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NATIONAL TRANSPORTATION SAFETY BOARD

# SPECIAL STUDY OF RAIL RAPID TRANSIT SAFETY

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591

REPORT NUMBER: NTSB-RSS-71-1

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16. Abstract The report explores the status of safety of rail rapid transit systems, identifies areas of risk, and recommends means for improving safety in new and existing systems. The report is based on the experiences, and practices of new and old transit systems located in the Chicago, New York and Philadelphia metropolitan areas. The subjects covered include accident reporting, accident experience, emergency preparedness, transit car design, signal systems, vehicular excursion, joint corridor usage, fixed plant design, maintenance procedures, safety efforts, operating rules, employee training, research, and the exchange of data. The report also explores the role of the Urban Mass Transportation Administration in the development of safe transit systems and urges the use of System Safety techniques for the development of safe rail rapid transit systems. The report recommends that system safety plans submitted by applicants be one basic requirement for obtaining funding assistance through the Urban Mass Transportation Assistance Act.

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WASHINGTON, D.C. 20591
SPECIAL STUDY

Adopted: June 16, 1971

# RAIL RAPID TRANSIT SAFETY

## I. INTRODUCTION

This *"Special Study of Rail Rapid Transit Safety"*[1] was initiated by the National Transportation Safety Board with the following objectives:

(1) To determine the status of safety in rail rapid transit systems.
(2) To identify overall hazards and approaches to safety control in rail rapid transit so that safety considerations can be incorporated into the design and construction of new systems, or the modernization of existing systems.
(3) To explore the existing function of the Urban Mass Transportation Administration (UMTA) and other Federal agencies in the control of safety in new or upgraded rail rapid transit systems, partially or wholly financed by Federal funds.

With the passage of the Urban Mass Transportation Act of 1970, the rising concern for ecology, and the increased traffic problems in the Nation's urban areas through past dependence upon the automobile, a renaissance of the rail rapid transit industry appears imminent. Throughout its history, the rail rapid transit industry has maintained a reputation as a safe method of urban transportation. In recent years, this reputation has been tarnished by many publicized accidents involving the older systems. In spite of these, the fact clearly has remained that a rail rapid transit passenger, on board a train, has not been subjected to the incidence of fatality associated with automobile travel in urban areas. This past record indicates the potential safety of new systems upon expansion, and the possibility that an increased proportion of rail rapid transit travel will mean fewer total transportation fatalities.

The Safety Board believes that new or modernized rail rapid transit systems, when developed, should use all current technology and experiences of the past to ensure optimum practical safety. Innovations should not unknowingly compromise previous levels of safety, nor should known mistakes of the past be repeated. These goals cannot be reached, in general, without building positive mechanisms to achieve them. It is with this intent that this report is presented.

The study involved a review of available accident statistics for the years 1968 and 1969, an examination of operating and safety procedures of the rail rapid transit industry, a cursory inspection of rail rapid transit properties, and an examination of the policies of Federal agencies as related to the regulation and/or funding of the industry.

[1] "Rail rapid transit" as used in this report refers to systems, excluding streetcars, that utilize single or multiple-unit trains supported by two-rail tracks for the intra-urban and suburban transportation of passengers. As utilized herein, "rail rapid transit" includes subway, elevated and surface trains operated by public or private transit authorities, and commuter trains operated by railway companies.

The acquisition of statistical data was deemed most significant to identify accident rates, accident causes, and accident contributory conditions. Unfortunately, the available data was of such a nature that complete meaningful analyses and conclusions generally were not possible.

The areas covered in this report are very broad in scope, encompassing most operations of the industry. There are undoubtedly other items of concern, and there are also many illustrations of efficient and safe operation which are not mentioned.

It was not possible to review all rail rapid transit operations in this country, but the rail rapid transit operations in Chicago, New York City, and Philadelphia were selected as being representative of the operations in the United States. The systems selected included subway, elevated, and surface systems operated by transit authorities and private railroad companies. The systems represented rail rapid transit in the various stages from 66 years of age to modern systems just recently completed and opened for use.

The Safety Board appreciates the cooperation and courtesy it received from the following:

Chicago and Northwestern Railway Company
Illinois Central Railroad Company
Long Island Railroad Company
Metropolitan Transportation Authority of New York State
New York City Transit Authority
Penn Central Company
Port Authority Trans-Hudson Corporation
Port Authority Transit Corporation of Pennsylvania and New Jersey
Reading Company
Southeastern Pennsylvania Transportation Authority

The scope of the study was intended to include the Chicago Transit Authority's (CTA) operation, which includes new equipment and newly constructed track. Observations were made only by riding CTA's trains, since the CTA initially declined to respond to the Safety Board's request for accident statistics and briefings on the approaches to safety in their transit operations. Accident data were offered near the completion of the study, but it was too late to be included. This occurrence is significant to the study in the context of the proposed UMTA mission to attain safety as a condition of funding assistance, which will be analyzed in the study.

## II. THE RAIL RAPID TRANSIT INDUSTRY

### A. Accidents

#### 1. Accident Reporting

The objectives of this study included the determination of the status of safety within the rail rapid transit industry. It is accepted generally that commuting by rail rapid transit is relatively safe; however, there are no statistical data available to confirm this. There is no single private or governmental agency to which all of the rail rapid transit industry reports regular, comprehensive, accident data. It appeared that each company observed for this study systematically compiles accident data; however, the methods vary considerably.

Railroads and a few of the interstate transit authorities have been required to report accidents to the Federal Railroad Administration (FRA). The reporting methods are consistent with those required for conventional freight and passenger traffic with no breakdown for commuter operations. This often results in all employee and passenger accidents being grouped together without separate identification for commuter operations or the activities associated with such operations. The FRA requirements classify a passenger as "persons who are on, or boarding, or alighting from, railroad cars for the purpose of travel." Accidents occurring in stations or on platforms not involving railroad operations are normally not reported, but even the reporting methods on this accident classification are inconsistent.

Within the transit industry, the American Transit Association (ATA) compiles operating accident rates for only motor coach, trolley coach, and street car operations; rail rapid transit is not included. There has been a recent effort by the transit members of the National Safety Council to establish a uniform system of compiling and exchanging accident information for rail rapid transit, but to date there has not been a uniform acceptance of procedures. As the result, each system has established its own procedures for compiling accident statistics, using different categories and entirely different bases for definition of an accident or incident. On at least one system, fatalities were not compiled systematically. On other systems, torn apparel received the same relative classification as a fractured arm or leg. The net result is a complete lack of data that can be used as an overall comparison of safety for operations within the industry, or between transportation modes.

The lack of complete accident data is significant. The absence of comparable fatality or injury rates precludes a complete analysis of sources of injury and the factors which make the difference between injury and fatality. Effective corrective measures are possible only when all causal factors of accidents and of resulting injuries are identified.

Accidents within the transit industry generally have been broken down into three main categories, namely, (1) on-board accidents, including boarding and alighting, (2) train accidents, and (3) station accidents. Efforts to relate these accidents to a base comparable for the industry have utilized a comparison between the number of accidents and the total number of passengers-carried for on-board and also for station accidents. For train accidents, a base of total car-miles operated has been used. Both total passengers-carried and car-miles operated have shortcomings for use as comparable bases. Car-miles tend to favor either the long-haul carrier or the carrier, that, for operating reasons, runs a large proportion of near-empty trains during non-peak hours. Passengers-carried does not reflect the time or distance of accident exposure. Passenger-miles would appear to offer the best comparative base, both for injuries and fatalities, within the industry or for comparative purposes with other transportation modes. Unfortunately, the means for compiling this information are not available because of different fare structures.

For the purpose of this report, a base of accidents per passenger-carried was used to indicate accident trends. As previously indicated, there are many inconsistencies in the present use of any base and the information was treated only as a guide to identify the areas of highest accident, or incident, potential. This is a very limited basis, not at all consistent with the social importance of rail rapid transit safety.

## 2. Accident Experience

### a. *Station Accidents*

The highest accident frequency in the industry has occurred in the "station accident" category. The accidents include falls on stairs, escalators, platforms, corridors and other passageways, injuries incurred when passing through turnstiles, injuries incurred by being assaulted or pushed by other persons, and those injuries resulting from fire, smoke, and other miscellaneous causes. Most of the station accidents involve stairways or escalators. Because of the nature of this exposure, it might be assumed that the injuries incurred generally are not severe, although there are no records to support this contention.

The facilities involved in most station accidents are those that receive substantial architectural consideration during construction or modernization programs. However, hazards do exist, sometimes because the aesthetic viewpoint dominates the safety considerations, or because safety factors are not understood. Open stairwells provide the "tightropes" and barrier-free escalator handholds provide the "slides" to challenge the acrobatic capabilities of children. Street entrances are often sloping ramps that can resemble ski slides during snowy winter weather. Subdued lighting in entrances is encountered by patrons wearing sun glasses. The wall and ceiling surfaces provided quickly lose their reflectivity upon exposure to rail and wheel dust, and the graffiti experts.

Revenue consideration also is involved with station accidents. Concessions and vending machines may not be included in original plans and often are located so that they interrupt the flow of pedestrian traffic. Litter consisting of ice cream or candy wrappers can provide the "banana peel" impetus to initiate a fall. Billboards interrupt traffic flow and divert the patron's attention from directional signs, the pedestrian flow, and approaching trains. Although these hazards can be observed, their related effect to accident frequency is unknown, as accidents generally are not systematically studied.

