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National Transportation Safety Board

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Safety Recommendation

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In reply refer to: H-98-38 and -39

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More than 4,000 accidents have occurred at the Nation's active and passive grade crossings each year from 1991 through 1996. Many of the accidents at active crossings have involved highway vehicle drivers who did not comply with train-activated warning devices installed at the crossings. This failure to comply often includes driver actions resulting from a deliberate decision, such as driving around a lowered crossing gate arm or ignoring flashing lights. Drivers at passive crossings are not provided warnings from train-activated devices; consequently, they must rely on a system of grade crossing signs and pavement markings, passive devices, that are designed to warn drivers only of the presence of a crossing. No element of this passive system changes to alert drivers to an oncoming train. Further, the effectiveness of the passive system is influenced by characteristics of the physical layout of the crossing, such as an adequate view of the area surrounding the crossing (sight distance) and roadway alignment, that affect the information given to an approaching motorist regarding an upcoming hazard.

According to the Federal Railroad Administration (FRA), there were 4,054 accidents in 1996 that involved highway vehicles at grade crossings; 54 percent (2,208) of those accidents occurred at passive grade crossings. About 60 percent of the fatalities from all grade crossing accidents in 1996 (247 of 415 fatalities) were at passive grade crossings.

The cost to eliminate or upgrade passive grade crossings is very high. According to the General Accounting Office, the average cost of adding lights and gates in 1995 was $150,000 per grade crossing. The total cost to upgrade the 96,759 passive crossings on public roadways would be about $14 billion. Gates and lights do not completely eliminate the hazards present at crossings, and, therefore, sole reliance on them would reduce but not eliminate all the fatalities. The ultimate solution from a safety standpoint would be a standard grade separation, which usually involves construction of bridges or overpasses and costs an estimated $3 million per crossing. The large number of passive grade crossings, the high percentage of fatalities that occur at passive grade crossings, and the cost to eliminate or upgrade passive grade crossings prompted the Safety Board to conduct a study to identify some of the common causes for accidents at

passive grade crossings, and to identify less costly remedies to improve safety at passive crossings not scheduled for closure or upgrade.[1]

For this study, the Safety Board investigated 60 grade crossing accidents that occurred between December 1995 and August 1996. The Safety Board selected for study accidents involving a collision between a train and a highway vehicle occurring at a passive grade crossing, wherein the highway vehicle was sufficiently damaged to require towing. The sample of accidents is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents.

In May 1997, the Safety Board convened a 2-day public forum in Jacksonville, Florida, to gather information about issues affecting safety at passive grade crossings. Witnesses included experts from the railroad industry; law enforcement; research groups; Operation Lifesaver; and Federal, State, and local government agencies. Those involved in grade crossing accidents, both highway vehicle occupants and traincrews, testified about their personal experiences. In addition, representatives from Canada and Italy discussed passive grade crossing issues and experiences in their countries.

Detecting a train at a passive crossing and making the correct decisions about whether a highway vehicle should stop at the crossing or can cross the tracks safely before the train arrives is a complex task that has confronted the Nation's motoring public for decades. The task is affected by the driver's ability to (1) detect the presence of the crossing, (2) detect the presence of a train, and (3) accurately gauge the train's speed and arrival time at the crossing. The task is further complicated by the driver's attention at a crossing, which as shown in the Safety Board's study, can be affected by what that individual expects to see. The Safety Board concludes that a driver's decision to look for a train may be adversely affected by the driver's familiarity with and expectations at a specific passive grade crossing and the driver's experience with passive crossings in general. Also, as shown in the Board's study, the train horn—one of only two active signals given to a driver to alert the driver that a train is present—is effective as a warning only if the driver recognizes it as a train horn. The Safety Board, therefore, concludes that in some circumstances, audible warning devices on trains fail to meet their objective of alerting motorists to an oncoming train because of highway vehicle design and environmental factors.

Despite the complexity of the task, the approach to passive grade crossing safety has remained relatively unchanged over the years. The current approach includes providing a sight distance triangle for an approaching motorist to see a train and installing a railroad crossing advance warning sign, pavement markings, and a crossbuck sign, where appropriate. The accident sample in the Safety Board's study illustrates that this approach has been inadequate in many instances.

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[1] National Transportation Safety Board. 1998. Safety at passive grade crossings. Volume 1: Analysis. Safety Study NTSB/SS-98/02. Washington, DC.

To eliminate the continuing problems encountered by the motoring public at passive crossings, the Safety Board concludes that a systematic and hierarchic approach to improving passive grade crossing safety is needed, an approach that does not depend primarily on the ability of the driver approaching the crossing to see an oncoming train. The hierarchic approach includes grade separation and closure, installation of active warning devices, improved signage, and intelligent transportation systems technology. The approach includes immediate and long-term measures. Concurrent with this approach is the need to educate drivers about the hazards of passive grade crossings.

The Safety Board's study identified several physical characteristics at passive highway–rail grade crossings that appear to contribute to the occurrence of accidents because they make it difficult for the motorist to see a train (inadequate sight distance, roadway-track intersection angles less than 90°, and roadway and track curvature), and/or because they distract the motorist's attention from the task of looking for a train (nearby roadway intersections). Further, a driver's attention at a crossing can be affected by what that individual expects to see and by distractions inside and outside the vehicle. This letter addresses these factors as they relate to driver education.

Sight Distance

Sight distance is the technical term describing the set of distances along the highway and along the railroad tracks needed by a motorist to detect the presence of a train in time to stop. According to American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets*[2] (the Greenbook), a grade crossing should be designed so that an approaching motorist is able to perceive the train, react to its presence, and stop the highway vehicle prior to the crossing. The required distance along the roadway (that is, from the vehicle to the crossing) and along the railroad tracks (from the crossing to the oncoming train) form two sides of a triangle. Together with the third side (an imaginary line from the train back to the highway vehicle) they form an area referred to as "quadrant sight distance," or the "sight triangle," the interior of which should be clear of any visual obstructions. For a vehicle stopped at the crossing, the driver must be able to see the train far enough along the tracks to have time to accelerate the vehicle and clear the crossing before the train's arrival.

The quadrant sight distance needed varies according to the speed of the train and of the highway vehicle, as well as the length and stopping distance of the highway vehicle. It is also affected by the angle at which the highway intersects the tracks and the slope of the roadway. When a grade crossing is designed, sight distances should be calculated by highway engineers. A stopped vehicle will need more sight distance along the track to see the oncoming train and cross the track before the train arrives, whereas a moving vehicle will need enough sight distance along the highway approach to the crossing to see the train along the tracks and to have time to stop.

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[2] American Association of State Highway and Transportation Officials. 1990. A policy on geometric design of highways and streets, 1990. Washington, DC. 1044 p.

The railroad track approaches at the accident crossings in the Safety Board's study were generally straight, and the sight distance along the tracks that was available to the drivers of most types of highway vehicles stopped at the crossing stop line was, for the most part, adequate (n = 50). In 10 cases, however, there were sight obstructions for a driver stopped at a crossing: in 7 cases, vegetation restricted visibility; in 2 cases, curvature of the tracks restricted visibility; and in 1 case, a building restricted visibility.

The generally adequate sight distance for vehicles stopped at the crossings, however, did not hold true for motorists approaching the crossings. In 33 cases, the grade crossing area afforded an approaching motorist less sight distance than was recommended by AASHTO guidelines.[3] At the majority of the crossings with limited sight distance (n = 24), the obstructions were trees, shrubs, or other types of plants: in one case, the trees were described as a forest (case 27); and in another case, the trees were fruit trees in an orchard (case 60). Six of the 33 cases had visual obstructions that included buildings, and in one of these cases the motorist's sight distance was obstructed by a hill. The following accident illustrates the potential consequences of inadequate sight distances for drivers of highway vehicles in motion.

About 8:15 a.m. on April 5, 1996, an eastbound Kansas City Southern freight train traveling about 40 mph struck a northbound Mazda at Golson Road near Calhoun, Louisiana (case 16).[4] The Mazda, traveling about 25 mph, which was about 10 mph below the posted speed limit, skidded onto the railroad tracks when the driver tried too late to stop her vehicle. The driver and her 8-year-old daughter in the right front seat of the car were both killed.

According to the AASHTO guidelines and based on the speeds of the highway vehicle and train in this case, the highway driver needed a clear sight triangle defined by a distance of 271 feet along the highway and 422 feet along the railroad tracks to see the train with enough time to safely stop the vehicle. However, because of the presence of a forested area on private property adjacent to the crossing, this sight triangle was not clear. The driver in this case actually had a clear sight triangle with only 72 of the 271 feet needed along the highway and 112 of the 422 feet needed along the railroad tracks. By the time the driver saw the train and applied the brakes, she did not have enough time to stop the vehicle prior to the crossing.

In addition to calculating the sight distance for each of the 60 accident crossings, the Safety Board also examined each crossing in terms of the time an approaching motorist needs to safely stop the vehicle prior to the crossing compared with the actual time available, given the sight distance along the highway. The differences in time needed compared with actual time available ranged from no shortage of time for some crossings to a shortage of 7½ seconds. For 18 (58 percent) of the crossings with limited sight distance, an approaching driver has only half or less of the time needed to safely negotiate the crossing. With such differences between the time needed and the time available, the driver's task to safely negotiate the crossing becomes more

[3] Three of the 33 crossings with limited sight distance for approaching motorists were on private roads.

[4] According to the traincrew, the locomotive headlight and auxiliary alerting lights were illuminated, and the train horn was sounded prior to the accident.

difficult. The Safety Board's study cases show a strong association between inadequate sight distance and accident occurrence.

Angle of Intersection

The angle at which the roadway meets the railroad tracks may also affect the driver's ability to see an oncoming train. The following accident illustrates this problem.

About 1:10 p.m. on Thursday, May 30, 1996, a northbound Pontiac Grand Am struck a westbound Consolidated Rail Corporation (Conrail) freight train traveling about 48 mph at a passive grade crossing near Montrose, Illinois (case 37). The speed limit along the road was 55 mph. The driver, who was transporting her 3-year-old child, stated that she slowed her vehicle when approaching the crossing, but she did not hear or see the train until just before impact. There were no injuries associated with this accident, but the vehicle was destroyed. Although there were no obstacles in the sight triangle for the approaching motorist, the highway met the railroad tracks at an angle of 35°; thus, the train approached essentially from behind the highway vehicle.

According to AASHTO guidelines, "[r]egardless of the type of intersection, for safety and economy, intersecting roads should generally meet at or nearly at right angles." AASHTO recommends that when there is an acute angle of intersection, the road be realigned so that the angle of intersection can be more nearly 90°.[5] The distance a highway vehicle must traverse in order to clear the intersection is greater when the angle is skewed, and therefore the time it takes to safely cross is greater. Trucks are particularly at risk in such a situation because elements of the truck cab environment can further obscure the truckdriver's vision of the train.

The Safety Board examined the angle of intersection to the right of the roadway on the side of the crossing from which each accident-involved vehicle approached.[6] In 27 of the 60 study accident grade crossings (45 percent), the roadway did not meet the tracks at right angles. The Board's study cases suggest that when the angle of intersection deviates from 90°, safety may be compromised.

Roadway or Track Curvature

Roadway or track curvature can also affect a driver's ability to see an oncoming train. Twenty-five of the 60 crossings in the Board's sample had track and/or roadway curvature: 9 sets of tracks were curved within the vicinity of the crossing, 13 of the roadways had curves on the sections leading to the crossing, and 3 crossings had curves on both the railroad tracks and the highway. There is no nationwide information on roadway or track curvature for comparison, thus

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[5] AASHTO (1990, page 686).

[6] For consistency, the Safety Board selected the angle on the right side of the intersection, although measurements taken from the left side would also have provided sufficient information

it is impossible to determine whether or not the study sample contains an inordinately high number of crossings with nearby curves in either the highway or the tracks.

AASHTO guidelines state that "to the extent possible, crossings should not be located on either highway or railroad curves."[7] Research into human perception shows that when a driver's trajectory includes a curve, the task of determining the speed and distance of another vehicle is much more difficult. Further, the highway vehicle driver may be distracted by the effort to correctly negotiate the curve.[8] Curves on the railroad tracks can obstruct a driver's view of the train, both on the approach to the crossing and while stopped at the crossing. In addition, AASHTO states that crossings where both the highway and the railroad tracks are curved provide "poor rideability for highway traffic due to conflicting superelevations."[9] This poor ride may cause a driver to concentrate on controlling the highway vehicle rather than looking for trains. Thus, on roads where either the roadway or tracks, or both, have a curve on the approach to the crossing, the highway vehicle driver may fail to recognize the hazards presented by the crossing until it is too late.

Driver Expectations

Driver attention at railroad crossings has been measured indirectly by watching drivers' head movements as they approach the crossing. An Australian study on human factors in grade crossing accidents shows that drivers' looking behavior, as determined by observable head movements, is far from optimal at grade crossings, with only about 30 percent of the drivers approaching a passive or active crossing conducting a search for a train.[10] Not only did very few of the drivers in that study look, but many of those that did look waited until just before the crossing, and some were still looking as their vehicles went over the crossing.

