beneficial for some of the present two-person operation systems to enhance between car and end door safety with one-person operation. Such modifications could include:

• Either cars designed with relatively small gaps between cars or barriers installed between the outer edges of adjacent cars.

- Passenger-activated emergency devices installed on station platforms to stop the train in the event someone falls from the platform.
- Either between car passageways modified to be relatively hazard free or discouragement or prevention of passengers from moving between cars during normal operation by means of warning signs, strict enforcement of rules, multiple "dog" latches on unlocked doors, locked doors with emergency means for opening by passengers (e.g., breakable glass or tear away covers over the door latch), electric locks that are locked when the train is moving and unlocked when it is stopped, and fail-open electric locks that can be remotely locked.
- Doors on the ends of trains treated as above.

On-Board Fare Collection

Of the 16 systems visited, only CTA, GCRTA, and SEPTA have on-board fare collection and that essentially is only done in off-peak hours. Possible solutions to the on-board fare collection problem with one-person operation of multiple-unit trains at those properties include:

- Collection of fares from boarding passengers by train operator through cab window before opening train doors.
- Operation of single-car trains with one crew member at shorter headways than current 2- or 3-car trains with two crew members.
- Substitution of a single longer articulated car with one crew member for present 2- and 3-car trains with the operator collecting fares as with current single-car trains.
- Installation of some type of "self service" fare collection system for night time use with a limited number of exact fares and spot checks for validated tickets.
- Installation of a limited capability automatic fare collection system for night time use only (e.g., similar to those at PATH or MARTA).
- Installation of a more extensive automatic fare collection system for use all day long.
- Operation with a second person (fare collector) on-board train during the off hours.

Operator Training

For those systems that use the conductor position to provide part of the operator's training, some additional or marginal operator training costs will be encountered with one-person operation. For economic analyses those additional costs can be reflected in an increased operator labor (burden) rate for one-person operation.

Incapacitation of Train Operator

Many systems thought this to be an unlikely problem. Two systems said they never had an incapacitated or trapped train operator. Two other systems could only recall one such instance in the past 20 years. In addition, all of the systems with manual train control have a "deadman" control to stop the train in the event of the incapacitation of the train operator. For their deep tunnels, London has developed a method for alerting central control via the radio in the event the deadman control on any train is activated.

Increased Train Operator Stress

Interviewees at one system and one union stated that increased operator stress may be a problem for one-person operation with manual train control. London plans to make a "before-and-after" study of this subject in connection with conversion of their District Line in 1985. In Europe, a wage differential and/or small reduction in working hours at the same pay is sometimes provided for operators of one-person operation trains.

Loss of Position for Medically Disqualified Operators

Officials at one union said that the conductor position is a good place to assign medically disqualified train operators. Most systems said that if a person is medically discharged from the operator position, it is likely he would also be medically unqualified for the conductor position and would be assigned to a different job classification.

Economic Concerns

With respect to concerns that new cars are still being delivered without provisions for further conversion to one-person operation, CTA staff has been evaluating alternative car design options. As a result of that effort, they have recommended to management the inclusion of convertible full-width cabs on all new rail cars. The reason for this is to provide the option of implementing one-person multiple-unit train operation at some point during the 30-year (plus) life of new equipment without requiring major car modifications. Such design studies should be incorporated into the planning and preparation of specifications for all new rail cars.

Other examples of cars that could be easily converted to one-person operation are the new Kawasaki cars at SEPTA, Pullman and Tokyu cars at GCRTA, and R-44, -46, -62, and -68 cars at NYCTA. The R-62 cars at NYCTA are particularly interesting in that they are currently running in two-person operation with right-hand corner cabs. However, they have built-in features that would permit them to be easily converted to convertible full-width cabs for one-person operation.

With respect to concerns that the costs of improving equipment reliability and upgrading facilities will in come cases more than offset reduced labor costs associated with one-person operation, a comprehensive assessment of the economic worth of the proposed conversion should be made before proceeding with the conversion. The most advantageous time to convert to one-person operation is the opening of a new or rehabilitated line or arrival of new or rehabilitated cars. The marginal capital costs for one-person operation would tend to be lowest at such times. Also, less reliable equipment may be acceptable for off-peak services with shorter trains, fewer passengers, and longer headways.