Station accidents perhaps are the most difficult to control. It is unknown to what degree architects systematically review hazards or whether their assumptions are subverted by changes at a later date. However, an analysis of rapid transit stations from a safety viewpoint would indicate many advantages in a systematic approach during the conceptual stage. The design of stairways and escalators, the placement of vending machines and other equipment, the design and installation of signs, the design and location of entrances and exits, the location of public address systems, and many other items might all be markedly influenced by a systematic approach, in which hazards are identified and solutions recorded.

b. *Collision with Persons*

The available records indicate that the highest fatality incidents for the rail rapid transit systems studied have resulted from persons on the roadway (track), including trespassers, and those who have fallen or jumped from station platforms and are subsequently struck by a train. An undefined proportion of the fatalities includes persons who are not considered by the industry as rail rapid transit passengers, some even being suicides. The classification of these persons was inconsistent. As in the case of automobile pedestrian accidents, however, the incident of occurrence cannot be divorced from the particular mode, and ultimately the death or injury of any party reverts to the accountability of the mode, or modes, involved. This is particularly important because it is technically feasible to greatly minimize the number of fatalities that occur on the roadway, irrespective of the particular person's intentions. It is significant to note that the highest incidence of fatality in rail rapid transit does not occur to the passenger on board the train.

The train-person involvement has been categorized normally into those incidents involving rail rapid transit patrons and those involving trespassers. Employees and the public, who are neither patrons nor trespassers, are also involved, but to a lesser extent. Because the train-person collision has resulted in the largest number of fatalities associated with the rail rapid transit, it is logical to assume that it would receive the greatest attention for preventative measures within the industry. However, this was observed to be not the case.

Those statistics available indicate that the train-person collisions involving patrons occur in the proximity of station platforms and are most frequent at car-floor height platforms. Station accidents involving a fall to the track also are experienced at these locations. In spite of this experience, the trend in the industry is toward open, car-floor height platforms to enhance faster discharge and receipt of passengers. In urban areas, there are very few other places where the public is allowed to congregate immediately adjacent to an unprotected opening which is 4 feet deep, and carries the threat of death at the bottom. For example, we do not expect elevator patrons to stand next to an open pit awaiting the arrival of an elevator. Rail rapid transit passengers, however, jostle each other daily on open, high-level platforms, and to complicate the hazard, they lean over the unprotected opening to identify approaching trains or satisfy idle curiosity.

In most older systems, if patrons were pushed, fell, or jumped onto the track, the possibility of being hit by a train was minimized to some extent by the fact that express tracks were separated horizontally from car-floor height platforms. New systems are not using this concept and nonstop trains now approach and pass crowded platforms at speeds up to 75 miles per hour. Platforms now are located in the median strips of crowded expressways where noise and other distractions are prevalent. Audible or visible warning systems are not provided and, therefore, the likelihood of a train approaching without detection has increased markedly. Aesthetic considerations in some new underground stations have dictated that the track zone be sparsely lighted so that unpleasant views of the track are not highlighted. This inevitably reduces the awareness of hazard. When an accident does occur, a person who has fallen on the track is in the shadows and less likely to be seen.

The Safety Board previously has called attention to the hazard of car-floor height platform design without separation[2] and has suggested that consideration be given to the separation of passengers from tracks and moving trains by a barrier wall with doors. The major problems in accomplishing this involve train braking, and ingress and egress to the transit cars. Modern cars are capable now of stopping within a few feet of designated locations, under normal operating conditions. Refinement is necessary only to accommodate the abnormal situation. Electrically operated sliding doors are provided on transit cars, and these doors are a source of injury and train delay. The interface of transit car doors with station doors would minimize these occurrences, accommodate station passenger flow, and thus improve efficiency as well as safety. Millions of passengers currently are accommodated in a similar manner daily by one of the safest known methods of transportation–the elevator. A thorough analysis of the situation may reveal other benefits not primarily safety related. Structural, architectural, heating, cooling, noise control, cleaning, and rubbish disposal considerations all could be markedly influenced by the enclosure of passengers away from the track.

Train-person collisions also are experienced at stations constructed at grade with low, rail-height platforms. According to transit employees, the majority of these accidents involve patrons taking shortcuts across tracks that either have no intertrack barriers or where the barriers are inadequate to discourage this practice. Unfortunately, many at-grade stations have highway grade crossings at one end or the other of the station platform that make the erection of totally effective intertrack barriers impossible. The installation of crossing gates at many of these locations would protect not only the automotive traffic, but also pedestrian traffic, whether patrons or the general public. Audible train warning signals also may be effective in minimizing train-person accidents at station platforms.

The positive control of train-person accidents involving trespassers only may be accomplished by effective securement of the right-of-way through fencing or grade separation. Unfortunately, even these means have not always deterred children from their fascination with the railroad tracks. As demonstrated by the Interstate Highway System, however, controlled fencing does deter general pedestrian traffic.

The Federal Railroad Safety Act of 1970 directed that a study be made of measures to protect pedestrians in densely populated areas adjacent to railroad rights-of-way. The recommendations derived from this study should be applicable to transit companies as well as to railroads.

c. *Highway Grade Crossings*

The railroad-highway grade crossing is recognized universally as a hazard, not only to the automotive public, but also to occupants of the train. Grade-crossing collisions have resulted in derailment of heavy diesel locomotives and overturning of railroad equipment. Rail rapid transit equipment generally is lighter than railroad equipment and, thus, more susceptible to this occurrence. In addition, all locomotive engineers or motormen have particular respect for tank trucks which may be carrying gasoline or other hazardous material. The consequence of a collision of a rail rapid transit train with a

[2] National Transportation Safety Board Report RSS-70-1–Study of Washington Metropolitan Area Transit Authority's Safety Procedures For the Proposed Metro System.

hazardous material truck could be a disaster of major scale. As an example, in December 1966, a rail commuter car struck a tank truck carrying fuel oil at a highway grade crossing in Everett, Massachusetts, and 11 of the 28 passengers and two of the three crewmembers perished in the resulting fire.[3] Grade crossings are not compatible with rail rapid transit operations.

The establishment of adequate automatic grade-crossing protection or the separation of grades should receive priority consideration by all authorities involved. In the past, many grade-crossing protection decisions have been based on the exposure of the respective vehicles involved without regard for the commodity carried. In rail rapid transit, the commodity that is being transported consists of people. Their lives warrant special consideration.

Although the ultimate elimination of highway grade crossings from rail rapid transit operations is desirable, this goal cannot be achieved immediately. Therefore, it is most important that the hazards be assessed and the risks minimized to the greatest extent possible. This responsibility, of course, extends not only to the rail rapid transit industry, but also to Federal, State, and local governmental bodies. Grade-crossing protection or elimination programs have proceeded with an unorganized approach, dependent in many instances not on the hazards involved, but on whether the road involved is classified as a "Federal Aid" route. Motor vehicle laws involving grade crossings are ignored in many instances by the general public and not enforced by local authorities. Zoning laws and other local ordinances are explicit in their requirements to insure compliance with environmental and other social values. These regulations also generally prohibit sight obstructions at street intersections. It is rare, however, to find any regulations affecting the type of construction or landscaping in the vicinity of a highway-rail grade crossing.

In other instances, local ordinances may affect grade-crossing safety adversely. Ordinances frequently are instituted to prohibit the whistling of trains at grade crossings. A motorized highway emergency vehicle is required by law, however, to sound a siren when proceeding through an intersection and demanding the right-of-way in a manner similar to a train.

Although grade-crossing accidents are recognized as a continuing hazard within the rail rapid transit industry, in many instances the design of the car equipment does not recognize this factor. Transit cars originally designed for operation in a closed system are operated over highway grade crossings where they can strike other vehicles. The protection provided by a heavy, sloped, metal pilot, deemed necessary in the railroad industry to minimize the chance of derailment upon hitting an obstruction, is not provided consistently on rail rapid transit cars. In some instances, passengers are seated at the front of the car immediately adjacent to a large windshield and exposed to all collision hazards. Passenger and motorman collision protection in rail rapid transit appears to be less than that provided in other modes. There have been no actual tests of transit vehicle crash protection, which are necessary if factors are to be fully assessed.

d. *On-board Accidents*

Injuries that have occurred in the on-board category have resulted from boarding and alighting; falls on board, including falls between cars; vandalism; fire or smoke; and to a lesser extent, derailments or collisions. Original design has been a factor in all of these incidents.

Boarding and alighting accidents have involved the car doors, the space between the platform and the car, open spaces between cars, the car steps, and the platform surface. As a general rule, car-floor height platforms were observed more in inner-city type operations, with low, rail-height platforms more often being provided at locations handling suburban service. The limited data available from the systems studied again indicate a lower accident frequency at low platforms than at the car-floor

[3] NTSB Railroad-Highway Accident Report—Boston and Maine Corporation Single Diesel-Powered Passenger Car 563 Collision with Oxbow Company Tank Truck at Second Street Railroad-Highway Grade Crossing—Everett, Massachusetts, December 28, 1966.