One factor that can affect whether a driver looks for a train is the driver's expectation of seeing a train. Overall, each of the 18 drivers interviewed by the Safety Board underestimated the frequency of train crossings per day, typically by a factor of 2 to 3. This low estimate suggests that drivers do not expect trains and thus may not look for trains at a crossing. Further, many train movements are unscheduled and would not be known even to drivers who are familiar with the crossing and with scheduled train traffic.

The driver's perception that a train is not likely to be at the crossing is reinforced each time that driver passes the crossing without seeing a train. Researchers have reported that a driver's response to a potential hazard is a function of both the perceived probability of the

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[7] AASHTO (1990, page 842).

[8] Berthelon, C. 1993. Curvilinear approach to an intersection and visual detection of a collision. Human Factors 35(3): 521–534 (page 522).

[9] (a) AASHTO (1990, page 842). (b) Superelevation is the technical term describing the angle at which a roadway is banked to enable a vehicle to operate smoothly around a curve at the design speed.

[10] Wigglesworth, E.C. [Royal Australasian College of Surgeons, Melbourne]. 1976. Report on human factors in road-rail crossing accidents. Melbourne, Victoria, Australia: Ministry of Transport. [Inclusive pages not known] (page 83).

adverse event occurring and of the driver's understanding of the severity of the consequence of the event.[11] A person's perception of the probability of a given event is strongly influenced by past experience,[12] and the frequency with which the driver encounters a train at a crossing will influence the likelihood of that driver stopping.

Personal circumstances also cause a driver to associate certain costs with the outcome of a decision to stop or not to stop. Stopping might make the driver late, or result in a collision with the highway vehicle behind; conversely, not stopping might result in an accident with a train. Research in signal detection theory has shown that because the frequency of trains at grade crossings is so low, drivers tend to bias their behavior toward not stopping.[13] The FRA has used signal detection theory models to predict which crossings are likely to have accidents and has found that a low train frequency at crossings is associated with a higher rate of accidents.

Driver Perception of
Train Speed and Distance

Even when a driver looks for a train, it may be difficult to accurately gauge the speed and arrival time of an approaching train. Once the train is detected, a driver must decide whether it is safe to proceed across the tracks and then take appropriate action. Guiding this decision will be the driver's perceptual judgments of train velocity and distance. The difficulty of making this judgment is illustrated by the following accidents.

About 10:40 p.m. on August 12, 1996, in Columbus, Ohio, a truckdriver was hauling trash to a nearby lot (case 58). As he approached a private passive crossing, he observed a Conrail train that appeared to be standing still near the crossing. According to the Conrail police department incident report, the locomotive headlight was illuminated; auxiliary lighting use is unknown. According to the traincrew, the train horn was not sounded prior to the accident. As the truckdriver reached the crossing, he realized the train was moving. His realization came too late to avoid the collision.

On March 20, 1996, a tanker truckdriver was leaving a company lot in Clairton, Pennsylvania, heading toward a two-track crossing (case 15). As he approached the crossing, he had an unobstructed view of the tracks. Looking down the tracks, he saw a Conrail freight train in the distance and decided it was safe to cross. According to the locomotive event recorder, the train horn was sounded prior to the accident; according to the traincrew, the locomotive headlight

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[11] Schoppert, D.W.; Hoyt, D.W. 1968. Factors influencing safety at highway-rail grade crossings. National Cooperative Highway Research Program Report 50. Washington, DC: National Academy of Sciences: National Academy of Engineering. 113 p. (page 96).

[12] Schoppert and Hoyt (1968, page 97).

[13] Raslear, Thomas. 1996. Driver behavior at rail-highway grade crossings: A signal detection theory analysis. In: Safety of highway-railroad grade crossings: research needs workshop. Vol. II: Appendices. DOT/FRA/ORD-95/14.2; DOT-VNTSC-FRA-95-12.2. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration: F-9 through F-56 (page F-22). [Workshop held at and in conjunction with Volpe National Transportation Systems Center, Cambridge, MA.]

was illuminated. However, the driver misjudged how fast the train was moving, and as the truck crossed the tracks, it was struck by the freight train.

Moving with traffic, merging into traffic, and turning left or right in front of traffic are daily tasks that require a driver to judge the speed and distance of other highway vehicles. Similarly, a driver must judge the speed and distance of an oncoming train to gauge the train's arrival at a grade crossing. However, visual illusions can interfere with the driver's perception of train velocity and distance. For example, an illusion of perspective can mislead a driver about the train's distance:

> Viewed from the crossing, railroad tracks produce the illusion of a great distance. That is because the parallel lines of the rails converge toward the horizon. (It is the same illusion used in art classes to create perspective.) The apparent convergence of the rails give the impression that the train is farther from the crossing than it is.[14]

Research describes illusions regarding train size that can mislead a motorist about the train's velocity.[15] First, the larger an object, the more slowly it appears to be moving; thus, because the train locomotive is a large object, it may appear to be moving more slowly than it is, causing the driver to overestimate the amount of time available to safely clear the crossing. Second, when a car and train are approaching each other at constant speeds, or when a vehicle is stopped at a crossing and looking down the tracks, the principal perceptual cue available to the driver is the rate of growth of the train's apparent size in the visual field. This apparent rate of growth is not linear but hyperbolic. When the train is at a distance, the apparent rate of growth for the object is slow, thereby giving the impression of slow speed. However, as the train gets closer, the increase in the size of the object in the visual field accelerates. For example, a 10-foot-wide by 15-foot-tall locomotive will occupy a visual angle of 0.43° when it is 2,000 feet from the observer. As the train reaches 1,000 feet, the locomotive's visual angle has doubled to 0.86°. When the train is even closer to the observer, the visual angle also doubles even though the train traverses less distance: the visual angle grows from 3.43° to 6.84° when the train travels from 250 feet to 125 feet from the observer. Drivers tend to be effective at estimating the speed of the train when it is closest because the change in visual angle is rapid. However, drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances, when the change in visual angle is slow and they are more likely to underestimate the train's speed.

Night also adds to the difficulty in perceiving train speed and distance. Drivers can determine train speed by comparing the train movement with that of the background. However, at night the background is not visible and drivers lose this important cue. The driver in case 58, described previously, who believed a slow moving train was standing still was observing the train at night.

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[14] Operation Lifesaver, Inc. 1997. School bus driver presentation. In: Operation Lifesaver Presenter Guide. Alexandria, VA. [Section 7, page 15].

[15] Liebowitz, H.W. 1985. Grade crossing accidents and human factors engineering. American Scientist 73: 558-562.

Driver Distractions

Objects or events both inside and outside a vehicle can provide competing stimuli or distractions that reduce driver attentiveness to the task of looking for a train. For example, as the driver in case 37 approached a passive crossing, she was reaching into the back seat to get some food for her child. Prior to entering the crossing, she looked up, saw a train, and hit the brakes. The driver was unable to stop the vehicle before striking the train.

Of the 18 interviewed drivers, 8 indicated they had been distracted by at least one source.[16] Stereo systems and passengers were the internal sources of distraction most frequently cited by these drivers; highway traffic was the external source most frequently identified. Two other drivers indicated that they might have been distracted, but they could not identify the source of distraction. The Safety Board cited distraction as the primary probable cause or contributing factor in 12 of the 60 study accidents: 2 nonfatal accidents, and 10 fatal accidents.

Passengers, particularly passenger conversation, was a common source of distraction. Three interviewed drivers stated that they were talking with passengers in their vehicles at the time of the accident, and in a fourth instance (case 6), witnesses stated they saw the driver talking with his passenger (both the driver and the passenger in the highway vehicle were fatally injured in the accident). Research indicates that passenger distraction accounts for the second biggest source of distraction in accidents; objects in the vehicle is the biggest source.[17]

Another source of driver distraction was highway traffic. Three interviewed drivers were distracted by oncoming traffic, and in two of the fatal accidents (cases 41 and 50), distraction attributed to highway traffic was cited in the accident's probable cause. In two of the study accidents, the drivers apparently were preoccupied with vehicles directly in front of them: the fatally injured driver in case 53 followed closely behind a vehicle that cleared the crossing just before the train arrived, and the fatally injured driver in case 41 stopped his vehicle on the tracks to wait for a vehicle in front of him to clear a nearby highway intersection. Even other drivers' attempts to warn of an oncoming train can distract drivers. In one accident (case 40), a driver was focused on another car flashing its headlights. The driver reported that he believed the flashing headlights indicated an impending speed trap; the driver continued into the path of a train.

Intersecting roads and traffic may also distract a driver from looking for a train. When another road intersects with the driver's roadway just before or after the grade crossing, it may increase the number of decisions the driver must make and distract the driver from looking for a train. Similarly, a driver may also be presented with multiple decisions when encountering a grade crossing immediately after turning off of an intersecting roadway onto a road with a grade crossing.

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[16] One of the eight drivers was not in the highway vehicle at the time of the accident: the vehicle had stalled while traversing the tracks and the driver had time to get out before the train arrived.

[17] Tijerina, Louis; Kiger, Steven M.; Rockwell, Thomas H.; Tornow, Carina. 1995. Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. In: Proceedings, 39th annual meeting of the Human Factors and Ergonomic Society, Vol. 2; 1995 October 9-13; San Diego, CA. Santa Monica, CA: Human Factors and Ergonomics Society: 1117-1121.

In the afternoon of June 21, 1996, the driver of a Buick Park Avenue approached a grade crossing in Pickerington, Ohio (case 41). About 22 feet beyond the tracks was an intersection with another city street. A car traveling in the same direction as the Buick had just crossed the tracks and was stopped at the intersection. According to witnesses, the driver of the Buick, who appeared to be using a cellular phone, was stopped on the tracks waiting for the vehicle in front of him to clear the intersection. While stopped, the Buick was struck by an arriving Conrail freight train, and the driver was killed.

For the purposes of this study, the Safety Board defined a nearby intersection to be one that lay within 75 feet of the crossing.[18] Twenty-nine of the grade crossings in the study cases had nearby highway intersections: on the far side of the crossing in 12 of the study cases, on the side of the crossing from which the accident-involved highway driver approached in 13 cases, and on both sides of the crossing in 4 cases.

A nearby highway intersection may present a distraction to the driver simply because the driver is aware of it. If a highway intersection on the departure side of the crossing is visible to an approaching driver, the driver's attention may be drawn toward that intersection and away from the crossing. This may be particularly hazardous in urban areas, where the driver's concern for traffic at the upcoming intersection may result in stopping directly on the tracks, as was the case in Pickerington, Ohio. In other situations, the driver of a vehicle turning off a parallel roadway may come upon the crossing before being able to direct attention away from negotiating the turn; at four study crossings, the highway intersection was less than 25 feet from the crossing (cases 1, 15, 44, and 58). In addition, if a train comes from the same direction as a highway vehicle on the parallel roadway, it will come from behind the vehicle, and a driver turning onto the road with the grade crossing may have few moments to react.

The presence of nearby intersections increases the risk at passive crossings. In an Australian study, it was discovered that at a crossing with a nearby intersection, "driver head movements and [train] search at Stanhope [the location of the crossing] were directed firstly at determining the presence of other road users and secondly at assessing the possible development of conflict situations."[19] The drivers observed in that study were more concerned with the dangers presented by other highway traffic and considered the grade crossing only secondarily.

Because nearby intersections could present problems for motorists at passive grade crossings, the Safety Board examined the FRA databases to determine how common nearby intersections are. Of the study accident crossings, 46.7 percent (28 of the 60) qualify as having a nearby intersection on either the approach or the departure side of the crossing, whereas 37.7 percent of all public passive crossings have such nearby intersections. The higher percentage of grade crossings with nearby intersections in the study sample than in the FRA inventory database

[18] The measurement of 75 feet is not intended to indicate an absolute boundary. Intersections farther from (or closer to) a crossing than 75 feet may still present the opportunity for driver distraction. The FRA inventory database indicates the presence of nearby highway intersections within 75 feet of the crossing; therefore, the Safety Board selected a cutoff point of 75 feet to facilitate comparison between the study data and data in the FRA inventory database.

[19] Wigglesworth (1976, page 80).

suggests that nearby intersections may be a factor associated with passive grade crossing accidents.

The Safety Board concludes that the physical characteristics described above (sight distances, angle of intersection, roadway or track curvature, and nearby roadway intersections) can affect the level of safety at passive grade crossings. Roadway and/or track conditions, which include all these characteristics, were determined to be the primary probable cause or a contributing factor in 20 of the 60 study accidents.

Although the Federal Highway Administration's *Railroad–Highway Grade Crossing Handbook*[20] and the AASHTO's Greenbook provide guidance to assist highway engineers in the physical and geometric design of safe roadway systems, the characteristics at 55 of the 60 study crossings failed to adhere to at least one of these guidelines.

Driver Education

The Safety Board's study indicates that the motoring public does not clearly understand the level of risk at passive crossings and the need for full driver attention each time a crossing is used. Further, in a 1988 survey conducted by the University of Tennessee, researchers asked drivers what motorists should do when approaching a crossing that does not have railroad signals. In response, 24.3 percent of the drivers said that the driver should slow down and be prepared to stop (which was determined by the researchers to be the correct response), 69.6 percent declared that one should "stop, look, and listen at the crossing for a train," and 6.1 percent stated that the question was "not applicable, because all crossings have railroad signals."[21] The Safety Board examined material from various driver educational programs to determine if passive crossings, the inherent risk at these crossings, and the driver's tasks were adequately addressed.