TRANSIT LABOR-RELATED REGULATIONS/CODES/LAWS

With respect to labor-related regulations/codes/laws, none of the U.S. personnel and labor management people interviewed believe that Section 13(c) of the Urban Mass Transportation Act of 1964, as amended, would prevent conversion to one-person operation. They said that most of the 13(c) actions to date at their properties were related to startup or expansion of services. At those times it was often necessary to absorb workers from acquired bus companies or bus and rail companies whose routes or lines they duplicated. They could not recall any instances where 13(c) considerations had been a major problem in implementation of a technological or procedural change in system operation. The unions have from time to time delayed in signing-off on a federal grant application but the problem has always been resolved.

Employees at GCRTA and NYCTA come under Civil Service Rules and Regulations which provide additional protection for employees from termination of their employment. PATH is a somewhat unique entity in that it is considered a railroad operation rather than a heavy-rail rapid-transit operation. It is subject to the rules of the Federal Railroad Administration (FRA) and the Interstate Commerce Commission. Its labor management relations are subject to the Railway Labor Act (RLA). Under the RLA provisions, the union involved with the job classification in effect "owns" the work. Unless the union chooses to negotiate away its jurisdiction, it could be necessary to "buy out" the conductor job.

TRANSIT SAFETY-RELATED REGULATIONS/CODES/LAWS

Presently, there are no Federal, state, or local regulations or laws banning one-person operation of rapid-transit trains at any of the systems visited. One minor exception to this is BART. During peak commute hours, the California Public Utilities Commission (CPUC) requires BART to have a second crew member on-board trains running through the Transbay Tubes and Berkely Hills Tunnel in the direction of the heavy commute.

Most of the U.S. systems visited said that they do not fall under the jurisdiction of any Federal, state, or local safety regulatory agency. Exceptions to this include BART, which is regulated by the CPUC; MBTA, which is subject to statutes of the Massachusetts State Legislature and to the Massachusetts Department of Public Utilities; and PATH, which is regulated by the FRA.

TIMING OF CONVERSION

Many of the system management people interviewed stated that "timing" is an important issue for conversion to or implementation of one-person train operation. Timing is important from both a technological and labor-management viewpoint. The suggested times for such conversion in descending order of preference are:

- Beginning of system operations.
- Opening of a new line.
- Reopening of a closed line.
- Arrival of new or rehabilitated rolling stock, resignaling or conversion to automatic train control, or rehabilitation of facilities.
- Time of labor shortage or financial difficulties.
- During negotiations for a new labor contract.

ECONOMIC ASSESSMENT

For comprehensive detailed analyses of the economic worth of conversion of specific heavy-rail rapid-transit systems, lines, or services from two- to one-person operation, the "net present value" measure of investment worth is preferred. The net present value of an investment is the net present value of the expected cash flows associated with the investment over the life of the investment. For less comprehensive "first-cut" analyses of conversions where the major costs of conversion essentially all occur at the beginning of the conversion period and the savings (or losses) in operating and maintenance costs between the two modes of operation are essentially constant from year to year, a "discounted payback period" as described in the Framework For Economic Assessment section of Chapter Two may be used.

However, regardless of the specific measure of investment worth chosen, there are certain cost elements that are common to all. In general, these cost elements are related to the differences in costs between continued two-person operation and conversion to one-person operation. Detailed listings of the cost elements that must be considered in a site specific economic analysis are presented in the Framework For Economic Assessment section of Chapter Two.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

Based on the findings of this study, it is concluded that:

1. Many heavy-rail rapid-transit systems, including older systems, lines, or services, have been successfully converted from two- to one-person operation of multiple-unit trains.

2. It should not be inferred from Conclusion 1 that there are no problems associated with conversion of the older U.S. two-person operation systems to one-person operation. The systems, lines, or services converted to date generally have reliable rolling stock with full-width or convertible full-width operator cabs and provisions, such as mirrors or closed circuit television (CCTV), to assist the train operator in seeing the car side doors particularly at curved station platforms. Also, while new one-person operation systems in the United States have demonstrated satisfactory door operation for trains up to 700 ft in length (i.e., BART), those systems generally have straight, unobstructed, and relatively uncrowded station platforms. Many of the older U.S. two-person operation systems have less-reliable rolling stock, antiquated facilities, curved, obstructed, and crowded station platforms and more severe security problems thus increasing the difficulty of conversion.

3. Potential solutions to most of the problems existing at the older U.S. two-person operation systems have been successfully demonstrated at European and/or U.S. one-person operation systems.

