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APPLICATION OF SYSTEM SAFETY

TO

RAIL TRANSIT SYSTEMS

By

Mr. Thomas DeW. Styles
Chief
Railroad Safety Division
National Transportation Safety Board
Department of Transportation

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Rail rapid transit, as we know it today, came into being shortly after the turn of the century. Although inter-city railroad passenger service was well established and thriving, the opening of New York City's first subway in 1904 was the beginning of rail rapid transit in this country. Since that time, development of the rail rapid transit industry has been sporadic. Until very recently most activity took place prior to World War II.

The term rail rapid transit as used in this paper refers to systems, excluding streetcars, that utilize single or multiple-unit trains on a two-rail track. As used here rail rapid transit includes subway, surface, and eleveated trains operated by public or private transit authorities as well as commuter-trains operated by railway companies.

The current urban renewal activity and emphasis on community planning and improvement has brought about a change in urban transportation philosophy. Once again, the modernization and expansion of rail rapid transit systems and the construction of entire new systems is underway. Large scale improvements and expansions are being planned or made to the systems in Boston, New York, Philadelphia, Chicago, and Cleveland. New commuter cars are being purchase for use in the New York area on railroads and in the subway system, and on the railroads in the Philadelphia area, and in Chicago. Complete new automated rail rapid transit systems are being built in San Francisco and here in the Washington metropolitan area. A successful automated system has been running for more than a year between Lindenwold, New Jersey and center city Philadelphia. Plans for rapid transit are in various stages of development in Atlanta, Baltimore, Los Angeles, and Seattle, while Pittsburgh's plans embrace an intermodal concept which includes the so called "Skybus."

The availability of Federal funds has been a moving factor in this rebirth. The Urban Mass Transportation Act of 1964 offered the first continuing program for urban mass transportation. The Urban Mass Transportation Act of 1970 continues and expands the role of the Federal Government by authorizing 3.1 billion dollars for mass transportation during the next five years. The 1970 Act also expresses the intention of the Congress to provide 10 billion dollars in assistance over the next 12 years. In addition to Federal grants, a marked increase in the financial participation of State and local governments has occurred, with the prospects of additional funds in the future.

The Urban Mass Transportation Act of 1970 includes as part of its purpose the word "safe." The meaning of the word safe is not spelled out in the Act; however, we at the National Transportation Safety Board have definite feelings about the future meaning of the word and will make some recommendations to UMTA regarding its implementation. These recommendations are the result of several months' observations made by Safety Board personnel of transit operations in New York, Philadelphia, and Chicago. These observations were supplemented by consultation ith the personnel of the Metropolitan Transportation Authority, the Port Authority, and Penn Central Transportation Company in New York; the Southeastern Pennsylvania Transportation Authority, the Port Authority Transit Company, the Reading Company, and the Penn Central Transportation Company in Philadelphia.

Let me clarify one thing at this point. The rail rapid transit industry historically has been considered a safe method of urban transportation. Recently among the older systems this image has been tarnished by highly publicized incidents of system failures. In spite of these system failures, and in spite of the absence of statistical data to confirm it, passengers on board a rapid transit train are exposed to a much lower risk than on any form of highway travel.

There is no single private or governmental agency to which all of the rail rapid transit industry reports comprehensive accident data on a regular basis. Railroads and certain of the interstate transit authorities are required to report accidents to the Federal Railroad Administration; however, the methods are oriented to conventional railroad operations with no separation for commuter operations.

Within the transit industry, the American Transit Association compiles operating accident statistics for transit systems but includes only motor coach, trolley coach, and street car operations. Recently, there has been an effort by the transit members of the National Safety Council to establish a uniform system of compiling and exchanging accident information, but there has not been uniform acceptance of these procedures. The net result is a complete lack of data that can be used as a comparison of safety within the industry or between transportation modes. When one does not know the characteristics of the accidents and where they are happening, and both accident and use history data are not available, operations analysis to identify problems areas becomes difficult.

Rail rapid transit systems and railroads are good examples of the highly wasteful, but normally used approach which attacks problems as they are revealed by accidents. Within the present state-of-the-art it is most inefficient to wait for the accidents to occur and then to correct the problems by making changes. Obviously what should be done, of course, is to find the hazards in advance. Through systematic analysis of the system one may predict the likelihood that those hazards will be activated by exposure of the system to a system failure, a human error, conditions external to the system, or combinations of these; determine the alternatives to the assumption of this risk; and recommend the corrections before the system is put into operation.

The problem becomes one of indoctrinating this concept into the rail rapid transit industry. Historically, the rail rapid transit industry has depended on a good past accident record rather than focusing on means for identifying hazards and evaluating risks. There appears to be an attitude in the railroad and transit community that no professional engineer would design or produce an unsafe product, and I agree that no professional would knowingly do this. However, there are concrete examples in the transit field today where these safety-conscious professionals have produced components that resulted in a system that contained hazards which could lead to disaster if they had not been found.

These examples of hazards are physical evidence that the application of a disciplined, systematic review of a system is necessary if optimum safety is to be accomplished. A review of some of these conditions will illustrate the applicability of system safety to the rail rapid transit industry.