Highway safety education is provided to motorists by several organizations. The American Association of Motor Vehicle Administrators (AAMVA), founded in 1933, is a voluntary, not-for-profit educational organization representing the State and provincial officials in the United States and Canada who are responsible for the administration and enforcement of motor vehicle laws. The AAMVA serves as an "information clearinghouse" for motor vehicle administration, police traffic services, and highway safety.[22] The Professional Truck Drivers Institute of America (PTDIA) develops curriculum and certification standards for training entry-level truck drivers. Operation Lifesaver (OL) is a not-for-profit organization that provides information about grade crossing safety to motor vehicle operators through safety educational

[20] U.S. Department of Transportation, Federal Highway Administration. 1986. Railroad-highway grade crossing handbook. 2nd ed. FHWA-TS-86-215. Washington, DC. 261 p.

[21] Richards, Stephen H.; Heathington, K.W. 1988. Motorist understanding of railroad-highway grade crossing traffic control devices and associated traffic laws. In: Traffic control devices 1988. Transportation Research Record 1160. Washington. DC: Transportation Research Board, National Research Council: 52-59.

[22] Information obtained on May 4, 1998, from the Web site of the American Association of Motor Vehicle Administrators: http://www.aamva.org/aboutaamva.html.

programs.[23] The American Automobile Association (AAA) has been involved in driver education since the mid-1930s. The AAA writes and provides driver education materials for use in high school and in professional driver's schools, conducts programs to assist driver education teachers with their preparations, and also conducts driver improvement programs for the general population.[24]

A review of the driver education material developed by the above organizations found that very little information is provided on the dangers of passive grade crossings or what actions are required of drivers at passive crossings. The AAA materials reviewed by the Board specify that passive grade crossings require more care on the part of the driver but do not discuss physical characteristics at grade crossings that can affect the driver's ability to see an approaching train. The PTDIA course outline material reviewed by the Board makes no mention of grade crossings.

Further, a review of the OL *Presenter Trainer's Manual* found that the section on school bus driver presentation addresses the visual illusions to which a driver is subject. However, the manual does not contain information about the unique problems present at passive grade crossings that require full driver attention, nor does it discuss how the physical characteristics of the crossing may affect the driver's ability to see a train approaching. Attendees at OL courses may not be aware of the unique dangers present at passive grade crossings because OL presentations do not address issues specific to passive grade crossings.

The Safety Board is also concerned that the States' written driver examinations may not always address issues specific to the dangers of passive grade crossings. According to one witness at the Safety Board's public forum, the motor vehicle administration in his State has five versions of the written driver's examination, only two of which contain a single question about grade crossings.[25] The Safety Board concludes that the dangers of passive grade crossings are not adequately addressed in current driver education material or in the States' written driver examination tests. The Safety Board is recommending, therefore, that the States ensure that questions on safety at passive grade crossings are included in every version of the State's written driver examinations. Further, the Safety Board believes that Operation Lifesaver, the American Association of Motor Vehicle Administrators, the American Automobile Association, and the Professional Truck Drivers Institute of America should include in their training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. The Safety Board also believes that OL, the AAMVA, the AAA, and the PTDIA should develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs.

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[23] OL volunteers give speeches at schools and community associations, and prepare exhibits for regional fairs, in addition to other activities.

[24] Telephone conversation with staff at the national office of the AAA, May 13, 1997.

[25] Remarks by a representative of the Missouri State Police. In: Transcript of the NTSB public forum on safety at passive grade crossings (page 96).

Therefore, the National Transportation Safety Board recommends that the Professional Truck Drivers Institute of America:

> Include in training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. (H-98-38)
>
> Develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs. (H-98-39)

Also as a result of this study, the Safety Board issued recommendations to the U.S. Department of Transportation, the Federal Railroad Administration, the National Highway Traffic Safety Administration, the Federal Highway Administration, the States, Operation Lifesaver, Inc., the American Association of Motor Vehicle Administrators, the American Automobile Association, the Advertising Council, Inc., the American Association of State Highway and Transportation Officials, the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transit Association.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility ". . . to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-98-38 and -39 in your reply.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman

M)5

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: AUG 11 1998

In reply refer to: H-98-38 and -39

Mr. Bob Darbelnet
President
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More than 4,000 accidents have occurred at the Nation's active and passive grade crossings each year from 1991 through 1996. Many of the accidents at active crossings have involved highway vehicle drivers who did not comply with train-activated warning devices installed at the crossings. This failure to comply often includes driver actions resulting from a deliberate decision, such as driving around a lowered crossing gate arm or ignoring flashing lights. Drivers at passive crossings are not provided warnings from train-activated devices; consequently, they must rely on a system of grade crossing signs and pavement markings, passive devices, that are designed to warn drivers only of the presence of a crossing. No element of this passive system changes to alert drivers to an oncoming train. Further, the effectiveness of the passive system is influenced by characteristics of the physical layout of the crossing, such as an adequate view of the area surrounding the crossing (sight distance) and roadway alignment, that affect the information given to an approaching motorist regarding an upcoming hazard.

According to the Federal Railroad Administration (FRA), there were 4,054 accidents in 1996 that involved highway vehicles at grade crossings; 54 percent (2,208) of those accidents occurred at passive grade crossings. About 60 percent of the fatalities from all grade crossing accidents in 1996 (247 of 415 fatalities) were at passive grade crossings.

The cost to eliminate or upgrade passive grade crossings is very high. According to the General Accounting Office, the average cost of adding lights and gates in 1995 was $150,000 per grade crossing. The total cost to upgrade the 96,759 passive crossings on public roadways would be about $14 billion. Gates and lights do not completely eliminate the hazards present at crossings, and, therefore, sole reliance on them would reduce but not eliminate all the fatalities. The ultimate solution from a safety standpoint would be a standard grade separation, which usually involves construction of bridges or overpasses and costs an estimated $3 million per crossing. The large number of passive grade crossings, the high percentage of fatalities that occur at passive grade crossings, and the cost to eliminate or upgrade passive grade crossings prompted the Safety Board to conduct a study to identify some of the common causes for accidents at

passive grade crossings, and to identify less costly remedies to improve safety at passive crossings not scheduled for closure or upgrade.[1]

For this study, the Safety Board investigated 60 grade crossing accidents that occurred between December 1995 and August 1996. The Safety Board selected for study accidents involving a collision between a train and a highway vehicle occurring at a passive grade crossing, wherein the highway vehicle was sufficiently damaged to require towing. The sample of accidents is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents.

In May 1997, the Safety Board convened a 2-day public forum in Jacksonville, Florida, to gather information about issues affecting safety at passive grade crossings. Witnesses included experts from the railroad industry; law enforcement; research groups; Operation Lifesaver; and Federal, State, and local government agencies. Those involved in grade crossing accidents, both highway vehicle occupants and traincrews, testified about their personal experiences. In addition, representatives from Canada and Italy discussed passive grade crossing issues and experiences in their countries.

Detecting a train at a passive crossing and making the correct decisions about whether a highway vehicle should stop at the crossing or can cross the tracks safely before the train arrives is a complex task that has confronted the Nation's motoring public for decades. The task is affected by the driver's ability to (1) detect the presence of the crossing, (2) detect the presence of a train, and (3) accurately gauge the train's speed and arrival time at the crossing. The task is further complicated by the driver's attention at a crossing, which as shown in the Safety Board's study, can be affected by what that individual expects to see. The Safety Board concludes that a driver's decision to look for a train may be adversely affected by the driver's familiarity with and expectations at a specific passive grade crossing and the driver's experience with passive crossings in general. Also, as shown in the Board's study, the train horn—one of only two active signals given to a driver to alert the driver that a train is present—is effective as a warning only if the driver recognizes it as a train horn. The Safety Board, therefore, concludes that in some circumstances, audible warning devices on trains fail to meet their objective of alerting motorists to an oncoming train because of highway vehicle design and environmental factors.

Despite the complexity of the task, the approach to passive grade crossing safety has remained relatively unchanged over the years. The current approach includes providing a sight distance triangle for an approaching motorist to see a train and installing a railroad crossing advance warning sign, pavement markings, and a crossbuck sign, where appropriate. The accident sample in the Safety Board's study illustrates that this approach has been inadequate in many instances.

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[1] National Transportation Safety Board. 1998. Safety at passive grade crossings. Volume 1: Analysis. Safety Study NTSB/SS-98/02. Washington, DC.

To eliminate the continuing problems encountered by the motoring public at passive crossings, the Safety Board concludes that a systematic and hierarchic approach to improving passive grade crossing safety is needed, an approach that does not depend primarily on the ability of the driver approaching the crossing to see an oncoming train. The hierarchic approach includes grade separation and closure, installation of active warning devices, improved signage, and intelligent transportation systems technology. The approach includes immediate and long-term measures. Concurrent with this approach is the need to educate drivers about the hazards of passive grade crossings.

The Safety Board's study identified several physical characteristics at passive highway–rail grade crossings that appear to contribute to the occurrence of accidents because they make it difficult for the motorist to see a train (inadequate sight distance, roadway-track intersection angles less than 90°, and roadway and track curvature), and/or because they distract the motorist's attention from the task of looking for a train (nearby roadway intersections). Further, a driver's attention at a crossing can be affected by what that individual expects to see and by distractions inside and outside the vehicle. This letter addresses these factors as they relate to driver education.

Sight Distance

Sight distance is the technical term describing the set of distances along the highway and along the railroad tracks needed by a motorist to detect the presence of a train in time to stop. According to American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets*[2] (the Greenbook), a grade crossing should be designed so that an approaching motorist is able to perceive the train, react to its presence, and stop the highway vehicle prior to the crossing. The required distance along the roadway (that is, from the vehicle to the crossing) and along the railroad tracks (from the crossing to the oncoming train) form two sides of a triangle. Together with the third side (an imaginary line from the train back to the highway vehicle) they form an area referred to as "quadrant sight distance," or the "sight triangle," the interior of which should be clear of any visual obstructions. For a vehicle stopped at the crossing, the driver must be able to see the train far enough along the tracks to have time to accelerate the vehicle and clear the crossing before the train's arrival.

The quadrant sight distance needed varies according to the speed of the train and of the highway vehicle, as well as the length and stopping distance of the highway vehicle. It is also affected by the angle at which the highway intersects the tracks and the slope of the roadway. When a grade crossing is designed, sight distances should be calculated by highway engineers. A stopped vehicle will need more sight distance along the track to see the oncoming train and cross the track before the train arrives, whereas a moving vehicle will need enough sight distance along the highway approach to the crossing to see the train along the tracks and to have time to stop.

[2] American Association of State Highway and Transportation Officials. 1990. A policy on geometric design of highways and streets, 1990. Washington, DC. 1044 p.

The railroad track approaches at the accident crossings in the Safety Board's study were generally straight, and the sight distance along the tracks that was available to the drivers of most types of highway vehicles stopped at the crossing stop line was, for the most part, adequate (n = 50). In 10 cases, however, there were sight obstructions for a driver stopped at a crossing: in 7 cases, vegetation restricted visibility; in 2 cases, curvature of the tracks restricted visibility; and in 1 case, a building restricted visibility.

The generally adequate sight distance for vehicles stopped at the crossings, however, did not hold true for motorists approaching the crossings. In 33 cases, the grade crossing area afforded an approaching motorist less sight distance than was recommended by AASHTO guidelines.[3] At the majority of the crossings with limited sight distance (n = 24), the obstructions were trees, shrubs, or other types of plants: in one case, the trees were described as a forest (case 27); and in another case, the trees were fruit trees in an orchard (case 60). Six of the 33 cases had visual obstructions that included buildings, and in one of these cases the motorist's sight distance was obstructed by a hill. The following accident illustrates the potential consequences of inadequate sight distances for drivers of highway vehicles in motion.

About 8:15 a.m. on April 5, 1996, an eastbound Kansas City Southern freight train traveling about 40 mph struck a northbound Mazda at Golson Road near Calhoun, Louisiana (case 16).[4] The Mazda, traveling about 25 mph, which was about 10 mph below the posted speed limit, skidded onto the railroad tracks when the driver tried too late to stop her vehicle. The driver and her 8-year-old daughter in the right front seat of the car were both killed.

According to the AASHTO guidelines and based on the speeds of the highway vehicle and train in this case, the highway driver needed a clear sight triangle defined by a distance of 271 feet along the highway and 422 feet along the railroad tracks to see the train with enough time to safely stop the vehicle. However, because of the presence of a forested area on private property adjacent to the crossing, this sight triangle was not clear. The driver in this case actually had a clear sight triangle with only 72 of the 271 feet needed along the highway and 112 of the 422 feet needed along the railroad tracks. By the time the driver saw the train and applied the brakes, she did not have enough time to stop the vehicle prior to the crossing.

