Chapter 1

FINDINGS

Definitions[2]

Train Control—the process by which the movement of rail rapid transit vehicles is regulated for the purposes of safety and efficiency. The system that accomplishes train control performs four types of functions:

Train Protection-assurance that trains maintain a safe following distance, that overspeed is prevented, and that conflicting movements at junctions, crossings, and switches are precluded;

Train Operation--control of train movements—specifically regulating speed, stopping at stations, and opening and closing doors;

Train Supervision-assignment of routes, dispatch of trains, and maintaining or adjusting schedule;

Communication—interchange of command and status information among trains, wayside elements, stations, and central control.

Automatic Train Control (ATC)—the use of machines to perform all or most of the functions of train control in the normal mode of operation. Human involvement in ATC systems consists mainly of monitoring and back-up. The acronyms ATP (automatic train protection), ATO (automatic train operation), and ATS (automatic train supervision) denote particular groups of automated functions.

Rail Rapid Transit-an electrified rail system operating in urban areas on exclusive rights-of-way. Rail rapid transit is considered here to exclude commuter railroad systems and light rail systems, although the technology of train control is similar for all three.

[2] A glossary of train control terms is presented in Appendix D. Explanation of the fundamentals of train control and descriptions of typical train control equipment are contained in Chapter 3.

INTRODUCTION

In requesting this assessment, the Senate Committee on Appropriations posed four major questions concerning automatic train control technology:

1. What is the state of ATC technology?
z. What application is made of ATC technology in existing and planned rail rapid transit systems?
3. Are the testing programs and methods for ATC systems adequate?
4. How is the level of automation selected, and what tradeoffs are considered?

These questions served initially as the basic framework for organizing and directing the assessment. As the study progressed, it became apparent that each issue raised by the requesting committee had many ramifications and that there were corollary questions that had to be addressed. Therefore, the study was expanded in scope and detail to consider not just the matters enumerated in the letter of request but, more generally, the entire field of automation technology in train control systems. The findings of this broader investigation dealing with policy, planning, and operational concerns are summarized below. Supporting data and discussion are presented in chapters 5, 6, and 7. At the conclusion of this chapter is a brief interpretation of the findings that responds directly and specifically to the issues raised by the Senate Committee on Appropriations.

POLICY AND INSTITUTIONAL FACTORS

The development of rail rapid transit systems is influenced by three major pieces of Federal legislation: the Urban Mass Transportation Act of 1964, the Department of Transportation Act of 1966, and the National Mass Transportation Assistance Act of 1974. Transit system planning, development, and (since 1975) operation are supported by these acts and the annual appropriations that flow from them. The administrative agency for Federal support of transit development programs is the Urban Mass Transportation Administration (UMTA). Neither the existing legislation nor the administrative programs of UMTA deal specifically with ATC systems as such. Research in train control technology and development of individual ATC systems are carried on within a more general program of activities relating to rail rapid transit as a whole.

Findings pertaining to policy and institutional considerations are as follows:

Regulation

At the Federal level, regulation of rail rapid transit (and ATC specifically) is of recent origin, Regulation is vested in two agencies—UMTA and the Federal Railway Administration (FRA), whose respective areas of responsibility are not clearly defined, It is not surprising, therefore, that so far neither agency has done much to regulate or standardize ATC systems. However, FRA has recently indicated the intention to start rulemaking procedures concerning ATP and the safety aspects of door operation.

The National Transportation Safety Board (NTSB) is charged with overseeing rail rapid transit safety and with accident investigation. Implementation of NTSB recommendations is left to either FRA or UMTA or is handled as a matter of voluntary compliance by transit agencies.

Most regulation of rail rapid transit (and ATC specifically) is carried out either by State public utility commissions or by the transit agencies themselves as self-regulating bodies. The concern of State regulatory bodies is primarily safety, Little attention is given to operational concerns, such as reliability, maintainability, level of service, efficiency, and economics.

Advantages in increased Federal regulation, particularly in the areas of safety assurance and equipment standardization, must be weighed carefully against the disadvantages of preempting State and local authority and raising possible barriers to innovation.