Station accidents represent the highest accident ratio in the industry and include falls on stairs, escalators, platforms and passageways, injuries from assault or being pushed by other persons, and injuries resulting from smoke and other miscellaneous causes.

The facilities involved in most station accidents are also those that receive substantial architectural consideration during construction or modernization programs. Too often the aesthetic viewpoint dominates the practical considerations. Open stairwells and barrier-free escalator handholds challenge the acrobatic capabilities of children. Street entrances are often sloping ramps that resemble ski slopes during snowy winter weather. Subdued lighting in entrances greets patrons wearing sun glasses. Wall and ceiling surfaces are covered with material which quickly lose their reflectivity upon exposure to rail and wheel dust and the graffiti experts.

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 but to persons on the track, including trespassers and those who have jumped from station platforms or were inadvertently pushed.

The train-person collision, where it involves patrons, occurs in the proximity of station platforms and is most frequent at car-floor height platforms. Station accidents involving a fall to the track are also experienced at these locations. In spite of this experience, the trend in the industry is towards open, car-floor height platforms to enhance faster discharge and receipt of passengers. In our society there are very few places where the public is allowed to congregate immediately adjacent to an unprotected opening four feet deep. This is the case where commuters jostle each other on high-level platforms while waiting for rapid transit trains. To increase the hazard, trains pass through the opening at speeds up to 75 miles per hour.

In most older systems, if a patron were pushed, fell, or jumped to the track the possibility of being hit by a train was minimized, to some extent, by the use of express tracks which were separated horizontally from car-floor height platforms. The newer systems are not utilizing this concept and nonstop trains whiz by crowded platforms. Platforms now are located also in the median strips of crowded expressways where noise and other distractions are prevalent. Warning systems are not provided and therefore the likelihood of a train approaching without detection has increased markedly. Architectural considerations in new underground stations have dictated that the track zone be sparsely lighted so that unaesthetic views of the track are not highlighted. Therefore, a person who has fallen on the track is obscured by shadows and is less likely to be seen.

Further, train-person collisions are experienced at surface stations constructed with low, rail-height platforms. The majority of these accidents involve patrons taking short cuts across tracks which either have no intertrack barriers or barriers 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 permanent effective intertrack barriers extremely difficult.

Grade crossings are not compatible with rail rapid transit operations. The consequences of a collision of a rail rapid transit train with a truck load of hazardous materials could be a major disaster. In December, 1966 at Everett, Massachusetts a rail commuter car struck a stalled tank truck of fuel oil and the resulting fire killed 13 persons because they could not escape from the car. There were no emergency exits and the inward-swinging door was jammed closed by the press of the people trying to escape the fire. It takes very little imagination to see what could happen to a commuter train with several hundred persons on it if it struck and ruptured a tank truck of gasoline or liquefied petroleum gas.

Grade crossing protection or elimination programs have been unorganized, 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 by the general public and not enforced by local authorities. Zoning laws and other local ordinances are explicit in their requirement 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.

Although grade crossing accidents are recognized as a hazard within the rail rapid transit industry, in some instances the design of the car equipment is not consistent with this recognition. Transit cars originally designed for operation in a closed system are operated over highway grade crossings. The pilot protection, 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. In the event of a grade crossing accident, the passengers will have an excellent view of the event if they survive to relate it.

Injuries that have occurred in the on-board category have involved or 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 being provided at locations handling suburban service. The experience again indicates a lower accident frequency at low platforms than at the car-floor height platforms.

New car equipment has been observed with no protection provided for the space between cars. This has resulted in falls to the track while boarding or alighting as well as on-board falls. Understandably, the results have generally been severe. Protection has been provided with intercar chains as well as retractable gates, both of which appear to be only a partial solution added as an afterthought.

On several systems car-floor height platforms are inter-mixed with those of low rail-height design. To accomodate boarding-and discharge this has necessitated car vestibules with trap doors in the down-position for car-floor height platforms and in the up position for the low platforms. The trap door has been the source of numerous injuries and its use should be discouraged.

I think we can assume that in rush hours there will be a large number of standees;

however, minimizing the number of standees will reduce the number of on-board falls. The provision of hand holds designed for passenger comfort and convenience should be reconsidered. Improved car suspension systems and smoother accelerating and braking characteristics would be helpful also.

Some of the newer commuter cars have the "flop-over" seats so that when the train reverses direction, the seat backs are "flopped over" to allow the passenger to ride facing forward. There have been instances where emergency stops have been made resulting in the standees grabbing the seat backs to prevent themselves from falling. This "flops over" the seat backs with passengers sitting in them. An analysis of this feature would have revealed the obvious hazard in this type seat arrangement.

Obviously, there are many operating factors which affected the design of rail rapid transit cars. Safety should be given high priority as a factor.

Window designs vary from the large picture window to the porthole type. Almost all transit passengers face the hazard of being injured by thrown objects, and design of windows can lessen the severity of injuries from thrown objects. Various types of glass panes are used and now tough plastic material which will withstand the impact of a thrown rock is being used.