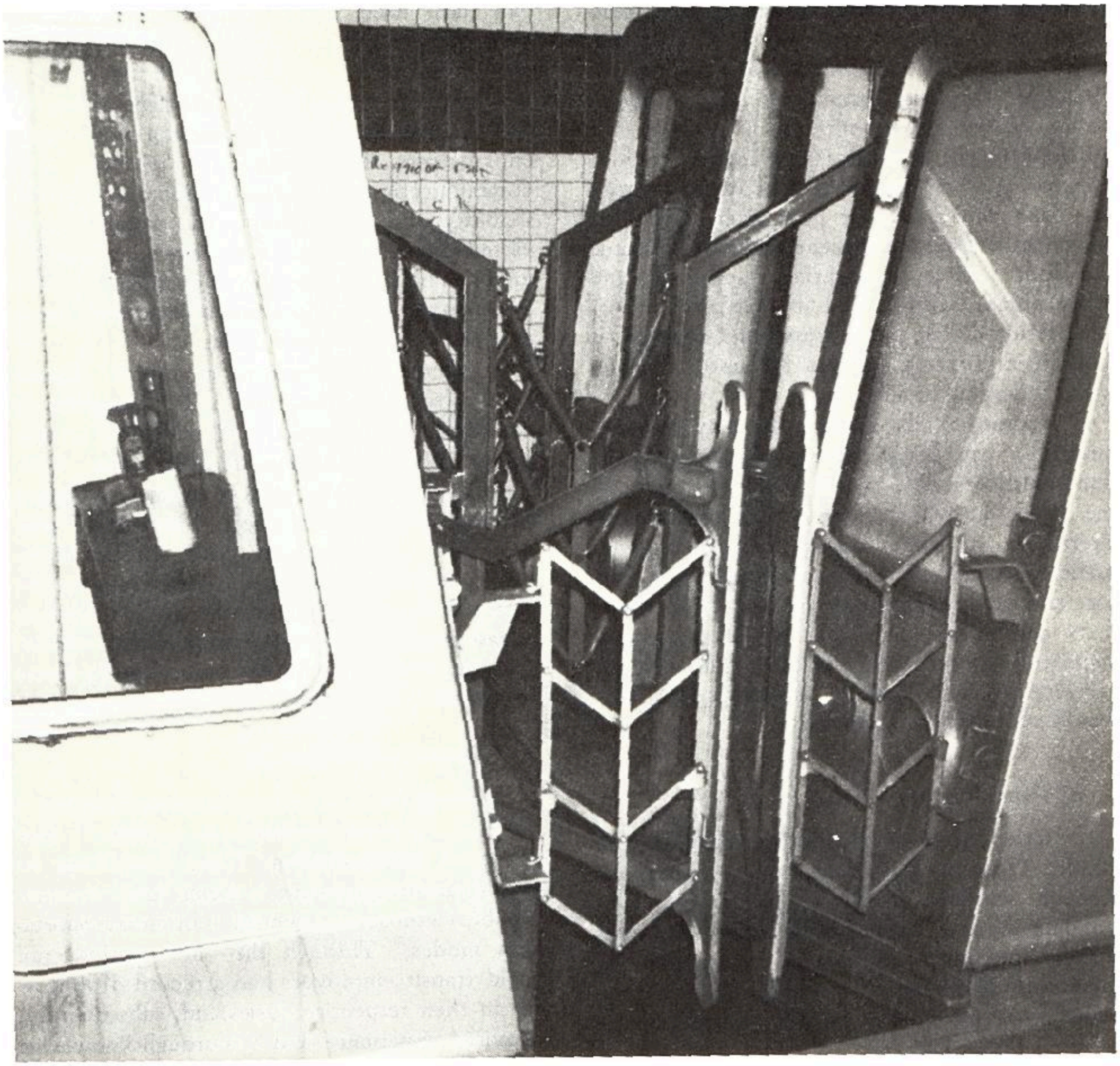

**Figure 1. Intercar passageway protection showing gates that were added after the completion of initial car design.**

height platforms on a passenger-carried base. This suggests that the car steps and the manually controlled doors, associated with cars used exclusively at low platforms, are less hazardous than the electrically operated car doors and the spaces between cars and platforms, synonymous with car-floor height transit service.

Specific hazards that have resulted in on-board accidents were observed. New car equipment has been purchased without protection provided for the space between cars. This has resulted in falls to the track while boarding or alighting at car-floor height platforms as well as on-board falls. The results are likely to be fatal. Protection has been provided with intercar chains as well as retractable gates, both of which appear to be only a partial solution and an afterthought. Figure 1 illustrates one such example.

On several systems, car-floor height platforms are intermixed with those of low, rail-height design. To accommodate boarding and discharge, this has necessitated car vestibules having trapdoors in the down position for car-floor height platforms, and in the up position for the low platforms. The trapdoor itself has been the source of numerous injuries. If crewmembers are not present, passengers assume the door raising or lowering operations, and many pinched fingers and abraded arms or legs have resulted. The raised trapdoor frequently is secured improperly and can fall upon a patron who is boarding or alighting.

Passenger falls aboard cars may be minimized by car design changes. Minimizing the number of standees would eliminate many of the falls, but plant capacity may prevent this alternative in some areas. The provision of sufficient handholds designed for passenger comfort and convenience may be a solution where seats cannot be provided for all passengers. Improved car suspension systems and smoother accelerating and braking characteristics also would minimize on-board falls.

e. *Vandalism and Assault*

Other causes of injuries are vandalism and assault. These actions involve on-board accidents through window stoning or even rifle fire. Vandalism also has caused train accidents through placement of objects on the track or improper alignment of switches. Station accidents may be caused by the destruction of handrails, the breakage of lights, and the removal of signs. Assault may involve shoving persons down stairs, off platforms, or robbery. The rail rapid transit industry is being forced into protecting the safety of its passengers by means that were formerly associated only with correctional institutions, such as steel cages and fences, unbreakable plastic windows, security police, and police dog protection.

Unfortunate as this may be, protection against vandalism and assault is now a necessary consideration in most rail rapid transit design and in maintenance work. The effects of vandalism have been minimized, however, by the reduction of car window size, the use of the aforementioned unbreakable plastic in car windows, the securement of the right-of-way by fencing, the use of pilot protection on the front ends of cars, the installation of two-way radio communications, increased station and platform visibility and illumination, the installation of closed-circuit television surveillance, and enclosure or shielding of the sides of overhead highway or street bridges to prevent objects from being dropped onto trains and tracks.

Sometimes measures to protect against assault, such as controlled exits, separation of passengers from tracks, and television surveillance, also assist safety in other areas. Conversely, measures to protect against vandalism also can detract from safety. Unbreakable windows may be a case in point. In the aforementioned Everett, Massachusetts, accident, the police attempted to break the car windows to release passengers from the smoke-filled interior. The car windows could not be broken by blows from police clubs, and 11 passengers succumbed.

3. Emergency Preparedness

Through most of rail rapid transit history, it has had a general reputation as a relatively safe mode of transportation. There have been no major catastrophes with resulting fatalities comparable to those experienced in other transportation modes.[4] Through this same period, rail rapid transit employees had a record of longevity in their respective duties and, subsequently, acquired experience and a thorough knowledge of the system, equipment, and their expected duties. This education was obtained through assimilation and on-the-job training. During this period, the system and equipment retained their inherent safety either through maintenance or because the span of their expected service life had not expired. As the result, there were few emergencies, and those that occurred were often

[4](a) The steamship "Sultana" exploded on the Mississippi River in April 1865, resulting in 1,547 fatalities; (b) A two-plane collision over New York City in December 1960 claimed 134 lives. ("Accident Facts")—1970 Edition—The National Safety Council.)

handled adequately by the experienced personnel.

On some of the older systems, a marked change has occurred in recent years. Employee turnover has become a distinct problem. Some properties have deteriorated in condition through age and lack of maintenance. Passengers who once would suffer a rare inconvenience are now frustrated by recurring delays, and as a result have reduced confidence in the system. Incidents, originally of minor consequence, now are becoming emergencies with the potential for a serious outcome. A thorough program of emergency preparedness has been understood to be essential to all rail rapid transit operations.

The first priority in any emergency preparedness program is the education of the employees in what to expect, corrective measures to take, and emergency facilities available. Vague safety rules indicating "Safety is of the first importance in the discharge of duty" and "In case of doubt, the safe course must be taken" are well meaning, but practically valueless to employees when they are confronted with an emergency situation. Rule books generally contain a wealth of information on how to report an accident, but do not describe with any specificity the desired course of action at an accident site. In many instances, emergency procedures are difficult to locate as they are buried in the rule book text. The training of employees in emergency preparedness is necessary to ensure that emergencies are safely and efficiently handled. Some systems have instituted formal training programs in emergency training, based on present-day technology, but this is not universal.

The orientation of passengers in emergency procedures has proven effective in the airline industry. To a limited extent, passenger information services have been provided on some of the transit systems included in this study and the results have been encouraging. A passenger who knows what to expect, and when, will be less likely to panic. In this respect, two-way radios and public address systems have, in some instances, proven valuable in keeping the public informed and in preventing exposure to the inherent danger of passing trains and electrified third rails.

Training in rail rapid transit emergency procedures extends also to the professionals outside of the industry. The local police, ambulance, firefighting and other emergency personnel must be versed on access routes, hazards involved, communication procedures, etc. As an example, in 1969 a New York City fireman was electrocuted while fighting a third-rail fire on an adjacent track. The railroad was unaware of the presence of the firemen and, therefore, had de-energized only the track involved. Pre-established procedures might have averted the fatality.

Emergency preparedness, by definition, involves not only procedures, but also the design and maintenance of the property. The benefits of preconceived emergency exits, emergency appliances, adequate communications, and system warning devices have been proven in every transportation mode. A further discussion of this subject is presented in Section B.4.–Fixed Plant Design.

Emergency preparedness is affected by the maintenance aspect of rail rapid transit to the extent that in a period of austerity, the maintenance of emergency appliances and devices is often the first to suffer. This is also the time when accident-preventing general maintenance suffers. Thus, in the period when these facilities may be required the most, they often are found missing or inoperable.