In addition to calculating the sight distance for each of the 60 accident crossings, the Safety Board also examined each crossing in terms of the time an approaching motorist needs to safely stop the vehicle prior to the crossing compared with the actual time available, given the sight distance along the highway. The differences in time needed compared with actual time available ranged from no shortage of time for some crossings to a shortage of 7½ seconds. For 18 (58 percent) of the crossings with limited sight distance, an approaching driver has only half or less of the time needed to safely negotiate the crossing. With such differences between the time needed and the time available, the driver's task to safely negotiate the crossing becomes more

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[3] Three of the 33 crossings with limited sight distance for approaching motorists were on private roads.

[4] According to the traincrew, the locomotive headlight and auxiliary alerting lights were illuminated, and the train horn was sounded prior to the accident.

difficult. The Safety Board's study cases show a strong association between inadequate sight distance and accident occurrence.

Angle of Intersection

The angle at which the roadway meets the railroad tracks may also affect the driver's ability to see an oncoming train. The following accident illustrates this problem.

About 1:10 p.m. on Thursday, May 30, 1996, a northbound Pontiac Grand Am struck a westbound Consolidated Rail Corporation (Conrail) freight train traveling about 48 mph at a passive grade crossing near Montrose, Illinois (case 37). The speed limit along the road was 55 mph. The driver, who was transporting her 3-year-old child, stated that she slowed her vehicle when approaching the crossing, but she did not hear or see the train until just before impact. There were no injuries associated with this accident, but the vehicle was destroyed. Although there were no obstacles in the sight triangle for the approaching motorist, the highway met the railroad tracks at an angle of 35°; thus, the train approached essentially from behind the highway vehicle.

According to AASHTO guidelines, "[r]egardless of the type of intersection, for safety and economy, intersecting roads should generally meet at or nearly at right angles." AASHTO recommends that when there is an acute angle of intersection, the road be realigned so that the angle of intersection can be more nearly 90°.[5] The distance a highway vehicle must traverse in order to clear the intersection is greater when the angle is skewed, and therefore the time it takes to safely cross is greater. Trucks are particularly at risk in such a situation because elements of the truck cab environment can further obscure the truckdriver's vision of the train.

The Safety Board examined the angle of intersection to the right of the roadway on the side of the crossing from which each accident-involved vehicle approached.[6] In 27 of the 60 study accident grade crossings (45 percent), the roadway did not meet the tracks at right angles. The Board's study cases suggest that when the angle of intersection deviates from 90°, safety may be compromised.

Roadway or Track Curvature

Roadway or track curvature can also affect a driver's ability to see an oncoming train. Twenty-five of the 60 crossings in the Board's sample had track and/or roadway curvature: 9 sets of tracks were curved within the vicinity of the crossing, 13 of the roadways had curves on the sections leading to the crossing, and 3 crossings had curves on both the railroad tracks and the highway. There is no nationwide information on roadway or track curvature for comparison, thus

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[5] AASHTO (1990, page 686).

[6] For consistency, the Safety Board selected the angle on the right side of the intersection, although measurements taken from the left side would also have provided sufficient information.

it is impossible to determine whether or not the study sample contains an inordinately high number of crossings with nearby curves in either the highway or the tracks.

AASHTO guidelines state that "to the extent possible, crossings should not be located on either highway or railroad curves."[7] Research into human perception shows that when a driver's trajectory includes a curve, the task of determining the speed and distance of another vehicle is much more difficult. Further, the highway vehicle driver may be distracted by the effort to correctly negotiate the curve.[8] Curves on the railroad tracks can obstruct a driver's view of the train, both on the approach to the crossing and while stopped at the crossing. In addition, AASHTO states that crossings where both the highway and the railroad tracks are curved provide "poor rideability for highway traffic due to conflicting superelevations."[9] This poor ride may cause a driver to concentrate on controlling the highway vehicle rather than looking for trains. Thus, on roads where either the roadway or tracks, or both, have a curve on the approach to the crossing, the highway vehicle driver may fail to recognize the hazards presented by the crossing until it is too late.

Driver Expectations

Driver attention at railroad crossings has been measured indirectly by watching drivers' head movements as they approach the crossing. An Australian study on human factors in grade crossing accidents shows that drivers' looking behavior, as determined by observable head movements, is far from optimal at grade crossings, with only about 30 percent of the drivers approaching a passive or active crossing conducting a search for a train.[10] Not only did very few of the drivers in that study look, but many of those that did look waited until just before the crossing, and some were still looking as their vehicles went over the crossing.

One factor that can affect whether a driver looks for a train is the driver's expectation of seeing a train. Overall, each of the 18 drivers interviewed by the Safety Board underestimated the frequency of train crossings per day, typically by a factor of 2 to 3. This low estimate suggests that drivers do not expect trains and thus may not look for trains at a crossing. Further, many train movements are unscheduled and would not be known even to drivers who are familiar with the crossing and with scheduled train traffic.

The driver's perception that a train is not likely to be at the crossing is reinforced each time that driver passes the crossing without seeing a train. Researchers have reported that a driver's response to a potential hazard is a function of both the perceived probability of the

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[7] AASHTO (1990, page 842).

[8] Berthelon, C. 1993. Curvilinear approach to an intersection and visual detection of a collision. Human Factors 35(3): 521–534 (page 522).

[9] (a) AASHTO (1990, page 842). (b) Superelevation is the technical term describing the angle at which a roadway is banked to enable a vehicle to operate smoothly around a curve at the design speed.

[10] Wigglesworth, E.C. [Royal Australasian College of Surgeons, Melbourne]. 1976. Report on human factors in road-rail crossing accidents. Melbourne, Victoria, Australia: Ministry of Transport. [Inclusive pages not known] (page 83).

adverse event occurring and of the driver's understanding of the severity of the consequence of the event.[11] A person's perception of the probability of a given event is strongly influenced by past experience,[12] and the frequency with which the driver encounters a train at a crossing will influence the likelihood of that driver stopping.

Personal circumstances also cause a driver to associate certain costs with the outcome of a decision to stop or not to stop. Stopping might make the driver late, or result in a collision with the highway vehicle behind; conversely, not stopping might result in an accident with a train. Research in signal detection theory has shown that because the frequency of trains at grade crossings is so low, drivers tend to bias their behavior toward not stopping.[13] The FRA has used signal detection theory models to predict which crossings are likely to have accidents and has found that a low train frequency at crossings is associated with a higher rate of accidents.

Driver Perception of Train Speed and Distance

Even when a driver looks for a train, it may be difficult to accurately gauge the speed and arrival time of an approaching train. Once the train is detected, a driver must decide whether it is safe to proceed across the tracks and then take appropriate action. Guiding this decision will be the driver's perceptual judgments of train velocity and distance. The difficulty of making this judgment is illustrated by the following accidents.

About 10:40 p.m. on August 12, 1996, in Columbus, Ohio, a truckdriver was hauling trash to a nearby lot (case 58). As he approached a private passive crossing, he observed a Conrail train that appeared to be standing still near the crossing. According to the Conrail police department incident report, the locomotive headlight was illuminated; auxiliary lighting use is unknown. According to the traincrew, the train horn was not sounded prior to the accident. As the truckdriver reached the crossing, he realized the train was moving. His realization came too late to avoid the collision.

On March 20, 1996, a tanker truckdriver was leaving a company lot in Clairton, Pennsylvania, heading toward a two-track crossing (case 15). As he approached the crossing, he had an unobstructed view of the tracks. Looking down the tracks, he saw a Conrail freight train in the distance and decided it was safe to cross. According to the locomotive event recorder, the train horn was sounded prior to the accident; according to the traincrew, the locomotive headlight

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[11] Schoppert, D.W.; Hoyt, D.W. 1968. Factors influencing safety at highway-rail grade crossings. National Cooperative Highway Research Program Report 50. Washington, DC: National Academy of Sciences; National Academy of Engineering. 113 p. (page 96).

[12] Schoppert and Hoyt (1968, page 97).

[13] Raslear, Thomas. 1996. Driver behavior at rail-highway grade crossings: A signal detection theory analysis. In: Safety of highway-railroad grade crossings: research needs workshop. Vol. II: Appendices. DOT/FRA/ORD-95/14.2; DOT-VNTSC-FRA-95-12.2. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration: F-9 through F-56 (page F-22). [Workshop held at and in conjunction with Volpe National Transportation Systems Center, Cambridge, MA.]

was illuminated. However, the driver misjudged how fast the train was moving, and as the truck crossed the tracks, it was struck by the freight train.

Moving with traffic, merging into traffic, and turning left or right in front of traffic are daily tasks that require a driver to judge the speed and distance of other highway vehicles. Similarly, a driver must judge the speed and distance of an oncoming train to gauge the train's arrival at a grade crossing. However, visual illusions can interfere with the driver's perception of train velocity and distance. For example, an illusion of perspective can mislead a driver about the train's distance:

> Viewed from the crossing, railroad tracks produce the illusion of a great distance. That is because the parallel lines of the rails converge toward the horizon. (It is the same illusion used in art classes to create perspective.) The apparent convergence of the rails give the impression that the train is farther from the crossing than it is.[14]

Research describes illusions regarding train size that can mislead a motorist about the train's velocity.[15] First, the larger an object, the more slowly it appears to be moving; thus, because the train locomotive is a large object, it may appear to be moving more slowly than it is, causing the driver to overestimate the amount of time available to safely clear the crossing. Second, when a car and train are approaching each other at constant speeds, or when a vehicle is stopped at a crossing and looking down the tracks, the principal perceptual cue available to the driver is the rate of growth of the train's apparent size in the visual field. This apparent rate of growth is not linear but hyperbolic. When the train is at a distance, the apparent rate of growth for the object is slow, thereby giving the impression of slow speed. However, as the train gets closer, the increase in the size of the object in the visual field accelerates. For example, a 10-foot-wide by 15-foot-tall locomotive will occupy a visual angle of 0.43° when it is 2,000 feet from the observer. As the train reaches 1,000 feet, the locomotive's visual angle has doubled to 0.86°. When the train is even closer to the observer, the visual angle also doubles even though the train traverses less distance: the visual angle grows from 3.43° to 6.84° when the train travels from 250 feet to 125 feet from the observer. Drivers tend to be effective at estimating the speed of the train when it is closest because the change in visual angle is rapid. However, drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances, when the change in visual angle is slow and they are more likely to underestimate the train's speed.

Night also adds to the difficulty in perceiving train speed and distance. Drivers can determine train speed by comparing the train movement with that of the background. However, at night the background is not visible and drivers lose this important cue. The driver in case 58, described previously, who believed a slow moving train was standing still was observing the train at night.

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[14] Operation Lifesaver, Inc. 1997. School bus driver presentation. In: Operation Lifesaver Presenter Guide. Alexandria, VA. [Section 7, page 15].

[15] Liebowitz, H.W. 1985. Grade crossing accidents and human factors engineering. American Scientist 73: 558-562.

Driver Distractions

Objects or events both inside and outside a vehicle can provide competing stimuli or distractions that reduce driver attentiveness to the task of looking for a train. For example, as the driver in case 37 approached a passive crossing, she was reaching into the back seat to get some food for her child. Prior to entering the crossing, she looked up, saw a train, and hit the brakes. The driver was unable to stop the vehicle before striking the train.

Of the 18 interviewed drivers, 8 indicated they had been distracted by at least one source.[16] Stereo systems and passengers were the internal sources of distraction most frequently cited by these drivers; highway traffic was the external source most frequently identified. Two other drivers indicated that they might have been distracted, but they could not identify the source of distraction. The Safety Board cited distraction as the primary probable cause or contributing factor in 12 of the 60 study accidents: 2 nonfatal accidents, and 10 fatal accidents.

Passengers, particularly passenger conversation, was a common source of distraction. Three interviewed drivers stated that they were talking with passengers in their vehicles at the time of the accident, and in a fourth instance (case 6), witnesses stated they saw the driver talking with his passenger (both the driver and the passenger in the highway vehicle were fatally injured in the accident). Research indicates that passenger distraction accounts for the second biggest source of distraction in accidents; objects in the vehicle is the biggest source.[17]

Another source of driver distraction was highway traffic. Three interviewed drivers were distracted by oncoming traffic, and in two of the fatal accidents (cases 41 and 50), distraction attributed to highway traffic was cited in the accident's probable cause. In two of the study accidents, the drivers apparently were preoccupied with vehicles directly in front of them: the fatally injured driver in case 53 followed closely behind a vehicle that cleared the crossing just before the train arrived, and the fatally injured driver in case 41 stopped his vehicle on the tracks to wait for a vehicle in front of him to clear a nearby highway intersection. Even other drivers' attempts to warn of an oncoming train can distract drivers. In one accident (case 40), a driver was focused on another car flashing its headlights. The driver reported that he believed the flashing headlights indicated an impending speed trap; the driver continued into the path of a train.

Intersecting roads and traffic may also distract a driver from looking for a train. When another road intersects with the driver's roadway just before or after the grade crossing, it may increase the number of decisions the driver must make and distract the driver from looking for a train. Similarly, a driver may also be presented with multiple decisions when encountering a grade crossing immediately after turning off of an intersecting roadway onto a road with a grade crossing.

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[16] One of the eight drivers was not in the highway vehicle at the time of the accident: the vehicle had stalled while traversing the tracks and the driver had time to get out before the train arrived.