The design of the front end of transit cars can influence the severity of a grade crossing collision. Large expanses of glass on the front ends of cars subject the operator and passengers to additional dangers from impacts of objects thrown from above as well as collisions at grade crossings.

There appears to have been no systematic approach to the design and use of windows. The obvious approach would be to determine the environmental exposure of the windows and surrounding structures during their operational life-time. Once these environments are understood, the optimum combination of window pane and surrounding structure can be determined as those which offer the least risk to the passengers and crew.

Although window design is the most conspicuous, there are many other car design areas that warrant re-examination for determination of the optimum design. These design characteristics vary in importance and include in part: exit location and design, passenger seating arrangements, accommodation of hand-luggage, motorman separation, intra-car passageways and barriers, rear-end illumination, front-end derailment and collision protection, braking systems, car-wheel metallurgy, and automatic control systems.

While new rail rapid transit cars are subject to differences in design criteria between systems, they also contain common innovations which are valuable in furthering passenger safety. These include such items as two-way radios or train-phones, complete train public-address systems, speedometers, improved ventilating systems, and emergency car lighting. The installation of these devices has been accomplished with safety in mind; however, experience has provided the hazard analysis.

As in other transportation networks, the traffic-control system of rail rapid transit is a necessity in the safety and effiency of operations. Unlike other transportation networks, however, a train must stay with the route established for it by the track and the traffic control system. The engineer does not have the option of selecting an alternative route at the last moment when an accident appears imminent. Therefore, both safety and reliability must be designed and built into the traffic control system as a prerequisite to efficient operation without a high accident frequency rate.

Although railroad and transit accident statistics indicate that the failure of signal systems does not cause a significant number of accidents, much can be done in the field of signals to enhance railroad and transit safety. Many accidents attributed to man failure and acts of God can be prevented by a good signal and train control system. The modernization, and extension of existing lines appears to perpetuate existing signal systems without due regard to the accident experience of the system involved.

New rail rapid transit lines are being designed with the capability of a fully automated signal and train control system. These new systems should be subjected to rigorous 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 requires the application of sophisticated safety analysis techniques.

Almost invariably rail rapid transit tunnel design shown 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.

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

The minimization of the hazards in existing emergency tunnel evacuation is an area that demands immediate attention. Upgrading programs have been undertaken on some systems and the results are markedly apparent, although no one system has accomplished all of the following steps. The 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 de-training ladders, bull-horn speakers, stretchers, lanterns, air-paks, first-aid kits, and between-rail walkways have been strategically located either in tunnels, at stations, or on equipment. The installation of this type of equipment is mandatory if operational delays, adverse publicity, lawsuits and most important, loss of life are to be minimized.

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 tracks. 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 has generally been provided. 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 relatively minor, but serious accidents have been caused by subsequent detraining and evacuation. For new systems this design warrants a complete reappraisal.

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 and the arguments for joint utilization are indeed convincing.

The safety of each mode must be assured at an interface such at this and to accomplish this requires a systematic evaluation of the hazards of each mode and the interface between the modes. These evaluations must be made in the planning stage rather than after the system has been constructed and alternative plans are too expensive to implement.

When one looks at the possibility of a gasoline or liquefied petroleum gas tank truck violating the transit track space the potential consequences are frightening. A comparable prospect exists where rapid transit tracks operate jointly or adjacent to a freight-carrying railroad. Shifted loads and derailments can foul the transit tracks resulting in catastrophic collisions.

I would be shocked genuinely to find a transit operation without a safety department. I would expect to find that safety is deemed the first responsibility of all employees, and each supervisor is charged with the responsibility for safe operations within its jurisdiction. For the most part, however, management emphasis on safety involves employee activities. It would be completely unfair to imply that there is a lack of concern for passenger safety within the rail rapid transit industry. There are concentrated efforts to investigate accidents and improve the lot of the passsenger; however, these efforts did not appear to receive the emphasis that was regularly placed on employee safety by the safety departments.

Safety department personnel generally are charged with the responsibility of "closing the barn door after the horse was stolen" without having an opportunity to review a new facility during design and construction. The safety input for new or modernized facilities has been accomplished historically 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. A system safety review of new or modernized facilities normally does not take place during the conceptual stage. As a 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 required to remove the hazard from the initial design. Safety personnel are not used to the extent of their potential, which I understand is not a new situation.

There is a ready application for system in the rail rapid transit field and the time to start is now. The degree of safety achieved in any system is directly dependent upon the emphasis of management. In the rapid transit industry this management emphasis on safety includes the management of the granting and use of funds by the Federal Government. This management emphasis must be applied during the conception, development, production, and operation of each system throughout its life cycle.

Much needs to be done with the existing operating systems. System safety programs for new systems are not the only needs in the industry. Keen analyses of the present systems would identify the hazards and evaluate the corrective actions so that management could determine what degree of safety is needed. The public which is paying the bills can no longer afford the inefficient method of waiting for an accident to occur and then correcting the problem.