## B. Opportunities in a Total Safe-System Approach

The status of safety has been analyzed thus far in this study in terms of accidents or injuries and correction of the problems that have caused them to prevent recurrence. This approach is being questioned increasingly, however, when major new design decisions and important new construction projects are ahead. It is possible to analyze a system in the original design stage, identify all the hazards, decide which hazards are to be removed, and thus, within economic constraints, remove the hazards before they are

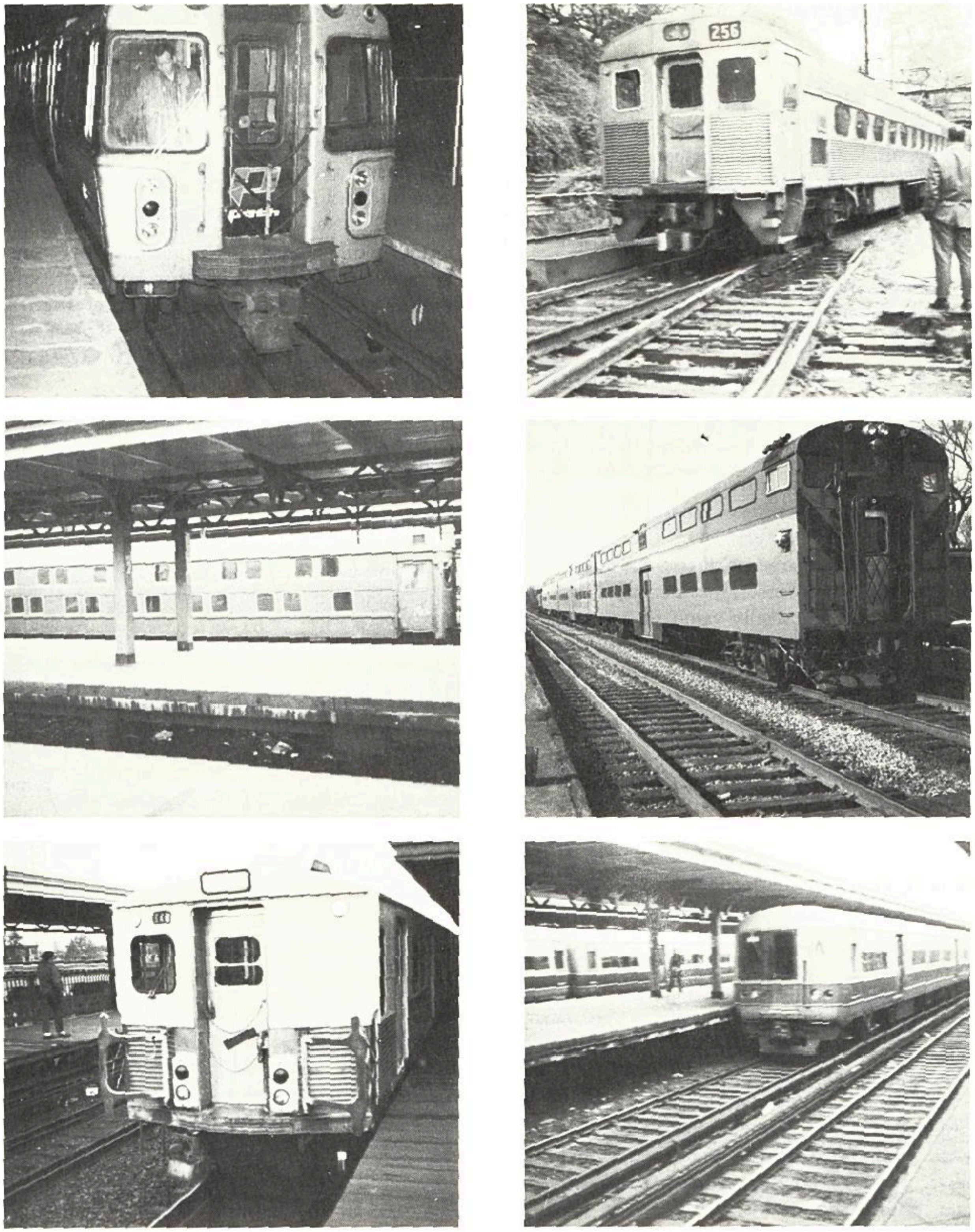


Figure 2. Various designs of rail rapid transit car windows.

cast in concrete or riveted in place, and before accidents occur. Such methods are especially useful in preventing new and unexpected hazards where the reasons for a past good record are not understood in detail. Such surprises have occurred in the rail car building industry recently, notably in the unexpected low reliability of cars furnished for a high-speed demonstration project and in some system design errors in cars for a rail rapid transit system, which might have allowed passengers to fall to the tracks.

The forthcoming expansion of transit funds for new systems will allow advanced predictive approaches an opportunity to produce lasting results if they can be applied from the first stages.

In this section, the status of safety is reviewed in terms beyond the occurrence of accidents, including problems in visible hazards, design deficiencies or errors, and shortages of systematic organization. Possible predictive methods of safety control are explained in relation to the problems found. The purpose is to provide examples of the results of the absence of predictive analytical approaches in determining the design safety.

## 1. Transit Car Design

There are many varying opinions of optimum design safety features of rail rapid transit cars, but none of the designs observed have been backed up by formal analyses of hazards and recorded decisions related to the analyses. For an example, transit car window design has run the gamut during the past 50 years from large to small. Figure 2 shows the different ideas regarding rail rapid transit car windows currently in use. The differences clearly illustrate the lack of an analytical approach, able to produce a justifiable decision as to window size and strength.

Factors to be considered in window design may conflict with each other. Almost all passengers are subjected to the danger of being injured by an object thrown at a window. Vandalism of this type is a serious problem on all of the properties reviewed. The type of window panes has been a factor in the severity of injury resulting from thrown objects. Recently, the Penn Central decided that all future replacements of window panes would be made with a tough plastic material which will withstand the impact of a thrown rock. Various types of glass panes are also used.

The photograph in Figure 3 illustrates the lack of protection afforded the operator and front-seat passengers on a transit car in the Chicago area. This particular car is subject to being struck by an object thrown by vandals, as well as to exposure to grade-crossing and expressway traffic.

In addition to the susceptibility to vandalism, large windows may also reduce the structural capability of the car to withstand impact stresses, and failures of large windows have been a factor in passenger injury and fatality in overturn accidents.[5] Ability to resist crash deformation and the exceptional structural strength of conventional railroad passenger cars have been demonstrated in past railroad accidents. However, if the window itself fails, allowing passengers to be spilled out on the ground, this structure is wasted.

There appears to have been no systematic evaluation of the factors affecting window design. For example, the value of affording passengers, many of whom are standing, a view of the outside environment day after day has not been determined.

The standard solution to this type of problem is to determine all the hazards to which passengers are exposed from environment and accidents during the operational lifetime, and then to make specific decisions in relation to the hazards. This would include the interface of the car with the impact of vandalism; normal operation conditions and abnormal conditions, such as derailment; normal and deferred maintenance conditions; and other parts of the basic and parent systems. Once these environments are identified in written and recorded form, the

[5]National Transportation Safety Board Report RAR-71-1—Derailment of Richmond, Fredericksburg and Potomac Railroad Company Train No. 10/76 at Franconia, Virginia, on January 27, 1970.


**Figure 3. An illustration of the lack of crash protection provided passengers and motormen of equipment operating over highway grade-crossings and adjacent to expressway traffic.**

environments can be classified and the frequency of exposure to various hazards determined. Alternate designs could then be considered and a decision made on a basis that can be documented, based upon the relative degree and frequency of risks.

Many other car features are dissimilar between systems of like environments. The above approach may be used effectively to determine the most safe and practical design. Further car characteristics vary in importance and include, in part, such areas as exit location and design concepts, passenger seating arrangement, accommodation of hand-luggage, motorman separation from the passengers, intra-car passageways and barriers, rear-end illumination, front-end derailment and collision protection, braking systems, and car-wheel metallurgy.

While new rail rapid transit cars exhibit differences in design criteria among systems, new cars also present innovations which are valuable in furthering passenger safety. These innovations include such items as two-way radios or train-phones, complete public address systems, speedometers, improved ventilating systems, and emergency car lighting. The installation of devices such as these has been based upon accident experience, rather than advance analyses which would disclose hazards.

## 2. Signal Systems

The traffic-control system of rail rapid transit is a necessity for efficiency of operations. A highly reliable system also is necessary for safety, as a train must stay with the route established for it by the traffic control system. The engineer does not have the option of taking evasive action at the last moment when an accident appears imminent. At the same time, the controlled pathway is a valuable safety measure because, in most cases, it prevents intrusion of foreign accident-causing objects.

Signal systems for rail rapid transit include automatic block, interlocked traffic control, automatic train stop, train control, cab signals, fully automated systems, manual block, and various combinations of all of these. The visual signals are wayside and cab signals, or both. The types of train control include full automatic train control, inductive train stop, and trip stop. This study did not develop any data indicating that attempts have been made to standardize or optimize signal or train control systems. Federal regulations in Title 49 CFR 236 permit the use of all types with various restrictions.

Although railroad and transit accident statistics indicate that specific failures of signal systems do not cause a significant number of accidents, the limited scope of signal systems and train controls definitely causes accidents attributed to other sources. Man-failure is a significant accident source, and most accidents involving signals have been attributed to man-failure rather than to any aspect of signalling. The potential for accidents due to man-failure varies with the degree of control exerted by different signal systems in use in railroad and transit operations. Efforts to modernize and extend existing lines which perpetuate existing signal systems may fail to exploit opportunities to reduce so-called "man-failure," even though the "man" is retained.

New rail rapid transit lines are being designed with the capability of a fully automated signal and train control system. These new systems can be subjected to rigorous reliability and safety analyses to assure that the system will operate safely for a prolonged period of time under varied maintenance conditions. The analysis of a computerized system using digital data inputs may necessitate the application of sophisticated safety analysis techniques, such as a fault tree analysis, to evaluate the safety of the system when operated either automatically or manually. In fact, system simulation may be necessary if the control system is highly complex and a complete safety analysis is to be performed.