[17] Tijerina, Louis; Kiger, Steven M.; Rockwell, Thomas H.; Tornow, Carina. 1995. Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. In: Proceedings, 39th annual meeting of the Human Factors and Ergonomic Society, Vol. 2; 1995 October 9-13; San Diego, CA. Santa Monica, CA: Human Factors and Ergonomics Society: 1117-1121.

In the afternoon of June 21, 1996, the driver of a Buick Park Avenue approached a grade crossing in Pickerington, Ohio (case 41). About 22 feet beyond the tracks was an intersection with another city street. A car traveling in the same direction as the Buick had just crossed the tracks and was stopped at the intersection. According to witnesses, the driver of the Buick, who appeared to be using a cellular phone, was stopped on the tracks waiting for the vehicle in front of him to clear the intersection. While stopped, the Buick was struck by an arriving Conrail freight train, and the driver was killed.

For the purposes of this study, the Safety Board defined a nearby intersection to be one that lay within 75 feet of the crossing.[18] Twenty-nine of the grade crossings in the study cases had nearby highway intersections: on the far side of the crossing in 12 of the study cases, on the side of the crossing from which the accident-involved highway driver approached in 13 cases, and on both sides of the crossing in 4 cases.

A nearby highway intersection may present a distraction to the driver simply because the driver is aware of it. If a highway intersection on the departure side of the crossing is visible to an approaching driver, the driver's attention may be drawn toward that intersection and away from the crossing. This may be particularly hazardous in urban areas, where the driver's concern for traffic at the upcoming intersection may result in stopping directly on the tracks, as was the case in Pickerington, Ohio. In other situations, the driver of a vehicle turning off a parallel roadway may come upon the crossing before being able to direct attention away from negotiating the turn; at four study crossings, the highway intersection was less than 25 feet from the crossing (cases 1, 15, 44, and 58). In addition, if a train comes from the same direction as a highway vehicle on the parallel roadway, it will come from behind the vehicle, and a driver turning onto the road with the grade crossing may have few moments to react.

The presence of nearby intersections increases the risk at passive crossings. In an Australian study, it was discovered that at a crossing with a nearby intersection, "driver head movements and [train] search at Stanhope [the location of the crossing] were directed firstly at determining the presence of other road users and secondly at assessing the possible development of conflict situations."[19] The drivers observed in that study were more concerned with the dangers presented by other highway traffic and considered the grade crossing only secondarily.

Because nearby intersections could present problems for motorists at passive grade crossings, the Safety Board examined the FRA databases to determine how common nearby intersections are. Of the study accident crossings, 46.7 percent (28 of the 60) qualify as having a nearby intersection on either the approach or the departure side of the crossing, whereas 37.7 percent of all public passive crossings have such nearby intersections. The higher percentage of grade crossings with nearby intersections in the study sample than in the FRA inventory database

[18] The measurement of 75 feet is not intended to indicate an absolute boundary. Intersections farther from (or closer to) a crossing than 75 feet may still present the opportunity for driver distraction. The FRA inventory database indicates the presence of nearby highway intersections within 75 feet of the crossing; therefore, the Safety Board selected a cutoff point of 75 feet to facilitate comparison between the study data and data in the FRA inventory database.

[19] Wigglesworth (1976, page 80).

suggests that nearby intersections may be a factor associated with passive grade crossing accidents.

The Safety Board concludes that the physical characteristics described above (sight distances, angle of intersection, roadway or track curvature, and nearby roadway intersections) can affect the level of safety at passive grade crossings. Roadway and/or track conditions, which include all these characteristics, were determined to be the primary probable cause or a contributing factor in 20 of the 60 study accidents.

Although the Federal Highway Administration's *Railroad–Highway Grade Crossing Handbook*[20] and the AASHTO's Greenbook provide guidance to assist highway engineers in the physical and geometric design of safe roadway systems, the characteristics at 55 of the 60 study crossings failed to adhere to at least one of these guidelines.

Driver Education

The Safety Board's study indicates that the motoring public does not clearly understand the level of risk at passive crossings and the need for full driver attention each time a crossing is used. Further, in a 1988 survey conducted by the University of Tennessee, researchers asked drivers what motorists should do when approaching a crossing that does not have railroad signals. In response, 24.3 percent of the drivers said that the driver should slow down and be prepared to stop (which was determined by the researchers to be the correct response), 69.6 percent declared that one should "stop, look, and listen at the crossing for a train," and 6.1 percent stated that the question was "not applicable, because all crossings have railroad signals."[21] The Safety Board examined material from various driver educational programs to determine if passive crossings, the inherent risk at these crossings, and the driver's tasks were adequately addressed.

Highway safety education is provided to motorists by several organizations. The American Association of Motor Vehicle Administrators (AAMVA), founded in 1933, is a voluntary, not-for-profit educational organization representing the State and provincial officials in the United States and Canada who are responsible for the administration and enforcement of motor vehicle laws. The AAMVA serves as an "information clearinghouse" for motor vehicle administration, police traffic services, and highway safety.[22] The Professional Truck Drivers Institute of America (PTDIA) develops curriculum and certification standards for training entry-level truck drivers. Operation Lifesaver (OL) is a not-for-profit organization that provides information about grade crossing safety to motor vehicle operators through safety educational

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[20] U.S. Department of Transportation, Federal Highway Administration. 1986. Railroad-highway grade crossing handbook. 2nd ed. FHWA-TS-86-215. Washington, DC. 261 p.

[21] Richards, Stephen H.; Heathington, K.W. 1988. Motorist understanding of railroad-highway grade crossing traffic control devices and associated traffic laws. In: Traffic control devices 1988. Transportation Research Record 1160. Washington, DC: Transportation Research Board, National Research Council: 52-59.

[22] Information obtained on May 4, 1998, from the Web site of the American Association of Motor Vehicle Administrators: http://www.aamva.org/aboutaamva.html.

programs.[23] The American Automobile Association (AAA) has been involved in driver education since the mid-1930s. The AAA writes and provides driver education materials for use in high school and in professional driver's schools, conducts programs to assist driver education teachers with their preparations, and also conducts driver improvement programs for the general population.[24]

A review of the driver education material developed by the above organizations found that very little information is provided on the dangers of passive grade crossings or what actions are required of drivers at passive crossings. The AAA materials reviewed by the Board specify that passive grade crossings require more care on the part of the driver but do not discuss physical characteristics at grade crossings that can affect the driver's ability to see an approaching train. The PTDIA course outline material reviewed by the Board makes no mention of grade crossings.

Further, a review of the OL *Presenter Trainer's Manual* found that the section on school bus driver presentation addresses the visual illusions to which a driver is subject. However, the manual does not contain information about the unique problems present at passive grade crossings that require full driver attention, nor does it discuss how the physical characteristics of the crossing may affect the driver's ability to see a train approaching. Attendees at OL courses may not be aware of the unique dangers present at passive grade crossings because OL presentations do not address issues specific to passive grade crossings.

The Safety Board is also concerned that the States' written driver examinations may not always address issues specific to the dangers of passive grade crossings. According to one witness at the Safety Board's public forum, the motor vehicle administration in his State has five versions of the written driver's examination, only two of which contain a single question about grade crossings.[25] The Safety Board concludes that the dangers of passive grade crossings are not adequately addressed in current driver education material or in the States' written driver examinations. The Safety Board is recommending, therefore, that the States ensure that questions on safety at passive grade crossings are included in every version of the State's written driver examinations. Further, the Safety Board believes that Operation Lifesaver, the American Association of Motor Vehicle Administrators, the American Automobile Association, and the Professional Truck Drivers Institute of America should include in their training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. The Safety Board also believes that OL, the AAMVA, the AAA, and the PTDIA should develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs.

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[23] OL volunteers give speeches at schools and community associations, and prepare exhibits for regional fairs, in addition to other activities.

[24] Telephone conversation with staff at the national office of the AAA, May 13, 1997.

[25] Remarks by a representative of the Missouri State Police. In: Transcript of the NTSB public forum on safety at passive grade crossings (page 96).

Therefore, the National Transportation Safety Board recommends that the American Automobile Association:

> Include in training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. (H-98-38)
>
> Develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs. (H-98-39)

Also as a result of this study, the Safety Board issued recommendations to the U.S. Department of Transportation, the Federal Railroad Administration, the National Highway Traffic Safety Administration, the Federal Highway Administration, the States, Operation Lifesaver, Inc., the American Association of Motor Vehicle Administrators, the Professional Truck Drivers Institute of America, the Advertising Council, Inc., the American Association of State Highway and Transportation Officials, the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transit Association.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility ". . . to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-98-38 and -39 in your reply.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman

Rec Book

National Transportation Safety Board

Washington, D.C. 20594

Log H-596

Safety Recommendation

Date: AUG 11 1998

In reply refer to: H-98-38 and -39

Ms. Gerri Hall
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More than 4,000 accidents have occurred at the Nation's active and passive grade crossings each year from 1991 through 1996. Many of the accidents at active crossings have involved highway vehicle drivers who did not comply with train-activated warning devices installed at the crossings. This failure to comply often includes driver actions resulting from a deliberate decision, such as driving around a lowered crossing gate arm or ignoring flashing lights. Drivers at passive crossings are not provided warnings from train-activated devices; consequently, they must rely on a system of grade crossing signs and pavement markings, passive devices, that are designed to warn drivers only of the presence of a crossing. No element of this passive system changes to alert drivers to an oncoming train. Further, the effectiveness of the passive system is influenced by characteristics of the physical layout of the crossing, such as an adequate view of the area surrounding the crossing (sight distance) and roadway alignment, that affect the information given to an approaching motorist regarding an upcoming hazard.

According to the Federal Railroad Administration (FRA), there were 4,054 accidents in 1996 that involved highway vehicles at grade crossings; 54 percent (2,208) of those accidents occurred at passive grade crossings. About 60 percent of the fatalities from all grade crossing accidents in 1996 (247 of 415 fatalities) were at passive grade crossings.

The cost to eliminate or upgrade passive grade crossings is very high. According to the General Accounting Office, the average cost of adding lights and gates in 1995 was $150,000 per grade crossing. The total cost to upgrade the 96,759 passive crossings on public roadways would be about $14 billion. Gates and lights do not completely eliminate the hazards present at crossings, and, therefore, sole reliance on them would reduce but not eliminate all the fatalities. The ultimate solution from a safety standpoint would be a standard grade separation, which usually involves construction of bridges or overpasses and costs an estimated $3 million per crossing. The large number of passive grade crossings, the high percentage of fatalities that occur at passive grade crossings, and the cost to eliminate or upgrade passive grade crossings prompted the Safety Board to conduct a study to identify some of the common causes for accidents at

passive grade crossings, and to identify less costly remedies to improve safety at passive crossings not scheduled for closure or upgrade.[1]

For this study, the Safety Board investigated 60 grade crossing accidents that occurred between December 1995 and August 1996. The Safety Board selected for study accidents involving a collision between a train and a highway vehicle occurring at a passive grade crossing, wherein the highway vehicle was sufficiently damaged to require towing. The sample of accidents is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents.

In May 1997, the Safety Board convened a 2-day public forum in Jacksonville, Florida, to gather information about issues affecting safety at passive grade crossings. Witnesses included experts from the railroad industry; law enforcement; research groups; Operation Lifesaver; and Federal, State, and local government agencies. Those involved in grade crossing accidents, both highway vehicle occupants and traincrews, testified about their personal experiences. In addition, representatives from Canada and Italy discussed passive grade crossing issues and experiences in their countries.

Detecting a train at a passive crossing and making the correct decisions about whether a highway vehicle should stop at the crossing or can cross the tracks safely before the train arrives is a complex task that has confronted the Nation's motoring public for decades. The task is affected by the driver's ability to (1) detect the presence of the crossing, (2) detect the presence of a train, and (3) accurately gauge the train's speed and arrival time at the crossing. The task is further complicated by the driver's attention at a crossing, which as shown in the Safety Board's study, can be affected by what that individual expects to see. The Safety Board concludes that a driver's decision to look for a train may be adversely affected by the driver's familiarity with and expectations at a specific passive grade crossing and the driver's experience with passive crossings in general. Also, as shown in the Board's study, the train horn—one of only two active signals given to a driver to alert the driver that a train is present—is effective as a warning only if the driver recognizes it as a train horn. The Safety Board, therefore, concludes that in some circumstances, audible warning devices on trains fail to meet their objective of alerting motorists to an oncoming train because of highway vehicle design and environmental factors.

Despite the complexity of the task, the approach to passive grade crossing safety has remained relatively unchanged over the years. The current approach includes providing a sight distance triangle for an approaching motorist to see a train and installing a railroad crossing advance warning sign, pavement markings, and a crossbuck sign, where appropriate. The accident sample in the Safety Board's study illustrates that this approach has been inadequate in many instances.

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[1] National Transportation Safety Board. 1998. Safety at passive grade crossings. Volume 1: Analysis. Safety Study NTSB/SS-98/02. Washington, DC.

To eliminate the continuing problems encountered by the motoring public at passive crossings, the Safety Board concludes that a systematic and hierarchic approach to improving passive grade crossing safety is needed, an approach that does not depend primarily on the ability of the driver approaching the crossing to see an oncoming train. The hierarchic approach includes grade separation and closure, installation of active warning devices, improved signage, and intelligent transportation systems technology. The approach includes immediate and long-term measures. Concurrent with this approach is the need to educate drivers about the hazards of passive grade crossings.