Institutions

Decisions relating to ATC design and development are influenced by several nongovernmental institutions or groups. The strongest influence is that of the local planning or operating authorities, which rely heavily on engineering and technical consultants employed to assist in planning and development activities,

Other institutions and groups acting to shape the course of ATC design and development are equip-

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ment manufacturers, industry associations, and organized labor. Except in isolated cases, only the equipment manufacturers exercise any significant influence during the ATC design and development process. The influence of labor is usually brought to bear only as a new system is being readied for operation and a contract with the union local is being negotiated.

Community planners, public-interest groups, and the public at large play only a small role in the design and development of ATC systems. There is some evidence that these groups may be assuming more influence, not in technical concerns, but in the area of establishing priorities and general service characteristics.

Policy Impacts

Federal policy from 1964 to 1974 may have tended to encourage the development of new, technologically advanced transit systems employing highly automated forms of train control. In part, this policy appears to have stemmed from the expectation that automation would lead to increased productivity-a benefit that, in the case of ATC, has not been substantiated. This policy may be in the process of change as a result of the National Mass Transportation Assistance Act of 1974.[3]

Transit agencies, when planning new systems, have also been inclined to favor technological advancement-partly as a reflection of how they perceived Federal Government policy and partly because they or their consultants believed advanced technology was necessary to win public support for development and patronage of the system.

This situation has created a tendency for system designers to turn to highly automated forms of train control as a means of offering improved performance and service. The superiority of automated over manual methods of train control is not certain, however, except in the area of train protection (ATP).

The public appears to attach greater importance to dependability of service and personal security than to ATC system performance characteristics. The cost of automatic train control has negligible influence on the public primarily because it is small in relation to the total cost of the system (typically between 2 and 5 percent). A question on train control system automation, as a specific issue, has never been submitted to the public for decision by referendum.

THE PLANNING, DEVELOPMENT, AND TESTING PROCESS

The evolution of a rail rapid transit system from concept to start of revenue service may span 10 to 20 years. The process has three major phases: planning, engineering development, and testing, Research and development to support design are conducted throughout but tend to be concentrated in the middle phase, where detail design and development takes place. The design and engineering of the train control system, while generally concurrent with the development cycle of the whole transit system, is usually neither the pacing item nor a dominant technical concern.

Findings concerning the planning, development, and testing process for ATC systems are as follows:

Planning

Formulation of the ATC design concept and determination of the extent to which the system will be automated are greatly influenced by nontechnical factors, notably social and political concerns, the prevailing attitude of decisionmakers and system designers toward technological innovation, and reaction to the recent experience of other transit agencies.

Cost-benefit analyses conducted during the system design process seldom, if ever, include evaluation of alternative ATC concepts and different levels of automation, perhaps because ATC represents only 2 to 5 percent of total system cost and benefits are not easily quantified.

The comparative operational costs of alternative levels of ATC are given very little consideration.

Engineering Development

ATC procurement specifications vary greatly in terms of approach and level of detail; but the trend in newer systems is toward a more quantitative form of specification, particularly for reliability, maintainability, and availability requirements.

[3] The OTA study, An Assessment *of* Community *Planning for* Urban Mass Transit, February 1976 (Report Nos. OTA–T–16 through OTA–T–27), deals extensively with the history and current trends of planning and public policy in mass transit.

There is a recognized need in the transit industry for improvement in the writing of specifications and in setting realistic requirements for reliability, maintainability, and availability.

In new transit systems, the ATC equipment is procured as a package through a single contractor. In existing transit systems, ATC equipment is often acquired piecemeal as additions or improvements to equipment already in operation.

In most instances, contractor selection is based on low bid from technically qualified competitors. This procedure is usually required by State law or local ordinance. Noncompetitive procurement is seldom used, except for a follow-on to an earlier contract.

Testing

Testing is conducted at several points in the development process, generally for one of three purposes: qualification and validation of component and subsystem design, assurance of conformity to specification, and demonstration of total system performance prior to final acceptance and start of revenue service.