## 3. Vehicular Excursion and Joint Corridors

Experience shows that injuries in derailments can be minimized if the derailed cars can be kept upright and in line with the track. Although derailments have not been a frequent occurrence in the rail rapid transit industry, all of the systems reviewed have recognized this accident possibility by the installation of various devices to prevent vehicular excursion after derailment. The criteria for the types and locations of these devices varied widely, not only between the different systems, but also between different locations on the same system.

The most common device used to minimize the possibility of transit vehicle excursion is the inner guardrail laid between the running rails. Tunnel walls, tunnel columns, bridge girders, and bridge spacer timber also sometimes accomplish this objective in accidents, even though they are not so designed. New transit systems have been observed without these controls and thus, unsuspected degradation of safety may have occurred.

Rail rapid transit construction recently has shown increased usage of the joint-corridor concept, sharing right-of-way with existing or new highways or railroads because of economic and social considerations. This concept has many proponents. The joint corridor concept can be satisfactorily developed where the relative safety of the overall system, or the safety of each independent mode, is either preserved or improved. The accomplishment of this, however, depends upon a systematic evaluation of the hazards of each mode independently and the

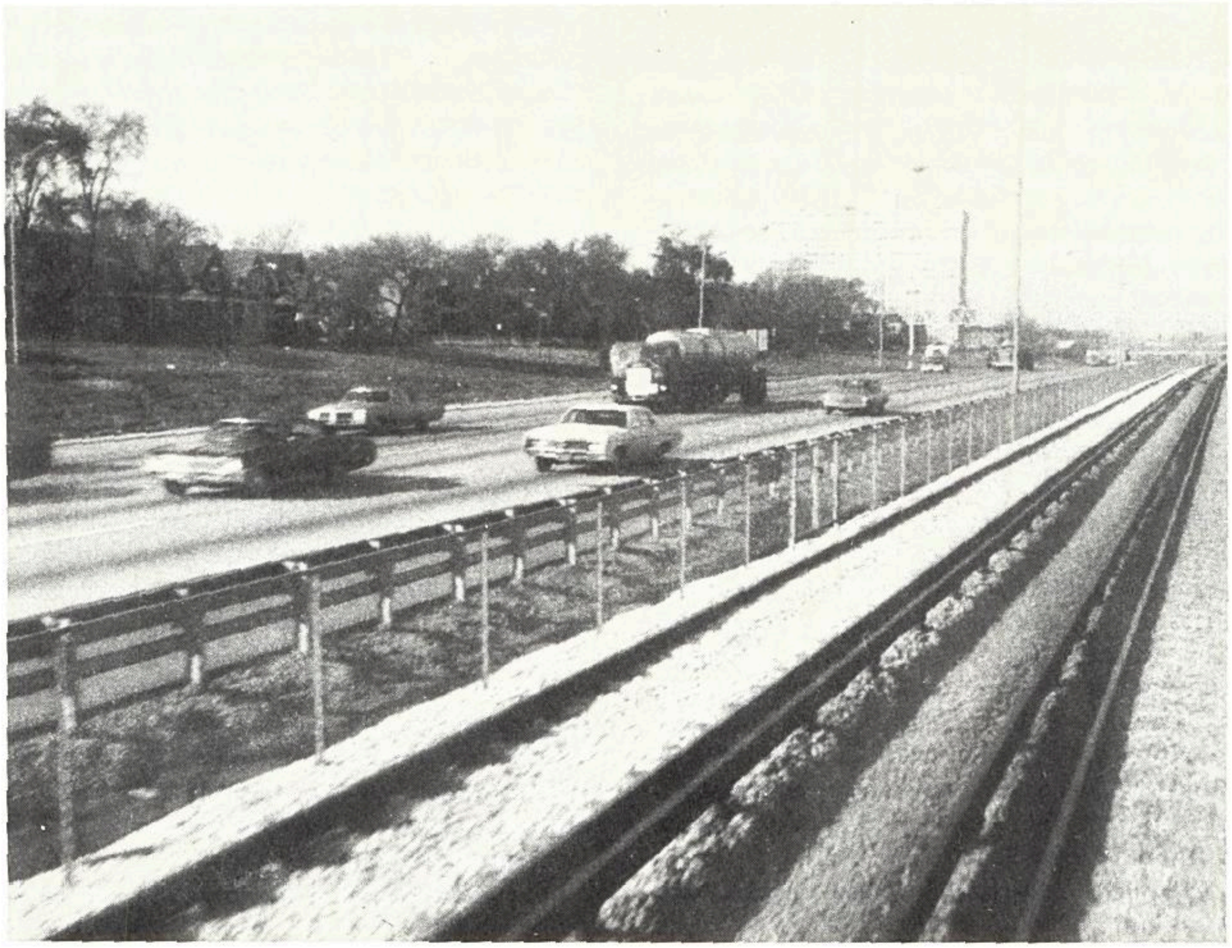

**Figure 4. An example of guardrail protection provided to minimize highway vehicle intrusion upon rail rapid transit right-of-way.**

hazards arising in the interface between the modes. This evaluation will result in assessing the risks involved with joint corridor usage and balancing it, in judgment, against the costs of either maintaining a high level of safety for each mode, or of separating the modes. These evaluations are necessary in the planning stage, rather than after the system has been constructed, and alternative courses of action either no longer exist or are too expensive to implement.

Vehicular excursion is not the only safety consideration involved with the joint corridor accommodation of rail transit vehicles, but it does present the most apparent potential for a serious accident. This has been recognized to some degree where rail rapid transit shares highway rights-of-way, and to a lesser extent where conventional railroad operations are immediately adjacent to transit systems.

To minimize the possibility of outside highway vehicular violation of rail rapid transit rights-of-way, various methods have been used, including horizontal or vertical separation of grades, and W-beam and boxbeam guardrails. Figure 4 shows one such example. Highway experience indicates that these types of guardrails may not maintain their structural integrity under all impacts of motor vehicle traffic.

On adjacent railroad tracks handling freight trains, there were various devices to detect dragging equipment, overhanging loads, broken wheels, and hotboxes, in addition to inner guardrails. These devices also minimize the chance for the violation of the rail rapid transit thoroughfare, but the frequency of usage was minimal, or nonexistent on some systems.

The installation of all of these various appurtenances indicates the awareness of the problem; however, there was no indication that systems analyses have been performed to define fully the interfaces and to determine the extent of the problem together with the optimum solution. The Safety Board previously pointed out the potential for serious accidents in joint highway or railroad corridors involving rail rapid transit.[6] The observations made during this study have reinforced this position.

### 4. Fixed Plant Design

Almost invariably rail rapid transit tunnel design shows lack of foresight in providing for emergency situations. Minor smoke or fire incidents in tunnels have turned into panic situations, resulting in injuries and loss of life. Department of Transportation, Federal Railroad Administration, Railroad Accident Investigation Report No. 4150 deals with five tunnel accidents in 1969 which are examples of how minor accidents have alarming and fatal results when design and procedures do not contemplate the possible circumstances of emergencies.

Safety walks originally intended for use in the evacuation of passengers have been used to accommodate signal and electrical facilities. Walks also are used for the storage of other maintenance-of-way material. Emergency exits have been located immediately adjacent to turnouts, presenting an obstacle course of running rails, guardrails, and electrically energized third rails. Exits also are widely spaced and difficult to identify under normal circumstances, both inside and outside of the tunnels. Exits are narrow and steep, easily negotiated by a spry young man, but another matter for the not-so-spry elderly as shown in Figure 5. In some instances, intunnel lighting is practically nonexistent and ventilation is dependent upon natural drafts. The fact that the hazards of tunnel evacuation have not been removed is stated in existing rule books which indicate that detraining of passengers within tunnels must be accomplished only as a last resort.

The reduction of hazards in emergency tunnel evacuation can be accomplished in existing tunnels. Upgrading programs have been undertaken on some systems and the results are markedly apparent, although no one system has accomplished all of the desirable steps. Steps that have been taken to improve conditions include the installation of additional lighting, signs, emergency telephones, fire alarms, power disconnects, handrails, and fire extinguishers. Portable emergency equipment, such as detraining ladders, loudspeakers, stretchers, lanterns, air-paks, first-aid kits, and between-rail walkways has been located strategically, either in tunnels, at stations, or carried on car equipment. The installation of emergency evacuation equipment has minimized operational delays and loss of life in some cases. There is a strong possibility that reactions of passengers to awkard evacuation fixes their attitudes toward the transportation system in general.

Closely related to the tunnel design problem is that of the third rail. The third rail conducts the electric power for the operation of most rail rapid transit cars. In most instances, the third rail carries 600 volts of direct-current power and is located immediately adjacent to the track. The third rail has been a source of electrical burns and fatalities for passengers, trespassers, and employees even though in both of the two basic designs, under-running and over-running, some protection against electrical shock generally has been provided. This protection consists of either a timber or plastic coverboard. An exception to this practice was noted on one system where the third rail was unprotected on both old and new lines. It is difficult to establish the reason for this practice, and the Safety Board was not provided a review of the system's accident experience. The inconsistency in third-rail protection warrants further investigation. The presence of any third rail underscores the necessity for right-of-way fencing and grade crossing elimination.

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[6] National Transportation Safety Board Report RSS-70-1, Study of Washington Metropolitan Area Transit Authority's Safety Procedures for the Proposed Metro System.


Figure 5. A rail rapid transit emergency exit.