The Safety Board's study identified several physical characteristics at passive highway–rail grade crossings that appear to contribute to the occurrence of accidents because they make it difficult for the motorist to see a train (inadequate sight distance, roadway-track intersection angles less than 90°, and roadway and track curvature), and/or because they distract the motorist's attention from the task of looking for a train (nearby roadway intersections). Further, a driver's attention at a crossing can be affected by what that individual expects to see and by distractions inside and outside the vehicle. This letter addresses these factors as they relate to driver education.

Sight Distance

Sight distance is the technical term describing the set of distances along the highway and along the railroad tracks needed by a motorist to detect the presence of a train in time to stop. According to American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets*[2] (the Greenbook), a grade crossing should be designed so that an approaching motorist is able to perceive the train, react to its presence, and stop the highway vehicle prior to the crossing. The required distance along the roadway (that is, from the vehicle to the crossing) and along the railroad tracks (from the crossing to the oncoming train) form two sides of a triangle. Together with the third side (an imaginary line from the train back to the highway vehicle) they form an area referred to as "quadrant sight distance," or the "sight triangle," the interior of which should be clear of any visual obstructions. For a vehicle stopped at the crossing, the driver must be able to see the train far enough along the tracks to have time to accelerate the vehicle and clear the crossing before the train's arrival.

The quadrant sight distance needed varies according to the speed of the train and of the highway vehicle, as well as the length and stopping distance of the highway vehicle. It is also affected by the angle at which the highway intersects the tracks and the slope of the roadway. When a grade crossing is designed, sight distances should be calculated by highway engineers. A stopped vehicle will need more sight distance along the track to see the oncoming train and cross the track before the train arrives, whereas a moving vehicle will need enough sight distance along the highway approach to the crossing to see the train along the tracks and to have time to stop.

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[2] American Association of State Highway and Transportation Officials. 1990. A policy on geometric design of highways and streets. 1990. Washington, DC. 1044 p.

The railroad track approaches at the accident crossings in the Safety Board's study were generally straight, and the sight distance along the tracks that was available to the drivers of most types of highway vehicles stopped at the crossing stop line was, for the most part, adequate (n = 50). In 10 cases, however, there were sight obstructions for a driver stopped at a crossing: in 7 cases, vegetation restricted visibility; in 2 cases, curvature of the tracks restricted visibility; and in 1 case, a building restricted visibility.

The generally adequate sight distance for vehicles stopped at the crossings, however, did not hold true for motorists approaching the crossings. In 33 cases, the grade crossing area afforded an approaching motorist less sight distance than was recommended by AASHTO guidelines.[3] At the majority of the crossings with limited sight distance (n = 24), the obstructions were trees, shrubs, or other types of plants: in one case, the trees were described as a forest (case 27); and in another case, the trees were fruit trees in an orchard (case 60). Six of the 33 cases had visual obstructions that included buildings, and in one of these cases the motorist's sight distance was obstructed by a hill. The following accident illustrates the potential consequences of inadequate sight distances for drivers of highway vehicles in motion.

About 8:15 a.m. on April 5, 1996, an eastbound Kansas City Southern freight train traveling about 40 mph struck a northbound Mazda at Golson Road near Calhoun, Louisiana (case 16).[4] The Mazda, traveling about 25 mph, which was about 10 mph below the posted speed limit, skidded onto the railroad tracks when the driver tried too late to stop her vehicle. The driver and her 8-year-old daughter in the right front seat of the car were both killed.

According to the AASHTO guidelines and based on the speeds of the highway vehicle and train in this case, the highway driver needed a clear sight triangle defined by a distance of 271 feet along the highway and 422 feet along the railroad tracks to see the train with enough time to safely stop the vehicle. However, because of the presence of a forested area on private property adjacent to the crossing, this sight triangle was not clear. The driver in this case actually had a clear sight triangle with only 72 of the 271 feet needed along the highway and 112 of the 422 feet needed along the railroad tracks. By the time the driver saw the train and applied the brakes, she did not have enough time to stop the vehicle prior to the crossing.

In addition to calculating the sight distance for each of the 60 accident crossings, the Safety Board also examined each crossing in terms of the time an approaching motorist needs to safely stop the vehicle prior to the crossing compared with the actual time available, given the sight distance along the highway. The differences in time needed compared with actual time available ranged from no shortage of time for some crossings to a shortage of 7½ seconds. For 18 (58 percent) of the crossings with limited sight distance, an approaching driver has only half or less of the time needed to safely negotiate the crossing. With such differences between the time needed and the time available, the driver's task to safely negotiate the crossing becomes more

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[3] Three of the 33 crossings with limited sight distance for approaching motorists were on private roads.

[4] According to the traincrew, the locomotive headlight and auxiliary alerting lights were illuminated, and the train horn was sounded prior to the accident.

difficult. The Safety Board's study cases show a strong association between inadequate sight distance and accident occurrence.

Angle of Intersection

The angle at which the roadway meets the railroad tracks may also affect the driver's ability to see an oncoming train. The following accident illustrates this problem.

About 1:10 p.m. on Thursday, May 30, 1996, a northbound Pontiac Grand Am struck a westbound Consolidated Rail Corporation (Conrail) freight train traveling about 48 mph at a passive grade crossing near Montrose, Illinois (case 37). The speed limit along the road was 55 mph. The driver, who was transporting her 3-year-old child, stated that she slowed her vehicle when approaching the crossing, but she did not hear or see the train until just before impact. There were no injuries associated with this accident, but the vehicle was destroyed. Although there were no obstacles in the sight triangle for the approaching motorist, the highway met the railroad tracks at an angle of 35°; thus, the train approached essentially from behind the highway vehicle.

According to AASHTO guidelines, "[r]egardless of the type of intersection, for safety and economy, intersecting roads should generally meet at or nearly at right angles." AASHTO recommends that when there is an acute angle of intersection, the road be realigned so that the angle of intersection can be more nearly 90°.[5] The distance a highway vehicle must traverse in order to clear the intersection is greater when the angle is skewed, and therefore the time it takes to safely cross is greater. Trucks are particularly at risk in such a situation because elements of the truck cab environment can further obscure the truckdriver's vision of the train.

The Safety Board examined the angle of intersection to the right of the roadway on the side of the crossing from which each accident-involved vehicle approached.[6] In 27 of the 60 study accident grade crossings (45 percent), the roadway did not meet the tracks at right angles. The Board's study cases suggest that when the angle of intersection deviates from 90°, safety may be compromised.

Roadway or Track Curvature

Roadway or track curvature can also affect a driver's ability to see an oncoming train. Twenty-five of the 60 crossings in the Board's sample had track and/or roadway curvature: 9 sets of tracks were curved within the vicinity of the crossing, 13 of the roadways had curves on the sections leading to the crossing, and 3 crossings had curves on both the railroad tracks and the highway. There is no nationwide information on roadway or track curvature for comparison, thus

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[5] AASHTO (1990, page 686).

[6] For consistency, the Safety Board selected the angle on the right side of the intersection, although measurements taken from the left side would also have provided sufficient information.

it is impossible to determine whether or not the study sample contains an inordinately high number of crossings with nearby curves in either the highway or the tracks.

AASHTO guidelines state that "to the extent possible, crossings should not be located on either highway or railroad curves."[7] Research into human perception shows that when a driver's trajectory includes a curve, the task of determining the speed and distance of another vehicle is much more difficult. Further, the highway vehicle driver may be distracted by the effort to correctly negotiate the curve.[8] Curves on the railroad tracks can obstruct a driver's view of the train, both on the approach to the crossing and while stopped at the crossing. In addition, AASHTO states that crossings where both the highway and the railroad tracks are curved provide "poor rideability for highway traffic due to conflicting superelevations."[9] This poor ride may cause a driver to concentrate on controlling the highway vehicle rather than looking for trains. Thus, on roads where either the roadway or tracks, or both, have a curve on the approach to the crossing, the highway vehicle driver may fail to recognize the hazards presented by the crossing until it is too late.

Driver Expectations

Driver attention at railroad crossings has been measured indirectly by watching drivers' head movements as they approach the crossing. An Australian study on human factors in grade crossing accidents shows that drivers' looking behavior, as determined by observable head movements, is far from optimal at grade crossings, with only about 30 percent of the drivers approaching a passive or active crossing conducting a search for a train.[10] Not only did very few of the drivers in that study look, but many of those that did look waited until just before the crossing, and some were still looking as their vehicles went over the crossing.

One factor that can affect whether a driver looks for a train is the driver's expectation of seeing a train. Overall, each of the 18 drivers interviewed by the Safety Board underestimated the frequency of train crossings per day, typically by a factor of 2 to 3. This low estimate suggests that drivers do not expect trains and thus may not look for trains at a crossing. Further, many train movements are unscheduled and would not be known even to drivers who are familiar with the crossing and with scheduled train traffic.

The driver's perception that a train is not likely to be at the crossing is reinforced each time that driver passes the crossing without seeing a train. Researchers have reported that a driver's response to a potential hazard is a function of both the perceived probability of the

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[7] AASHTO (1990, page 842).

[8] Berthelon, C. 1993. Curvilinear approach to an intersection and visual detection of a collision. Human Factors 35(3): 521–534 (page 522).

[9] (a) AASHTO (1990, page 842). (b) Superelevation is the technical term describing the angle at which a roadway is banked to enable a vehicle to operate smoothly around a curve at the design speed.

[10] Wigglesworth, E.C. [Royal Australasian College of Surgeons, Melbourne]. 1976. Report on human factors in road-rail crossing accidents. Melbourne, Victoria, Australia: Ministry of Transport. [Inclusive pages not known] (page 83).

adverse event occurring and of the driver's understanding of the severity of the consequence of the event.[11] A person's perception of the probability of a given event is strongly influenced by past experience,[12] and the frequency with which the driver encounters a train at a crossing will influence the likelihood of that driver stopping.

Personal circumstances also cause a driver to associate certain costs with the outcome of a decision to stop or not to stop. Stopping might make the driver late, or result in a collision with the highway vehicle behind; conversely, not stopping might result in an accident with a train. Research in signal detection theory has shown that because the frequency of trains at grade crossings is so low, drivers tend to bias their behavior toward not stopping.[13] The FRA has used signal detection theory models to predict which crossings are likely to have accidents and has found that a low train frequency at crossings is associated with a higher rate of accidents.

Driver Perception of Train Speed and Distance

Even when a driver looks for a train, it may be difficult to accurately gauge the speed and arrival time of an approaching train. Once the train is detected, a driver must decide whether it is safe to proceed across the tracks and then take appropriate action. Guiding this decision will be the driver's perceptual judgments of train velocity and distance. The difficulty of making this judgment is illustrated by the following accidents.

About 10:40 p.m. on August 12, 1996, in Columbus, Ohio, a truckdriver was hauling trash to a nearby lot (case 58). As he approached a private passive crossing, he observed a Conrail train that appeared to be standing still near the crossing. According to the Conrail police department incident report, the locomotive headlight was illuminated; auxiliary lighting use is unknown. According to the traincrew, the train horn was not sounded prior to the accident. As the truckdriver reached the crossing, he realized the train was moving. His realization came too late to avoid the collision.

On March 20, 1996, a tanker truckdriver was leaving a company lot in Clairton, Pennsylvania, heading toward a two-track crossing (case 15). As he approached the crossing, he had an unobstructed view of the tracks. Looking down the tracks, he saw a Conrail freight train in the distance and decided it was safe to cross. According to the locomotive event recorder, the train horn was sounded prior to the accident; according to the traincrew, the locomotive headlight

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[11] Schoppert, D.W.; Hoyt, D.W. 1968. Factors influencing safety at highway-rail grade crossings. National Cooperative Highway Research Program Report 50. Washington, DC: National Academy of Sciences; National Academy of Engineering. 113 p. (page 96).

[12] Schoppert and Hoyt (1968, page 97).

[13] Raslear, Thomas. 1996. Driver behavior at rail-highway grade crossings: A signal detection theory analysis. In: Safety of highway-railroad grade crossings: research needs workshop. Vol. II: Appendices. DOT/FRA/ORD-95/14.2; DOT-VNTSC-FRA-95-12.2. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration: F-9 through F-56 (page F-22). [Workshop held at and in conjunction with Volpe National Transportation Systems Center, Cambridge, MA.]

was illuminated. However, the driver misjudged how fast the train was moving, and as the truck crossed the tracks, it was struck by the freight train.