4. While conversion of many of the older U.S. heavy-rail rapid-transit systems with two-person operation of multiple-unit trains to one-person operation is believed to be feasible, it is believed that such conversion will generally follow an evolutionary process. That is, rather than systemwide conversion of all services and lines at one time, systems will most likely convert those services and/or lines that are most compatible to one-person operation first, followed by conversion of less compatible services and/or lines over time. The most compatible services include new lines, lines or services with new or rehabilitated cars and/or facilities, and off-peak service with shorter trains, fewer passengers and longer headways. This process is presently being followed by SEPTA and London. The most likely exception to this is GCRTA. GCRTA operates a single heavy-rail line (Red Line) with all island platforms except one. They plan to convert to all right-hand running in approximately 3 years. By that time, all of their older cars should be retired. All of their newer cars and cars on order have convertible full-width cabs with the operator's console on the left-hand or platform side of the cab for right-hand running. At that time, it should be rather straightforward to convert the total system to one-person train operation. On the other hand, NYCTA may never choose to convert their crush-loaded, 10-car, 600-ft long, rush-hour trains to one-person operation.

5. Personnel and labor relations management people interviewed at all of the systems visited stated that train crew members displaced as a result of conversion to one-person train operation would either be used to improve service by running shorter more frequent trains, assigned to other job classifications, or absorbed through normal attrition. They would not be laid off. An evolutionary process for conversion to one-person operation will minimize the problems encountered with this approach.

6. Before proceeding with conversion of a specific system, line, or service to one-person operation, a comprehensive assessment of the economic worth of the conversion should be made. For such an assessment, investment or capital costs include all of the costs required to convert that specific system, line, or service from two- to one-person operation. Likewise, the future savings (or losses) resulting from that investment include the sum of all the differences in operating and maintenance costs between the two- and one-person operation versions of the specific system, line, or service over its useful life.

7. Where a new line or cars or overall rehabilitation of cars or facilities are being evaluated, it may be difficult to identify the marginal costs associated with one-person operation. In fact, in some instances and for some cost elements there may be little or no difference in the capital cost of the one- and two-person operation versions.

8. Approximately 9 to 14 percent of the employees at U.S. two-person operation rapid-transit systems are classified as train conductors. It is unlikely that any eventual reduction in staff as a result of conversion to one-person operation would be so large. Additional employees will most likely be required in the following areas: security/police department, maintenance, ad hoc platform attendants (i.e., at busy stations during peak hours), and supplemental crew members or wayside coverage persons at critical locations during peak commute hours.

SUGGESTED RESEARCH

There are several technical areas that merit special attention before proceeding with conversion to one-person train operation. These include:

- Overall car and operator cab design.
- Minimization of increase in station dwell time.
- Car side door observation aids.
- Passenger emergency stop provisions.

All of these areas are essentially local design issues and can probably be best addressed by individual transit systems for their specific needs. The single exception to this is the area of car side door observation aids which could be the subject of a national research program.

Overall Car and Operator Cab Design

As discussed, as part of the development process for their next railcar specifications, CTA staff have been evaluating alternative design options. As a result of that effort, they have recommended to management the inclusion of convertible full-width cabs on all new rail cars. The reason for this is to provide the option of implementing one-person multiple-unit train operation at some point during the 30-year (plus) life of new equipment without requiring major car modifications. Such design studies should be incorporated into the planning and preparation of specifications for all new rail cars.

Minimization of Station Dwell Time

As illustrated earlier in the report, there is a potential for high capital and operating costs associated with possible increases in station dwell time with one-person operation. To minimize any such increase in station dwell time, careful attention should be given to selection of the method for observing and controlling the car side doors and location of the door control switches. Also, effort should be devoted to the human factor aspects of the cab and cab equipment design including experiments with cab mockups before finalizing the cab design for new or retrofitted cars.

Car Side Door Observation Aids

Although CCTV and mirrors are extensively used in Europe to assist the train operator in observing the car side doors at both curved and straight platforms, they are not trouble-free and their use should be carefully tested and evaluated for specific applications. In the United States, PATCO is experimenting with CCTV for use with 8-car trains and has encountered contrast problems with CCTV at outdoor platforms.

Passenger Emergency Stop Provisions

To reduce the likelihood of emergency evacuation between stations, a number of systems are converting their passenger emergency stop systems to passenger emergency alert systems. With such systems, passengers cannot stop trains between stations. Systems contemplating conversion to one-person operation should review their policies relative to passenger emergency stop provisions on trains. It may be desirable to provide a:

- Passenger emergency stop system that will permit the train to proceed to the next station before stopping.
- Passenger emergency stop system that is only active at or in close proximity to station platforms.
- Passenger emergency alert system (intercom and/or buzzer) rather than passenger emergency stop system.
- Passenger emergency stop system that activates service or emergency brakes that can be overridden or revoked by the train operator from his operating position.