The third rail has been a contributing or causal factor in other rail rapid transit accidents, particularly in recent years. The third rail and the associated connecting appurtenances on the transit car have initiated fire and smoke incidents. Generally, the fire and smoke injuries have been minor, but serious injuries and fatalities have been incurred in subsequent detraining and evacuation. The chance for injury or death in these occurrences can be minimized through more extensive emergency procedures. The cause of the incidents, however, originates in the basic design of the third rail and the connecting appurtenances. The state of maintenance also is a contributing factor. For entirely new systems, this design may warrant a complete reappraisal. On existing systems, the need for adequate maintenance is emphasized.

The initiation of a safety analysis of all fixed plant facilities prior to the completion of design would identify hazardous conditions and point out high-risk areas, as well as providing safety criteria as an input to the design. The application of these analyses and criteria would assure that hazards are not designed and built into the system. These analyses should consider passenger handling under normal operations, peak load conditions, and the emergency operations of escape and rescue, and include the total passenger-system interface.

## 5. Maintenance Procedures

With the exception of the new systems or those recently modernized, all rail rapid transit systems observed showed evidence of a low level of maintenance. The systems had not retained the degree of inherent safety that they possessed upon completion of construction.

The degree to which safety has been sacrificed is related somewhat to the degree of deferred maintenance on the property involved. In some instances, the safety margin has been reduced so that continued safe operation is dependent upon the judgment of one responsible supervisor or workman. Should this individual's services be lost through attrition or his duties substantially expanded to encompass other areas, the judgment factors are lost with him, or weighed against the needs at the other areas. In any case, it is poor practice to allow a system to be dependent upon judgment unchecked by any objective criteria.

During this period of deferred maintenance, most rail rapid transit systems have depended on the revenue from fares for maintenance funds. The establishment of relative fare levels has been dependent upon many considerations other than maintenance requirements. This procedure has resulted in decay of the original level of safety of the system.

## 6. Operating Procedures

### a. *Safety Efforts*

All of the transit systems visited have established safety departments whose functions involve the safety of employees and passengers. In addition, safety was generally deemed the first responsibility of all employees, and each supervisor was charged with the responsibility for safe operations within his jurisdiction. For the most part, however, the management emphasis on safety was directed toward employee activities. Extensive statistics on employee accidents are related to various inner-organizational departments, previous months' and years' safety records, and general industrial averages were readily available, and in most instances, displayed at safety department and management offices. While this is certainly desirable and commendable, it also served to highlight the lack of similar information as it pertained to passenger safety. It would be completely unfair to imply that there was a lack of concern for passenger safety within the rail rapid transit industry, as there were concentrated efforts to investigate accidents and improve the lot of the passenger. However, this effort did not appear to receive the same visible emphasis that was placed on employee safety.

The position of safety experts in system development was generally without influence. With one exception, safety department personnel were given the function only of "closing the barn door after the horse was stolen." They did not have the opportunity to review a new facility during design and construction. The safety input for new or modernized facilities historically has been accomplished by the design engineers and/or operating and maintenance personnel. While these groups surely have safety in mind, they are influenced also by architectural, operating, maintenance, and economic considerations.

Safety reviews of new or modernized facilities normally do not take place during the conceptual stage, and there may be no formal safety review documents. As the result, it has not been unusual for new facilities to be modified after they are operational and the first accident occurs, at a cost that is greatly in excess of that which would have been required to remove the hazard in the initial design.

In some systems, safety department personnel are organizationally located within the operating department, while in other systems they are in the personnel department. Their influence in implementing safety recommendations apparently did not depend upon their organizational location, except on properties that appeared to be undermaintained. At these locations, the specific safety recommendations seemed to be weighed against other maintenance priorities by the responsible maintenance supervisor. The maintenance supervisor necessarily tempered individual safety recommendations against the overall safety requirements of his responsibility. The net result was a fragmented approach resulting in "firefighting," without elimination of the combustible material. While the organizational structures of the various systems provided safety expertise, the available capabilities were not exploited fully. The lack of adequate maintenance funds had affected directly the safety of the system.

b. *Operating Rules*

The safety of a rail rapid transit system, which is not completely automated, is dependent upon the operating rules of the system and employee compliance with these rules. As the result, most systems have an extensive set of rules. For railroad operations, the rules generally are tailored to follow the Association of American Railroad's "Standard Code of Operating Rules." However, consistency was not found in the operating rules of different transit authorities; the number and type of rules varied considerably between properties. Inconsistency is not a fault where systems and control methods are different, but the accident experience with particular rules apparently had not been shared within the industry.

Rule compliance is essential to safety. Enforcement is generally the responsibility of individual supervisors, although various electronic or mechanical devices also are used. The economic condition of the system involved is reflected frequently in the attitude of supervisors toward enforcement of rules and operating procedures. Rule observance frequently necessitates a time or material expenditure that may be deferred by economic constraints imposed upon individual supervisors. Noncompliance with a minor rule or procedure may be followed by a general decay in rule observance attitudes. The supervisors' attitude also may be reflected by the fact that a well-maintained property requires less supervisory attention, and therefore, more time is available to apply to rule enforcement procedures by the individual supervisors. It is also possible that the condition of the property has an effect upon the individual employee's attitude toward doing a good job, consistent with the rules.

The most extensive rule compliance program observed was probably the source of a very good comparative accident record. On this particular property, the efficiency testing of employees was not left entirely to the individual supervisor's discretion. Testing procedures and intervals were a programmed requirement for all supervisors. Rule violations were noted, and action was taken for all violations—not just for those deemed important by the individual supervisor at the particular time. The result appeared to be an efficient and relatively safe operation, appreciated equally by passengers and employees. Similar results from concentrated rule compliance programs were noted on other systems.

Examples of inconsistent, ambiguous, or unenforceable rules were noted in all rail rapid transit operations. It appears that in some instances, the rules were established to determine fault for disciplinary purposes after an accident.

The one rule that has been involved in a great many rear-end collisions, and which is used in one form or another on all rail rapid transit systems, concerns the method of passing restricting and/or stop signals. Almost universally in the transportation industry, a red signal in the past meant "stop." In the rail rapid transit industry, as well as in conventional railroad operations, the red signal now indicates "stop and stay," "stop and proceed," or "proceed at restricted speed." In most cases, except for a "stop and stay" signal, a red signal may be passed if the train proceeds at restricted speed. "The Standard Code of Operating Rules" of the Association of American Railroads defines restricted speed as:

> "Proceed prepared to stop short of train, obstruction, or switch not properly lined looking out for broken rail, not exceeding ** miles per hour. (**Carrier may insert suitable speed up to 20 miles per hour.)"

Some of the transit companies use terms other than "restricted"; however, the basic definition and intent is the same. Passing a restricting signal puts all of the responsibility for detection and judgment to avoid a collision or broken rail on the engineer or motorman. Many rail rapid transit cars have no speedometers; therefore, the tendency to move the train as rapidly as possible is a complicating factor. The engineer or motorman has no objective guide to what is necessary. In some cases, a red signal may be passed with authority from certain "responsible persons," but the rules do not define who the "responsible persons" are.

The placement of different connotations on a danger signal minimizes the respect for that signal. Railroad accident records indicate that many train collisions occur when trains are advanced beyond a red signal.[7] In many instances, the rules involved are inconsistent or ambiguous.

A solution to this problem may involve a safety analysis of the system's operating procedures or rules. The purpose of this analysis should be to learn whether hazardous operations are described fully, and whether cautions and warnings are identifiable, clear, concise statement indicating what is expected. It is possible, by systematic methods, not only to detect rules that are vague, but also to find rules which are inoperable or ineffective under a variety of predictable environments or operating conditions.

c. *Employee Training*

Training programs for employees of rail rapid transit systems show considerable variance among systems. At one extreme, employee training consists of furnishing the new employee a rule book, with instructions to learn its contents. As the result of this program, qualification is dependent upon memory, with little employee understanding as to applicability or interpretation and no written examination. This type of training appears to be disappearing from most systems. Most rail rapid transit systems are adopting formal methods of training for new employees and requiring requalification at periodic intervals. The training that is provided is oriented primarily to the engineer or motorman, with some systems also providing training programs for other personnel.

One rail rapid transit system has introduced a compulsory 3-week training program for new employees. This course primarily was classroom oriented, with time equally distributed between train operation, rule understanding, and customer relations. Included in the curriculum were emergency procedures. Examination of enrollees was accomplished at the conclusion of

[7] Federal Railroad Administration Accident Bulletin No. 138 "Summary and Analysis of Accidents of Railroads in the United States"—Calendar Year 1969.

the course, and assumption of duties was not permitted until the exam had been passed. Although this program had been introduced recently, and included limited facilities and curriculum length, all those interviewed were enthusiastic about the results.

Accidents involving negligence and rule violation reflect upon the safety efforts, the operating rules, and the training programs of the company involved. A finding that an employee is responsible for an accident frequently indicts the organization itself. For example, the Safety Board's accident report,[8] concerning a head-on collision between two New York Central trains, determined the probable cause as man-failure. However, contributing causal factors were determined to be the failure of the railroad to establish explicit boundaries of authority, explicit operating rules, and procedures to insure that its personnel were instructed in and complied with such rules.

### C. Research and Exchange of Data

The fact that questions of design safety are unresolved, and the existence of inconsistent accident reporting procedures previously referred to, indicates that there has been a lack of communication within the rail rapid transit industry. Although differences in opinion are healthy and desirable, it is essential that the experience gained in resolving these differences be used. Until recent years, there has been no unified effort within the industry to compile the results of these experiences. Consequently, each individual company has compiled its own specifications for various property items. Smaller companies, without in-house capabilities or experience, have been dependent upon suppliers for technical information. The economic cost of these practices has been high and the result has affected safety adversely.