Moving with traffic, merging into traffic, and turning left or right in front of traffic are daily tasks that require a driver to judge the speed and distance of other highway vehicles. Similarly, a driver must judge the speed and distance of an oncoming train to gauge the train's arrival at a grade crossing. However, visual illusions can interfere with the driver's perception of train velocity and distance. For example, an illusion of perspective can mislead a driver about the train's distance:

> Viewed from the crossing, railroad tracks produce the illusion of a great distance. That is because the parallel lines of the rails converge toward the horizon. (It is the same illusion used in art classes to create perspective.) The apparent convergence of the rails give the impression that the train is farther from the crossing than it is.[14]

Research describes illusions regarding train size that can mislead a motorist about the train's velocity.[15] First, the larger an object, the more slowly it appears to be moving; thus, because the train locomotive is a large object, it may appear to be moving more slowly than it is, causing the driver to overestimate the amount of time available to safely clear the crossing. Second, when a car and train are approaching each other at constant speeds, or when a vehicle is stopped at a crossing and looking down the tracks, the principal perceptual cue available to the driver is the rate of growth of the train's apparent size in the visual field. This apparent rate of growth is not linear but hyperbolic. When the train is at a distance, the apparent rate of growth for the object is slow, thereby giving the impression of slow speed. However, as the train gets closer, the increase in the size of the object in the visual field accelerates. For example, a 10-foot-wide by 15-foot-tall locomotive will occupy a visual angle of 0.43° when it is 2,000 feet from the observer. As the train reaches 1,000 feet, the locomotive's visual angle has doubled to 0.86°. When the train is even closer to the observer, the visual angle also doubles even though the train traverses less distance: the visual angle grows from 3.43° to 6.84° when the train travels from 250 feet to 125 feet from the observer. Drivers tend to be effective at estimating the speed of the train when it is closest because the change in visual angle is rapid. However, drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances, when the change in visual angle is slow and they are more likely to underestimate the train's speed.

Night also adds to the difficulty in perceiving train speed and distance. Drivers can determine train speed by comparing the train movement with that of the background. However, at night the background is not visible and drivers lose this important cue. The driver in case 58, described previously, who believed a slow moving train was standing still was observing the train at night.

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[14] Operation Lifesaver, Inc. 1997. School bus driver presentation. In: Operation Lifesaver Presenter Guide. Alexandria, VA. [Section 7, page 15].

[15] Liebowitz, H.W. 1985. Grade crossing accidents and human factors engineering. American Scientist 73: 558-562.

Driver Distractions

Objects or events both inside and outside a vehicle can provide competing stimuli or distractions that reduce driver attentiveness to the task of looking for a train. For example, as the driver in case 37 approached a passive crossing, she was reaching into the back seat to get some food for her child. Prior to entering the crossing, she looked up, saw a train, and hit the brakes. The driver was unable to stop the vehicle before striking the train.

Of the 18 interviewed drivers, 8 indicated they had been distracted by at least one source.[16] Stereo systems and passengers were the internal sources of distraction most frequently cited by these drivers; highway traffic was the external source most frequently identified. Two other drivers indicated that they might have been distracted, but they could not identify the source of distraction. The Safety Board cited distraction as the primary probable cause or contributing factor in 12 of the 60 study accidents: 2 nonfatal accidents, and 10 fatal accidents.

Passengers, particularly passenger conversation, was a common source of distraction. Three interviewed drivers stated that they were talking with passengers in their vehicles at the time of the accident, and in a fourth instance (case 6), witnesses stated they saw the driver talking with his passenger (both the driver and the passenger in the highway vehicle were fatally injured in the accident). Research indicates that passenger distraction accounts for the second biggest source of distraction in accidents; objects in the vehicle is the biggest source.[17]

Another source of driver distraction was highway traffic. Three interviewed drivers were distracted by oncoming traffic, and in two of the fatal accidents (cases 41 and 50), distraction attributed to highway traffic was cited in the accident's probable cause. In two of the study accidents, the drivers apparently were preoccupied with vehicles directly in front of them: the fatally injured driver in case 53 followed closely behind a vehicle that cleared the crossing just before the train arrived, and the fatally injured driver in case 41 stopped his vehicle on the tracks to wait for a vehicle in front of him to clear a nearby highway intersection. Even other drivers' attempts to warn of an oncoming train can distract drivers. In one accident (case 40), a driver was focused on another car flashing its headlights. The driver reported that he believed the flashing headlights indicated an impending speed trap; the driver continued into the path of a train.

Intersecting roads and traffic may also distract a driver from looking for a train. When another road intersects with the driver's roadway just before or after the grade crossing, it may increase the number of decisions the driver must make and distract the driver from looking for a train. Similarly, a driver may also be presented with multiple decisions when encountering a grade crossing immediately after turning off of an intersecting roadway onto a road with a grade crossing.

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[16] One of the eight drivers was not in the highway vehicle at the time of the accident: the vehicle had stalled while traversing the tracks and the driver had time to get out before the train arrived.

[17] Tijerina, Louis; Kiger, Steven M.; Rockwell, Thomas H.; Tornow, Carina. 1995. Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. In: Proceedings, 39th annual meeting of the Human Factors and Ergonomic Society, Vol. 2; 1995 October 9-13; San Diego, CA. Santa Monica, CA: Human Factors and Ergonomics Society: 1117-1121.

In the afternoon of June 21, 1996, the driver of a Buick Park Avenue approached a grade crossing in Pickerington, Ohio (case 41). About 22 feet beyond the tracks was an intersection with another city street. A car traveling in the same direction as the Buick had just crossed the tracks and was stopped at the intersection. According to witnesses, the driver of the Buick; who appeared to be using a cellular phone, was stopped on the tracks waiting for the vehicle in front of him to clear the intersection. While stopped, the Buick was struck by an arriving Conrail freight train, and the driver was killed.

For the purposes of this study, the Safety Board defined a nearby intersection to be one that lay within 75 feet of the crossing.[18] Twenty-nine of the grade crossings in the study cases had nearby highway intersections: on the far side of the crossing in 12 of the study cases, on the side of the crossing from which the accident-involved highway driver approached in 13 cases, and on both sides of the crossing in 4 cases.

A nearby highway intersection may present a distraction to the driver simply because the driver is aware of it. If a highway intersection on the departure side of the crossing is visible to an approaching driver, the driver's attention may be drawn toward that intersection and away from the crossing. This may be particularly hazardous in urban areas, where the driver's concern for traffic at the upcoming intersection may result in stopping directly on the tracks, as was the case in Pickerington, Ohio. In other situations, the driver of a vehicle turning off a parallel roadway may come upon the crossing before being able to direct attention away from negotiating the turn; at four study crossings, the highway intersection was less than 25 feet from the crossing (cases 1, 15, 44, and 58). In addition, if a train comes from the same direction as a highway vehicle on the parallel roadway, it will come from behind the vehicle, and a driver turning onto the road with the grade crossing may have few moments to react.

The presence of nearby intersections increases the risk at passive crossings. In an Australian study, it was discovered that at a crossing with a nearby intersection, "driver head movements and [train] search at Stanhope [the location of the crossing] were directed firstly at determining the presence of other road users and secondly at assessing the possible development of conflict situations."[19] The drivers observed in that study were more concerned with the dangers presented by other highway traffic and considered the grade crossing only secondarily.

Because nearby intersections could present problems for motorists at passive grade crossings, the Safety Board examined the FRA databases to determine how common nearby intersections are. Of the study accident crossings, 46.7 percent (28 of the 60) qualify as having a nearby intersection on either the approach or the departure side of the crossing, whereas 37.7 percent of all public passive crossings have such nearby intersections. The higher percentage of grade crossings with nearby intersections in the study sample than in the FRA inventory database

[18] The measurement of 75 feet is not intended to indicate an absolute boundary. Intersections farther from (or closer to) a crossing than 75 feet may still present the opportunity for driver distraction. The FRA inventory database indicates the presence of nearby highway intersections within 75 feet of the crossing: therefore, the Safety Board selected a cutoff point of 75 feet to facilitate comparison between the study data and data in the FRA inventory database.

[19] Wigglesworth (1976, page 89)

suggests that nearby intersections may be a factor associated with passive grade crossing accidents.

The Safety Board concludes that the physical characteristics described above (sight distances, angle of intersection, roadway or track curvature, and nearby roadway intersections) can affect the level of safety at passive grade crossings. Roadway and/or track conditions, which include all these characteristics, were determined to be the primary probable cause or a contributing factor in 20 of the 60 study accidents.

Although the Federal Highway Administration's *Railroad–Highway Grade Crossing Handbook*[20] and the AASHTO's Greenbook provide guidance to assist highway engineers in the physical and geometric design of safe roadway systems, the characteristics at 54 of the 60 study crossings failed to adhere to at least one of these guidelines.

Driver Education

The Safety Board's study indicates that the motoring public does not clearly understand the level of risk at passive crossings and the need for full driver attention each time a crossing is used. Further, in a 1988 survey conducted by the University of Tennessee, researchers asked drivers what motorists should do when approaching a crossing that does not have railroad signals. In response, 24.3 percent of the drivers said that the driver should slow down and be prepared to stop (which was determined by the researchers to be the correct response), 69.6 percent declared that one should "stop, look, and listen at the crossing for a train," and 6.1 percent stated that the question was "not applicable, because all crossings have railroad signals."[21] The Safety Board examined material from various driver educational programs to determine if passive crossings, the inherent risk at these crossings, and the driver's tasks were adequately addressed.

Highway safety education is provided to motorists by several organizations. The American Association of Motor Vehicle Administrators (AAMVA), founded in 1933, is a voluntary, not-for-profit educational organization representing the State and provincial officials in the United States and Canada who are responsible for the administration and enforcement of motor vehicle laws. The AAMVA serves as an "information clearinghouse" for motor vehicle administration, police traffic services, and highway safety.[22] The Professional Truck Drivers Institute of America (PTDIA) develops curriculum and certification standards for training entry-level truck drivers. Operation Lifesaver (OL) is a not-for-profit organization that provides information about grade crossing safety to motor vehicle operators through safety educational

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[20] U.S. Department of Transportation, Federal Highway Administration. 1986. Railroad-highway grade crossing handbook. 2nd ed. FHWA-TS-86-215. Washington, DC. 261 p.

[21] Richards, Stephen H.; Heathington, K.W. 1988. Motorist understanding of railroad-highway grade crossing traffic control devices and associated traffic laws. In: Traffic control devices 1988. Transportation Research Record 1160. Washington, DC: Transportation Research Board, National Research Council: 52-59.

[22] Information obtained on May 4, 1998, from the Web site of the American Association of Motor Vehicle Administrators: http://www.aamva.org/aboutaamva.html.

programs.[23] The American Automobile Association (AAA) has been involved in driver education since the mid-1930s. The AAA writes and provides driver education materials for use in high school and in professional driver's schools, conducts programs to assist driver education teachers with their preparations, and also conducts driver improvement programs for the general population.[24]

A review of the driver education material developed by the above organizations found that very little information is provided on the dangers of passive grade crossings or what actions are required of drivers at passive crossings. The AAA materials reviewed by the Board specify that passive grade crossings require more care on the part of the driver but do not discuss physical characteristics at grade crossings that can affect the driver's ability to see an approaching train. The PTDIA course outline material reviewed by the Board makes no mention of grade crossings.

Further, a review of the OL *Presenter Trainer's Manual* found that the section on school bus driver presentation addresses the visual illusions to which a driver is subject. However, the manual does not contain information about the unique problems present at passive grade crossings that require full driver attention, nor does it discuss how the physical characteristics of the crossing may affect the driver's ability to see a train approaching. Attendees at OL courses may not be aware of the unique dangers present at passive grade crossings because OL presentations do not address issues specific to passive grade crossings.

The Safety Board is also concerned that the States' written driver examinations may not always address issues specific to the dangers of passive grade crossings. According to one witness at the Safety Board's public forum, the motor vehicle administration in his State has five versions of the written driver's examination, only two of which contain a single question about grade crossings.[25] The Safety Board concludes that the dangers of passive grade crossings are not adequately addressed in current driver education material or in the States' written driver examination tests. The Safety Board is recommending, therefore, that the States ensure that questions on safety at passive grade crossings are included in every version of the State's written driver examinations. Further, the Safety Board believes that Operation Lifesaver, the American Association of Motor Vehicle Administrators, the American Automobile Association, and the Professional Truck Drivers Institute of America should include in their training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. The Safety Board also believes that OL, the AAMVA, the AAA, and the PTDIA should develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs.

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[23] OL volunteers give speeches at schools and community associations, and prepare exhibits for regional fairs, in addition to other activities.

[24] Telephone conversation with staff at the national office of the AAA, May 13, 1997.

[25] Remarks by a representative of the Missouri State Police. In: Transcript of the NTSB public forum on safety at passive grade crossings (page 96).

Therefore, the National Transportation Safety Board recommends that Operation Lifesaver, Inc.:

> Include in training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. (H-98-38)
>
> Develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs. (H-98-39)

Also as a result of this study, the Safety Board issued recommendations to the U.S. Department of Transportation, the Federal Railroad Administration, the National Highway Traffic Safety Administration, the Federal Highway Administration, the States, the American Association of Motor Vehicle Administrators, the American Automobile Association, the Professional Truck Drivers Institute of America, the Advertising Council, Inc., the American Association of State Highway and Transportation Officials, the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transit Association.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility ". . . to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-98-38 and -39 in your reply.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman

Log H-596

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: AUG 11 1998

In reply to refer to: H-98-38 and -39

Mr. John Strandquist
President
American Association of Motor Vehicle Administrators
4301 Wilson Boulevard., Suite 400
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More than 4,000 accidents have occurred at the Nation's active and passive grade crossings each year from 1991 through 1996. Many of the accidents at active crossings have involved highway vehicle drivers who did not comply with train-activated warning devices installed at the crossings. This failure to comply often includes driver actions resulting from a deliberate decision, such as driving around a lowered crossing gate arm or ignoring flashing lights. Drivers at passive crossings are not provided warnings from train-activated devices; consequently, they must rely on a system of grade crossing signs and pavement markings, passive devices, that are designed to warn drivers only of the presence of a crossing. No element of this passive system changes to alert drivers to an oncoming train. Further, the effectiveness of the passive system is influenced by characteristics of the physical layout of the crossing, such as an adequate view of the area surrounding the crossing (sight distance) and roadway alignment, that affect the information given to an approaching motorist regarding an upcoming hazard.