Performance verification and acceptance testing of train control systems, coming near the end of the development cycle, may be slighted because of pressure to open the system for service. The preoperational test program may be either abbreviated or deferred until after the start of revenue service and often extends into the first year of operation or longer.

The quality and extent of assurance and acceptance testing vary greatly among transit systems, largely as a function of the qualifications and experience of the organization managing the development of the system. There is a need for more detailed and comprehensive test plans, more clearly defined criteria and methods of measurement, more rigorous procedures for conducting tests, and more complete documentation of test findings.

Research and Development

There are no test tracks and experimental facilities for carrying out R&D activities related to train control, except at individual transit systems or at a manufacturer's plant as part of a product development program. The Pueblo facility does not permit detailed study of ATC design and engineering problems in a realistic operational setting.

The state of ATC technology is such that the greatest R&D need is refinement of existing designs and not development of innovative or more advanced technology. Yet, relatively little R&D effort is concentrated on presently known operational problems, such as reliability, maintainability, and availability, performance testing methods and standards, and development of a uniform data base on ATC system performance.

OPERATIONAL EXPERIENCE

No rail rapid transit system now operating or under development in the United States has a train control system that is completely automatic. All employ some mixture of manual and automatic control, and all have at least one person on board the train to carry out some control functions. Only two rail rapid transit systems operating in the United States at the end of 1975—BART in San Francisco and the PATCO Lindenwold Line in Philadelphia and suburban New Jersey-are automated to the extent that the trainman has little or no direct part in operating the train. In all other U.S. rail rapid transit systems, trains are operated manually, with automation employed only for train protection and some supervisory functions. New transit systems being planned and developed in Washington, Baltimore, and Atlanta show the influence of BART and PATCO with respect to both the level of automation and the use of advanced ATC technology.

A survey of the operational experience with ATC leads to the following findings:

Safety

Automatic Train Protection (ATP) systems are superior to manual methods of preventing collisions and derailments, principally because ATP safeguards against human error and inattention. The use of ATP is becoming universal in the U.S. transit industry.

Automatic Train Operation (ATO) offers no clear safety advantages over manual modes of operation.

Automatic Train Supervision (ATS) does not produce additional safety benefits beyond those attainable with traditional manual or machine-aided forms of supervision carried out by dispatchers, towermen, and line supervisors.

In conjunction with increased automation, the size of the train crew is often reduced to one. One-man operation does not appear to have an adverse effect on passenger security from crime or on protection of equipment from vandalism.

Performance

Under normal operating conditions, the ride quality provided by ATO is comparable to that of manually operated trains. The principal advantage of ATO is that it eliminates variation due to the individual operator's skill and provides a ride of more uniform quality. Manual operation is considered to be the more effective mode of control under certain unfavorable weather and track conditions.

Systems with ATC have experienced problems of schedule adherence during the start-up period, but it is not certain how much of this is a result of train control automation and how much is due to other factors such as the complexity and reliability of other new items of transit system equipment.

Reliability of ATC equipment has been a major operational problem. Failure rates for both wayside and carborne components have been higher than anticipated, but not greater than those of other transit system components of comparable complexity and sophistication (e.g., communications equipment, propulsion motors, electrical systems, air-conditioning equipment, and door-operating mechanisms).

Maintenance of ATC equipment, like other items of new technology, has been troublesome because of longer repair time, more complicated troubleshooting procedures, higher levels of skill required of maintenance personnel, and the lack of people with these skills. A shortage of spare parts. has also hindered maintenance efforts.