For example, one system recently acquired a fleet of new cars. This organization was new in the field of rail rapid transit operation, and before making this sizeable purchase, attempted to accumulate the available transit car design information from the transit and railroad industry, the manufacturers and suppliers, the trade organizations, and the Federal regulatory agencies. The data available were limited, but were used in coordination with the expertise of the manufacturer in the preparation of car specifications. Shortly after the cars were placed in service, wheel failures were detected in alarming frequency. Considerable expense, involving wheel replacement and wheel research, was necessary to resolve the problem. Only the alertness of the systems operating personnel obviated the potential of a broken wheel on a revenue-service train.

The Institute for Rapid Transit and the American Transit Association[9] are industry organizations whose objectives include promoting the development and improvement of technology within the industry, and the dissemination of information generated thereby. The documents distributed by these organizations, however, generally appear to be more descriptive rather than the result of analysis or systematic industrywide technical study. The technical data that are available are subjective, dependent to a large extent upon the suppliers' judgment; the data do not appear to be usable for objective conclusions which might be used to determine performance standards.

Although there are technical areas where experience has resulted in a satisfactory level of performance, there are also many areas where improvements are desirable and necessary. Basically, there is a vast grey area in the definable technical relationship of track/train and passenger/train, both before and after an accident. As in conventional railroading, the internal forces and stresses involved in the transit car wheel-to-rail contact and the ability of track to sustain definable forces are not understood; the variables in car and track that might be used to determine margins of safety objectively have not

[8] NTSB–RAR–New York Central Railroad Company, Train 1/NY-4 Extra 2020 East and Train ND-5 Extra 5305 West, New York City, New York, May 22, 1967.

[9] *Appendix A.*

been determined. Currently, "experienced judgment" is used in this connection. However, this is not a real solution, since the experience of individuals is varied and there is no basis for enforcement.

Studies are underway to improve the environment of rail rapid transit passengers while on board a train or within a station, but to the knowledge of the Safety Board, there has been no research whatever involving the interaction of train, track, and passenger during and after initiation of a derailment or crash. By contrast, most other modes of public transportation are actively engaged in crash testing or other testing of safety during system failure. A review of the available literature indicates that safety research efforts, in general, have been minimal in rail rapid transit.

Rail rapid transit probably is more conducive to the gathering of accident data and the performance of research than most other modes of transportation. This is because equipment and operations are all under company discipline, the number of organizations involved is relatively small, and the geographical areas covered are narrow. Accidents can be subject to disciplined investigations that will reveal areas that require improvement or additional research. To ensure benefit to all, it is necessary that the lessons learned be understood and shared. However, there is no system for accident investigation and exchange within the industry. This area now has come under the jurisdiction of the Federal Railroad Administration and the National Transportation Safety Board, under the Federal Railroad Safety Act of 1970.

## III. A SAFETY ROLE UNDER THE URBAN MASS TRANSPORTATION ASSISTANCE ACT OF 1970

The Urban Mass Transportation Administration (UMTA) was established as part of the Department of Transportation in 1968 to facilitate development of urban transportation systems.

In 1970, Congress added safety to the UMTA mission in the form of a condition under which mass transportation was to be assisted: "The Congress finds . . . that it is imperative, if efficient, *safe*, and convenient transportation compatible with soundly planned urban areas is to be achieved, to continue and expand the Urban Mass Transportation Act of 1964. . . ." (emphasis supplied). This provision for safety in the Urban Mass Transportation Assistance Act of 1970 is a new condition not named in the Urban Mass Transportation Act of 1964.

This language appears to support reasonable activity on the part of UMTA to provide for safety in projects for which it grants funds, such as the use of contract provisions to require employment of advanced practices in safety, or measures to determine the status of safety in existing projects. If modern safety analyses, safety planning, and continuous safety management methods of a general nature could be developed and implemented by the fund-seeking transit agencies themselves, such actions might be considered as indicating probable satisfactory achievement of safe conditions in their projects.

UMTA assists and promotes urban transportation systems through programs of financial aid to local public bodies and through directed research, developments, and demonstrations which include:

Capital Improvements . . . for new transit system equipment and modernization of transit facilities.

Demonstration, Research and Development Projects . . . for studies, tests, and demonstrations of new ideas, methods, systems and equipment for improved transportation planning and operations.

Technical Studies Grants . . . for engineering plans and designs of urban mass transportation systems, and for other technical studies.

Managerial Training Grants . . . for fellowship awards for advanced training of personnel employed in managerial, technical and professional positions in the urban mass transportation field.

University Research and Training Grants . . . for non-profit educational institutions combining comprehensive research and research-training in urban transportation problems.

Among other provisions, the Act of 1970 also requires that special consideration be given environmental protection, and the needs of the elderly and handicapped, and encourages the use of industries hurt by cutbacks in other areas of Federal spending. The Act also requires UMTA to initiate a study on the feasibility of providing Federal assistance to help defray operating costs of mass transportation companies.

It appears that the tools available to UMTA by which to encourage or even assure safety results through research and good management in the various UMTA-aided projects are ample. Encouragement of this nature has a different and additional effect upon safety as compared to safety by regulation. The various transit authorities compete for the limited funds available. If grants were conditional upon safety by analysis, as well as other factors, individual applicants would not only study their own systems, but also learn for themselves the most recent state of the art. The result could be that appreciation of the technical content of safety would develop within each rail rapid transit agency. If this system is introduced in a timely manner, the safety results could be lasting and they would continue even upon adoption of the concept of "revenue sharing" presently being advanced.

Where direct regulation of safety is the only governmental tool for encouraging safety, the normal approach begins with government studies and detailed governmental proposals. This is followed by reaction to the proposals by the regulated system. The questions of each detail of regulation are expected to be controversial and are controlled by the Administrative Procedures Act. The reasoning for regulations tends to revolve around proof of necessity for each step, and the best proof has come from the lessons of past accidents. Thus, it tends to be difficult to employ analytical prediction of hazards to prevent new hazards by the use of regulations. It is almost impossible to prevent, by regulations, unsuspected degradation of safety in new designs. New designs may not be initially covered by regulation, or may contain new characteristics which often are not covered by regulation until the need has been demonstrated.

For these reasons, the encouragement of self-analysis of safety by applicants seeking grants does not duplicate government regulatory action in the same field. Encouraging transit systems or operators to speak projectively about their own safety in order to obtain grants, and encouraging safety research, may even be more important than direct regulation at this particular stage in rail rapid transit development.

The so-called System Safety methods, such as system safety plans, hazard analysis, failure mode and effect analysis, and fault-tree analysis, tend to lead to optimum safety by design of both technical and safety management systems. These methods are highly effective before new systems are placed in operation and also are usable in existing systems. The use of these methods logically precedes the safety data from accidents which lead to specific regulations. The use of these methods also saves lives because it is not necessary to wait for accidents to occur.

In addition, the System Safety methods require cooperation within and among contractors, and it would appear that incentives, such as fund availability, are better tools for producing cooperation than mandatory regulation. Regulatory actions are based upon the expectation of controversy and facilitating resolution on a detailed basis, issue by issue. The procedures of the Administrative Procedures Act are slow. The System Safety methods are more capable of being administered by contract or grant procedures.

The Safety Board already has recommended to the Washington Metropolitan Area Transit Authority (WMATA) that it install, for its own administrative control of the safety of operation of the system, methods of hazard analysis and evaluation, which are part of advanced techniques collectively called System Safety.[10] WMATA is one of the rail transit systems which will be dependent partially upon Federal funds. WMATA has responded to the recommendation by having several contractor personnel attend courses in System Safety. Two other transit systems—namely, the New York Transit Authority and the Chicago Transit Authority—also have sent personnel to schools to be trained in System Safety. System Safety is taught by at least five educational institutions in various parts of the United States, and its application to rail rapid transit is clearly practical.

It also should be noted that a strong capability in System Safety exists in industries hurt by cutbacks in Federal spending, notably the aerospace industries. The UMTA statutory mission requires consideration of this factor in the use of industries on transportation projects. The full employment of such techniques as hazard analysis, fault-tree analysis, human factors analysis, and development of equipment failure rates and other System Safety methods could be a normal part of the planning and engineering effort of a rail rapid transit system, and a significant proportion of that work. Thus, it appears that the use of UMTA funds to assist industries hurt by Federal spending cutbacks would be applicable directly to the performance of such safety engineering work, as well as to the needed safety research.

UMTA has not as yet developed specific procedures to provide for achievement of "safe" transportation through the administration of grants under the Urban Mass Transportation Assistance Act of 1970. UMTA's staff currently does not include the capability for review of systems safety engineering and analyses of the safety-insuring features of projects for which funds are granted.

Prior to the passage of the Federal Railroad Safety Act of 1970, the Federal Railroad Administration (FRA) had very limited regulatory jurisdiction of rail rapid transit systems. This jurisdiction extended to interstate carriers only and, except for accident reporting, generally exempted transit authorities from any Federal regulation. Interstate railroads were regulated to the extent of varying degrees of control over locomotives, signal systems, hours of service for certain employees, airbrakes, certain safety appliances, and accident reporting.

The Federal Railroad Safety Act of 1970 extended FRA's authority. House Report No. 91-1194, dated June 15, 1970, amplifies the intent of the bill by stating:

> "The Secretary's authority to regulate extends to all areas of railroad safety. This legislation is intended to encompass all those means of rail transportation as are commonly included within the term. Thus, "railroad" is not limited to the confines of "common carrier by railroad" as that language is defined in the Interstate Commerce Act. The Secretary will have jurisdiction under the bill to regulate all areas of railroad safety in addition to those areas currently regulated. It should be noted that this new grant of authority will enable the Secretary, if necessary, to regulate intrastate carriers in such areas as safety appliances, power brakes and the like, in the same manner as interstate carriers are now regulated under existing statutes. In addition, the Secretary's jurisdiction would extend to rail operations in areas presently governed by compacts and by other municipal authorities such as the Metropolitan Transit Authority in New York. The Secretary, after affording an opportunity for oral hearing, has discretionary authority under section 202(c), discussed below, to exempt those railroads and those activities not now involved in or affected by the rail safety problem."