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APPENDIX A

STATISTICAL DATA FOR SYSTEMS VISITED

During this study, 16 heavy-rail rapid-transit systems in the United States and Europe were visited to solicit their opinion and obtain data and information relative to the issues, problems, and problem solutions associated with conversion of heavy-rail rapid-transit systems to one-person operation of multiple-unit trains. Those systems are:

1. *U.S. Two-Person Operation Systems*
   - CTA—Chicago Transit Authority (Chicago)
   - GCRTA—Greater Cleveland Regional Transit Authority (Cleveland) Red Line
   - MBTA—Massachusetts Bay Transportation Authority (Boston) Blue, Orange, and Red Lines

NYCTA—New York City Transit Authority (New York City)

PATH—Port Authority Trans-Hudson Corporation (New York City)

SEPTA—Southeastern Pennsylvania Transportation Authority (Philadelphia) Broad Street and Market-Frankford Lines

2. *U.S. One-Person Operation Systems*

BART—Bay Area Rapid Transit District (San Francisco)

MARTA—Metropolitan Atlanta Rapid Transit Authority (Atlanta)

PATCO—Port Authority Transit Corporation (Philadelphia)

WMATA—Washington Metropolitan Transit Authority (Washington, D.C.)

3. *European Metro Systems*

BVG—Berliner Vekehrs - Betriebe (Berlin, West Germany) U-Bahn

HHA—Hamburger Hochbahn A. G. (Hamburg, West Germany) U-Bahn

LT—London Transport Executive (London, England) Underground

RATP—Regie Autonome des Transports Parisiens (Paris, France) Metro

SL—AB Storstockholms Lokaltrafik (Stockholm, Sweden) T-Banan

VAL—Vehicle Light Automatic (Lille, France).

Table A-1 presents selected descriptive, operating, and employee statistics for each of these systems.

Table A-1. Selected descriptive, operating, and employee statistics heavy-rail, rapid-transit systems visited.

System	Location	Year Service Began	Train Crew Size	Maximum Present Train Length, feet	Manned Stations	Route Length, miles	Stations, number	Cars, number	Annual Car Miles, millions	Annual Passengers, millions	Annual Passenger Miles, millions	Employees, number	Police Department, number[a]
CTA	Chicago	1892	2[b]	384	Yes[d]	95.0	142	1,200	49.0	150	1,090	4,039	287
GCRTA	Cleveland	1955	2[b]	300	Yes[d]	19.0	18	101	3.0	8	80	418	36
MBTA	Boston	1894	2	280	Yes	42.0	46	354	13.5	96	270	1,481	105
NYCTA	New York	1904	2	600	Yes	232.0	465	6,183	278.0	1,030	5,450	27,552	3,600
PATH	N.Y.-New Jersey	1908	2	357	Unmanned	13.8	13	290	9.8	53	258	1,046	87
SEPTA	Philadelphia	1907	2&1[c]	340	Yes[d]	24.1	51	388	15.6	80	460	1,876	133
BART	San Francisco	1972	1	700	Yes	71.5	34	436	29.5	56	736	1,931	138
MARTA	Atlanta	1979	1	600	Unmanned	25.0	25	120	6.0	48	--	511	96
PATCO	Phil.-Lindenwold	1969	1	408	Unmanned	14.2	13	121	4.2	11	93	315	25
WMATA	Washington	1976	1	600	Yes	42.3	47	298	17.3	84	400	2,653	321
BVG	Berlin	1902	1	340	Yes	62.6	111	1,016	45.8	346	--	5,000	45
HHA	Hamburg	1912	1	387	Yes	55.6	80	850	32.6	188	632	--	35
LT	London	1863	2&1[c]	424	Yes	247.0	272	3,875	205.1	563	2,700	23,600	300
RATP	Paris	1900	1	300	Yes	119.3	360	3,500	--	1,100	--	11,200	350
SL	Stockholm	1950	1	492	Yes	64.6	94	888	39.9	223	--	--	140
VAL	Lille	1983	Unmanned	172	Unmanned	8.5	18	76	--	25	--	170	40

(a) Not included in Employee count.

(b) CTA and GCRTA operate some single-car trains with one crew member.

(c) SEPTA and London have recently or are in the process of converting some lines or services from two- to one-person operation of multiple-unit trains.

(d) CTA, GCRTA, and SEPTA operate some stations unmanned in off peak hours.

Note: Data are from numerous sources including direct communication with personnel at systems visited, system brochures, and published documents. Data are for heavy-rail rapid-transit lines only as defined in this appendix and are compiled from 1981 through 1984 sources.

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