On the whole, however, ATC equipment contributes proportionally no more to vehicle downtime or service interruptions than other transit system components. The problem is that ATC, like any other new element added to a transit system, has an effect that is cumulative and tends to lower the general reliability of the system.

costs

ATC typically accounts for 2 to 5 percent of the capital cost of rail rapid transit; the variation is almost directly proportional to the level of automation,

Because of the reduction in train crew that often accompanies ATO and because of the centralization and consolidation of train supervisors brought about by ATS, automated systems are somewhat cheaper to operate than manual systems. These savings are offset, however, by the increased labor costs of maintaining ATC equipment. In comparison with manual systems, the maintenance force for ATC systems is larger, skill requirements and the corresponding salary levels are higher, training of technicians must be more extensive and hence costly, and repairs are more frequent and take longer. The combined operation and maintenance costs of automated systems are about the same as those of manual systems, There is no evidence that ATC systems lead to more efficient train operation or to any significant change in energy consumption. Vehicle weight, route layout, and propulsion system characteristics are far more dominant factors in energy use than automated or manual operation.

Human Factors

Monotony and light responsibility make it difficult for operators of highly automated systems to maintain vigilance. There has also been a tendency for ATC system designers, notably in BART, to make insufficient use of the human operator to back up or enhance automatic system performance. The designers of systems now under development are seeking to integrate the operator more effectively into the ATC system, to give man a more meaningful set of responsibilities, and to make automatic equipment more amenable to human intervention.

For maintenance employees and train supervision personnel, ATC systems impose new and higher skill qualifications and more demanding performance requirements.

The effect of automation on passengers is negligible, except insofar as it maybe more difficult for them to obtain information with fewer transit system employees on the train.

ASSESSMENT OF ATC TECHNOLOGY

The following is an analysis and interpretation of the findings in light of the concerns expressed in the letter of request from the Senate Committee on Appropriations.[4]

[4]This letter and related correspondence are contained in appendix I.

The State of ATC Technology

ATC technology is a mature technology insofar as train protection (ATP) and train operation (ATO) functions are concerned. The major difficulties encountered in these areas have arisen from the application of new, unproven techniques that represent departures from conventional train control system engineering. Train supervision (ATS), except for certain well-established dispatching and routing techniques, is the least advanced area of ATC technology. Research and development efforts are now underway to devise computer programs and control techniques to permit comprehensive, real-time supervision and direction of train movement by automated methods.

Operational experience indicates that automatic train protection (ATP) enhances the safety of a transit system because it safeguards against collisions and derailments more effectively than manual and procedural methods. Performance and service characteristics of ATC systems are as good as, and perhaps better than, manual systems once the somewhat lengthier period of debugging and system shakedown has passed. Reliability and maintenance continue to be serious problems for systems using higher levels of ATC and probably account for an increase in operating costs that outweighs any manpower savings achieved through automation.

Application of ATC Technology in New Systems

In assessing the application of technology in new transit systems, a distinction must be made between train protection (ATP) and train operation and supervision (ATO and ATS). All systems-old, new, and planned—rely on automatic devices to accomplish train protection functions. Two forms of technology are employed. One uses wayside signals with trip stops, the other uses cab signals. The trend in the transit industry today is toward cab signaling, which is the newer technology, because it offers somewhat more flexible protection than wayside signaling, and because it provides an evolutionary path to partially or fully automated train operation. The new systems in Washington, Atlanta, and Baltimore and the recent extensions to existing systems (e.g., the CTA Dan Ryan extension and the MBTA Red Line) all employ cab signaling and the more automated forms of operation derived from it.

With regard to ATO and ATS, the new systems under development and those in the planning stages will employ more advanced technology and higher levels of automation than those built and put in operation before 1969. With some exceptions, such as door closure or train starting, train operation in the new systems will be entirely automatic, but supervised by an on-board operator who will intervene in case of emergency or unusual conditions, Central control functions (ATS) will be assisted, or in some cases accomplished entirely, by automatic devices. Thus, train operation and supervision in new systems will resemble those of PATCO and BART, and the general trend is toward extensive use of ATO and ATS.