Because rail rapid transit will be subject to Federal regulation of safety in the future, there is an opportunity to coordinate safety encouragement by UMTA funds with statutory regulation.

[10] National Transportation Safety Board Report RSS-70-1—Study of Washington Metropolitan Area Transit Authority's Safety Procedures For the Proposed Metro System.

The present fund authorization for enforcement, and all other efforts to support FRA regulations, is not large, only about $21 million per year, and this funding must be used for both railroad and rail rapid transit problems. By comparison, the authorized funding for grants of UMTA average over $600 million per year for 5 years, a rate almost 30 times greater than that for safety regulation. Part of this funding could create leverage by requiring safety analyses by grantees. Thus, it is quite possible that the results of advanced rail transit safety techniques developed under the "safe" mission of UMTA will produce information to aid FRA regulatory actions, and might equal or exceed the results from FRA research funds.

At this time, it appears that the manner of distributing these UMTA funds to transit systems, whether direct to transit systems or through State agencies, would not influence the intention of the statute to obtain safe systems. The requirement for published safety analyses could be established by administrative guidelines and applied to contract or grant procedures.

It also appears that the withholding from public knowledge of safety approaches used by transit systems, records of accidents, or accident data and analyses is not justified where funds to support the transit effort are derived from taxation, and are distributed under the statutory intent to obtain safe transportation. It seems clear that UMTA cannot achieve its safe transportation goal without access to accident information from existing systems seeking added funds.

## IV. SUMMARY OF FINDINGS

1. All rail rapid transit systems compile accident statistics; however, there is no uniformity of data between systems. Interstate carriers report accidents to the Federal Railroad Administration, but the data developed from these reports do not identify rail rapid transit accidents and related causal factors. Intrastate transit systems are not required to report accident statistics to any Federal agency.

2. The greatest frequency of rail rapid transit passenger injury has occurred to those passengers within station locations, not on board a train. The highest incidence of fatality has resulted from persons on the roadway (track) who have been struck by a train. This incidence may be minimized by the separation of passengers from the track in stations, by train-approach warning systems, and by the protection of roadway with fences or grade separation.

3. Although new rail rapid transit lines are being constructed without highway grade crossings, existing systems regularly subject trainloads of commuters to the possibility of a collision with highway vehicles at grade crossings. Grade crossings are not compatible with rail rapid transit operations.

4. Transit car design is dissimilar between systems, with slight evidence of systematic analyses accounting for the disparities. Cars originally intended for operation in closed systems now are exposed to new environments and hazards.

5. Vandalism offers a serious problem to safe rail rapid transit operation. The lack of adequate fencing encourages trespassing and subsequent vandalism. Existing laws and law enforcement procedures have not been effective in deterring this vandalism.

6. Emergencies are now encountered on rail rapid transit systems that were not anticipated in the original design. A complete emergency preparedness program is a prerequisite to safe operation.

7. The modernization and extension of existing rail rapid transit lines have perpetuated existing signal systems, without due regard of employee rule violations associated with the signal system involved.

8. The safety of rail rapid transit lines in highway medians or adjacent to conventional freight-hauling railroads appears to have been evaluated inadequately. The distractions and effects on each individual transportation mode require further evaluation.

9. Maintenance funds generally have been dependent upon operating revenues, and the

declination of revenues has affected the level of maintenance and safety of the systems.

10. Safety personnel within the rail rapid transit industry are not used to the extent of their potential.

11. There is an apparent relationship between the economic health of the rail rapid transit industry, the quality of the operating procedures, and the morale of the employees.

12. In spite of the inherent safety of the rail rapid transit mode of operation, the existence of inconsistent, ambiguous, and unenforceable operating rules creates an atmosphere in which effective risk management is difficult.

13. There has been a noticeable lack of research and exchange of information in the rapid transit field, resulting in perpetuation of errors in design of components and systems.

14. In spite of the apparent problems, rail rapid transit passengers have been relatively secure from serious accidents while on board. Rail rapid transit, in a systematically planned urban transportation system, is desirable from a passenger safety standpoint, and should be encouraged.

15. The Urban Mass Transportation Administration is granting funds for construction of new systems, upgrading of existing systems, demonstrations, and research and development without instituting procedures to provide for achievement of safe transportation.

16. The Urban Mass Transportation Administration could implement its mission to achieve a condition of safe mass transportation by the use of contract or grant provisions to require advanced practices in safety by grantees. Actions also are possible which would be consistent with the use of industries hurt by cutbacks in other areas of Federal spending.

17. The safety results of Urban Mass Transportation Administration funding could be coordinated with future safety regulatory actions of the Federal Railroad Administration in the rail rapid transit field.

## V. RECOMMENDATIONS

The Safety Board recommends that:

1. The Urban Mass Transportation Administration require that all rail rapid transit applications for capital improvement, demonstration, and research and development grants include a system safety plan for the project for which funds are being requested. This plan might include, but not be limited to, such items as:
   a. A description of the safety organization and its position in the total organization.
   b. Identification of the tasks to be accomplished by the safety organization.
   c. The technical methods to be used for accomplishment of these tasks.
   d. A schedule for task completion, keyed to major program milestones.
   e. A description of the output from the safety effort.
   f. The methods for applying this output to identify the hazards, to evaluate the risks, and to determine the alternatives to assumption of these risks.
   g. The documentation to be developed.

2. The Urban Mass Transportation Administration evaluate comparatively the system safety plans submitted by applicants for rail rapid transit funding assistance, and employ such evaluations as a partial basis for selecting applicant to be funded. In addition, UMTA develop, or obtain through cooperation with other agencies, a permanent system safety engineering capability to evaluate the safety plan of each project for which funds are requested.
3. The Urban Mass Transportation Administration include safety considerations in

its study of the feasibility of providing Federal assistance to help defray operating costs of mass transportation companies, insofar as rail rapid transit is concerned.

4. The Urban Mass Transportation Administration undertake a study of selected rail rapid transit systems in the planning stage to determine the feasibility of separating passengers from tracks, in underground and above-grade stations.
5. The Federal Railroad Administration establish, by regulation, a uniform system of data gathering and accident reporting encompassing all the rail rapid transit operations in the United States from which statistics can be compiled to determine the status of safety in rail rapid transit operations. The Safety Board is aware that FRA is studying the existing accident reporting system for railroad accidents under the Accident Reports Act, and recommends that the rail rapid transit accident reporting requirements be included in any new system of accident reporting.
6. The Federal Railroad Administration give particular consideration to the different conditions of rail rapid transit operations when establishing methods of pedestrian and highway grade crossing protection, as required by the Federal Railroad Safety Act of 1970.
7. The Federal Railroad Administration, with the cooperation of the Urban Mass Transportation Administration, provide a continuing review of the study now underway involving the effects of vandalism and assault on rail rapid transit vehicles and passengers. This review should include scrutiny of existing laws and regulations to determine their adequancy, with recommendations for appropriate Federal action.
8. The Federal Highway Administration, Department of Housing and Urban Development, and Urban Mass Transportation Administration cooperatively evaluate highway planning in urban areas with regard to the potential for joint corridor accommodation of rail rapid transit lines, and establish criteria for proper and safe accommodation of such lines.
9. The Federal Highway Administration establish criteria aimed at protecting rail rapid transit lines from potential vandalism resulting from the construction of adjacent or bisecting Federal-Aid highways.

10. The individual systems of the rail rapid transit industry review the responsibilities, capabilities, and authorities of each of their own respective safety organizations with a view toward instituting a more systematic and authoritative approach to safety, not only in new projects, but in day-to-day operation and maintenance.
11. The individual systems of the rail rapid transit industry review their emergency procedures to ensure that employees, passengers, and others involved are prepared adequately to cope with emergency situations.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

June 16, 1971

# FUNCTIONAL DESCRIPTIONS OF RAIL RAPID TRANSIT TRADE ORGANIZATIONS

## American Transit Association (ATA)

The ATA was founded originally in 1882 as the American Street Railway Association. Subsequent changes in technology brought changes in the name of the organization until the present form was adopted in 1932. The ATA is a trade organization with membership comprised of local motorbus operators, rail transit systems, consultants, manufacturers, and suppliers throughout the United States and Canada. The objectives of ATA are:

A. To collect, compile, and make available to members data and information relative to public transportation.
B. To provide a medium for exchange of experiences, discussion, and comparative study of industry problems.
C. To promote research and investigation to the end of improving public transportation.
D. To aid members in dealing with special problems.
E. To encourage cooperation among its members, their employees, and the general public.
F. To represent nationally the common policies, requirements, and purposes of public transportation.

## Institute for Rapid Transit (IRT)

The IRT was founded in 1961. The membership of IRT is comprised of transit companies, planning organizations, manufacturers, suppliers, and consulting engineering firms. The purposes and functions of IRT are:

1. To act as a spokesman for the rapid transit industry.
2. To provide assistance and information to all agencies, public and private, working for the revitalization and expansion of existing rapid transit systems, and the creation of needed new systems to serve burgeoning urban areas.
3. To act as a catalyst for the development and improvement of rapid transit technology.
4. To act as a clearinghouse for all agencies and organizations involved and interested in all aspects of rapid transit systems.