There is almost no research and development now in progress to produce new ATC technology for rail rapid transit. The development work currently underway is devoted primarily to refinement of existing techniques and their application in particular localities. The transit industry has watched closely the experience of BART and PATCO. The results of the PATCO approach, which made use of conventional technology, have been compared to those of BART, where innovative technology and more extensive automation were employed. The designers of the Washington, Atlanta, and Baltimore systems have generally opted for a middle ground with regard to automation and have followed a cautious approach to new technology, inclining more toward PATCO than BART. Particular care has been given to the role of the human operator in backing up or augmenting the performance of ATO. and ATS equipment. The experience of BART and PATCO has also led the newer systems to give careful attention to the reliability and maintainability of ATC equipment and to developing strategies for assuring system performance in adverse conditions or degraded modes of operation. It is certain that WMATA, the next of the new systems to be put in operation, will be scrutinized by the transit industry for other lessons to be learned.

The Testing Process

As train control systems have grown more complex, the testing process has been burdened in two ways: there are more elements that must be tested from prototype through final installation, and there are more interrelationships that must be checked out before the system can be placed in revenue service. The problem of testing is especially difficult in a new transit system, where all the equipment is new and untried and where all the parts need to be tested before initiating passenger operations.

The experience of BART has underscored both the basic need for testing and the importance of giving careful attention to test methods, procedures, and documentation of results. The application of new technology on a large scale in a transit system involves more than just development and installation of equipment; it also involves the application of management techniques to integrate the parts of the system and to test and evaluate the performance of these parts, singly and in the system as a whole. Perhaps the greatest shortcoming in the area of testing in the transit industry today is the lack of a satisfactory method for comprehensive evaluation of transit system performance, under realistic conditions, in the preoperational period, This is often compounded by political, social, and economic pressures to open the system for revenue service as soon as possible, with the result that the test program may be truncated or deferred until after opening day and the full certification of the system may not come until months or years later.

The managers of the new systems under development appear to be mindful of these problems. Improved testing methods and procedures are being devised. More complete programs of preoperational testing, even at the expense of postponing revenue service, are being planned. An incremental approach to testing and full system operation has been adopted, with each step building on the results of earlier phases and with testing timed to the pace of system growth. Methods of testing in revenue service, both in regular hours of operation and during nighttime periods, are being explored. More attention is being given to documentation of test plans and results.

Selecting the Level of Automation

There is no single procedure for selecting the type of train control system and the level of automation. Individual transit authorities follow rules of their own devising. Some rely on the advice of consultants; others draw upon the experience of their own technical staff, Only a few generalizations can be made about the nature of this process.

The decisionmaking process does not appear to be deeply analytical. Criteria of choice are not often defined, the rules of choice are not made explicit, and the analysis of alternatives is not documented except in a fragmentary fashion by internal memoranda and working papers.

Established transit systems, where extensions or new lines are being planned, give considerable attention to the engineering characteristics of the proposed train control system, primarily to assure that new ATC equipment can be successfully integrated with other parts of the existing system, In this case, engineering criteria serve primarily as constraints upon the type of ATC equipment that can be used or upon the level of automation to be selected. The established rules and procedures of the transit system act in much the same way to limit the choice of design alternatives. But there is no evidence to indicate that the planning and design process includes studies directed specifically at determining an optimum train control system or at balancing train control system design features against the service and operating characteristics of other equipment or of the transit system as a whole.

In new transit systems, the process for selecting a train control system is governed even less by system engineering and trade-off studies. The level of automation appears to be selected, more or less arbitrarily, early in the system development cycle. It is treated more as a postulate or a design goal than as a point for analysis and trade-off. It also appears that characteristics of the proposed ATC system are derived more from general, nontechnical decisions about the nature of the whole system and its desired service features (speed, headways, station spacing, etc.) than from technical considerations of control system design or automation technology.

During the planning process, the development and acquisition costs of ATC equipment are considered, but formal cost-benefit studies specific to the ATC system are usually not conducted. ATC costs-and, to a lesser extent, benefits—are sometimes factored into cost-benefit studies for the transit system as a whole; but the objective of these studies is to analyze other aspects of the system or to justify a more general choice regarding transit mode, system size, or route structure. The operational costs of ATC are seldom included in system cost-benefit studies, and they are not subjected to separate analysis to determine their potential influence on the life-cycle costs of the transit system,