According to the Federal Railroad Administration (FRA), there were 4,054 accidents in 1996 that involved highway vehicles at grade crossings; 54 percent (2,208) of those accidents occurred at passive grade crossings. About 60 percent of the fatalities from all grade crossing accidents in 1996 (247 of 415 fatalities) were at passive grade crossings.

The cost to eliminate or upgrade passive grade crossings is very high. According to the General Accounting Office, the average cost of adding lights and gates in 1995 was $150,000 per grade crossing. The total cost to upgrade the 96,759 passive crossings on public roadways would be about $14 billion. Gates and lights do not completely eliminate the hazards present at crossings, and, therefore, sole reliance on them would reduce but not eliminate all the fatalities. The ultimate solution from a safety standpoint would be a standard grade separation, which usually involves construction of bridges or overpasses and costs an estimated $3 million per crossing. The large number of passive grade crossings, the high percentage of fatalities that occur at passive grade crossings, and the cost to eliminate or upgrade passive grade crossings prompted the Safety Board to conduct a study to identify some of the common causes for accidents at

passive grade crossings, and to identify less costly remedies to improve safety at passive crossings not scheduled for closure or upgrade.[1]

For this study, the Safety Board investigated 60 grade crossing accidents that occurred between December 1995 and August 1996. The Safety Board selected for study accidents involving a collision between a train and a highway vehicle occurring at a passive grade crossing, wherein the highway vehicle was sufficiently damaged to require towing. The sample of accidents is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents.

In May 1997, the Safety Board convened a 2-day public forum in Jacksonville, Florida, to gather information about issues affecting safety at passive grade crossings. Witnesses included experts from the railroad industry; law enforcement; research groups; Operation Lifesaver; and Federal, State, and local government agencies. Those involved in grade crossing accidents, both highway vehicle occupants and traincrews, testified about their personal experiences. In addition, representatives from Canada and Italy discussed passive grade crossing issues and experiences in their countries.

Detecting a train at a passive crossing and making the correct decisions about whether a highway vehicle should stop at the crossing or can cross the tracks safely before the train arrives is a complex task that has confronted the Nation's motoring public for decades. The task is affected by the driver's ability to (1) detect the presence of the crossing, (2) detect the presence of a train, and (3) accurately gauge the train's speed and arrival time at the crossing. The task is further complicated by the driver's attention at a crossing, which as shown in the Safety Board's study, can be affected by what that individual expects to see. The Safety Board concludes that a driver's decision to look for a train may be adversely affected by the driver's familiarity with and expectations at a specific passive grade crossing and the driver's experience with passive crossings in general. Also, as shown in the Board's study, the train horn—one of only two active signals given to a driver to alert the driver that a train is present—is effective as a warning only if the driver recognizes it as a train horn. The Safety Board, therefore, concludes that in some circumstances, audible warning devices on trains fail to meet their objective of alerting motorists to an oncoming train because of highway vehicle design and environmental factors.

Despite the complexity of the task, the approach to passive grade crossing safety has remained relatively unchanged over the years. The current approach includes providing a sight distance triangle for an approaching motorist to see a train and installing a railroad crossing advance warning sign, pavement markings, and a crossbuck sign, where appropriate. The accident sample in the Safety Board's study illustrates that this approach has been inadequate in many instances.

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[1] National Transportation Safety Board. 1998. Safety at passive grade crossings. Volume 1: Analysis. Safety Study NTSB/SS-98/02. Washington, DC.

To eliminate the continuing problems encountered by the motoring public at passive crossings, the Safety Board concludes that a systematic and hierarchic approach to improving passive grade crossing safety is needed, an approach that does not depend primarily on the ability of the driver approaching the crossing to see an oncoming train. The hierarchic approach includes grade separation and closure, installation of active warning devices, improved signage, and intelligent transportation systems technology. The approach includes immediate and long-term measures. Concurrent with this approach is the need to educate drivers about the hazards of passive grade crossings.

The Safety Board's study identified several physical characteristics at passive highway–rail grade crossings that appear to contribute to the occurrence of accidents because they make it difficult for the motorist to see a train (inadequate sight distance, roadway-track intersection angles less than 90°, and roadway and track curvature), and/or because they distract the motorist's attention from the task of looking for a train (nearby roadway intersections). Further, a driver's attention at a crossing can be affected by what that individual expects to see and by distractions inside and outside the vehicle. This letter addresses these factors as they relate to driver education.

Sight Distance

Sight distance is the technical term describing the set of distances along the highway and along the railroad tracks needed by a motorist to detect the presence of a train in time to stop. According to American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets*[2] (the Greenbook), a grade crossing should be designed so that an approaching motorist is able to perceive the train, react to its presence, and stop the highway vehicle prior to the crossing. The required distance along the roadway (that is, from the vehicle to the crossing) and along the railroad tracks (from the crossing to the oncoming train) form two sides of a triangle. Together with the third side (an imaginary line from the train back to the highway vehicle) they form an area referred to as "quadrant sight distance," or the "sight triangle," the interior of which should be clear of any visual obstructions. For a vehicle stopped at the crossing, the driver must be able to see the train far enough along the tracks to have time to accelerate the vehicle and clear the crossing before the train's arrival.

The quadrant sight distance needed varies according to the speed of the train and of the highway vehicle, as well as the length and stopping distance of the highway vehicle. It is also affected by the angle at which the highway intersects the tracks and the slope of the roadway. When a grade crossing is designed, sight distances should be calculated by highway engineers. A stopped vehicle will need more sight distance along the track to see the oncoming train and cross the track before the train arrives, whereas a moving vehicle will need enough sight distance along the highway approach to the crossing to see the train along the tracks and to have time to stop.

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[2] American Association of State Highway and Transportation Officials. 1990. A policy on geometric design of highways and streets, 1990. Washington, DC. 1044 p.

The railroad track approaches at the accident crossings in the Safety Board's study were generally straight, and the sight distance along the tracks that was available to the drivers of most types of highway vehicles stopped at the crossing stop line was, for the most part, adequate (n = 50). In 10 cases, however, there were sight obstructions for a driver stopped at a crossing: in 7 cases, vegetation restricted visibility; in 2 cases, curvature of the tracks restricted visibility; and in 1 case, a building restricted visibility.

The generally adequate sight distance for vehicles stopped at the crossings, however, did not hold true for motorists approaching the crossings. In 33 cases, the grade crossing area afforded an approaching motorist less sight distance than was recommended by AASHTO guidelines.[3] At the majority of the crossings with limited sight distance (n = 24), the obstructions were trees, shrubs, or other types of plants: in one case, the trees were described as a forest (case 27); and in another case, the trees were fruit trees in an orchard (case 60). Six of the 33 cases had visual obstructions that included buildings, and in one of these cases the motorist's sight distance was obstructed by a hill. The following accident illustrates the potential consequences of inadequate sight distances for drivers of highway vehicles in motion.

About 8:15 a.m. on April 5, 1996, an eastbound Kansas City Southern freight train traveling about 40 mph struck a northbound Mazda at Golson Road near Calhoun, Louisiana (case 16).[4] The Mazda, traveling about 25 mph, which was about 10 mph below the posted speed limit, skidded onto the railroad tracks when the driver tried too late to stop her vehicle. The driver and her 8-year-old daughter in the right front seat of the car were both killed.

According to the AASHTO guidelines and based on the speeds of the highway vehicle and train in this case, the highway driver needed a clear sight triangle defined by a distance of 271 feet along the highway and 422 feet along the railroad tracks to see the train with enough time to safely stop the vehicle. However, because of the presence of a forested area on private property adjacent to the crossing, this sight triangle was not clear. The driver in this case actually had a clear sight triangle with only 72 of the 271 feet needed along the highway and 112 of the 422 feet needed along the railroad tracks. By the time the driver saw the train and applied the brakes, she did not have enough time to stop the vehicle prior to the crossing.

In addition to calculating the sight distance for each of the 60 accident crossings, the Safety Board also examined each crossing in terms of the time an approaching motorist needs to safely stop the vehicle prior to the crossing compared with the actual time available, given the sight distance along the highway. The differences in time needed compared with actual time available ranged from no shortage of time for some crossings to a shortage of 7½ seconds. For 18 (58 percent) of the crossings with limited sight distance, an approaching driver has only half or less of the time needed to safely negotiate the crossing. With such differences between the time needed and the time available, the driver's task to safely negotiate the crossing becomes more

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[3] Three of the 33 crossings with limited sight distance for approaching motorists were on private roads.

[4] According to the traincrew, the locomotive headlight and auxiliary alerting lights were illuminated, and the train horn was sounded prior to the accident.

difficult. The Safety Board's study cases show a strong association between inadequate sight distance and accident occurrence.

Angle of Intersection

The angle at which the roadway meets the railroad tracks may also affect the driver's ability to see an oncoming train. The following accident illustrates this problem.

About 1:10 p.m. on Thursday, May 30, 1996, a northbound Pontiac Grand Am struck a westbound Consolidated Rail Corporation (Conrail) freight train traveling about 48 mph at a passive grade crossing near Montrose, Illinois (case 37). The speed limit along the road was 55 mph. The driver, who was transporting her 3-year-old child, stated that she slowed her vehicle when approaching the crossing, but she did not hear or see the train until just before impact. There were no injuries associated with this accident, but the vehicle was destroyed. Although there were no obstacles in the sight triangle for the approaching motorist, the highway met the railroad tracks at an angle of 35°; thus, the train approached essentially from behind the highway vehicle.

According to AASHTO guidelines, "[r]egardless of the type of intersection, for safety and economy, intersecting roads should generally meet at or nearly at right angles." AASHTO recommends that when there is an acute angle of intersection, the road be realigned so that the angle of intersection can be more nearly 90°.[5] The distance a highway vehicle must traverse in order to clear the intersection is greater when the angle is skewed, and therefore the time it takes to safely cross is greater. Trucks are particularly at risk in such a situation because elements of the truck cab environment can further obscure the truckdriver's vision of the train.

The Safety Board examined the angle of intersection to the right of the roadway on the side of the crossing from which each accident-involved vehicle approached.[6] In 27 of the 60 study accident grade crossings (45 percent), the roadway did not meet the tracks at right angles. The Board's study cases suggest that when the angle of intersection deviates from 90°, safety may be compromised.

Roadway or Track Curvature

Roadway or track curvature can also affect a driver's ability to see an oncoming train. Twenty-five of the 60 crossings in the Board's sample had track and/or roadway curvature: 9 sets of tracks were curved within the vicinity of the crossing, 13 of the roadways had curves on the sections leading to the crossing, and 3 crossings had curves on both the railroad tracks and the highway. There is no nationwide information on roadway or track curvature for comparison, thus

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[5] AASHTO (1990, page 686).

[6] For consistency, the Safety Board selected the angle on the right side of the intersection, although measurements taken from the left side would also have provided sufficient information.

it is impossible to determine whether or not the study sample contains an inordinately high number of crossings with nearby curves in either the highway or the tracks.

AASHTO guidelines state that "to the extent possible, crossings should not be located on either highway or railroad curves."[7] Research into human perception shows that when a driver's trajectory includes a curve, the task of determining the speed and distance of another vehicle is much more difficult. Further, the highway vehicle driver may be distracted by the effort to correctly negotiate the curve.[8] Curves on the railroad tracks can obstruct a driver's view of the train, both on the approach to the crossing and while stopped at the crossing. In addition, AASHTO states that crossings where both the highway and the railroad tracks are curved provide "poor rideability for highway traffic due to conflicting superelevations."[9] This poor ride may cause a driver to concentrate on controlling the highway vehicle rather than looking for trains. Thus, on roads where either the roadway or tracks, or both, have a curve on the approach to the crossing, the highway vehicle driver may fail to recognize the hazards presented by the crossing until it is too late.

Driver Expectations

Driver attention at railroad crossings has been measured indirectly by watching drivers' head movements as they approach the crossing. An Australian study on human factors in grade crossing accidents shows that drivers' looking behavior, as determined by observable head movements, is far from optimal at grade crossings, with only about 30 percent of the drivers approaching a passive or active crossing conducting a search for a train.[10] Not only did very few of the drivers in that study look, but many of those that did look waited until just before the crossing, and some were still looking as their vehicles went over the crossing.

One factor that can affect whether a driver looks for a train is the driver's expectation of seeing a train. Overall, each of the 18 drivers interviewed by the Safety Board underestimated the frequency of train crossings per day, typically by a factor of 2 to 3. This low estimate suggests that drivers do not expect trains and thus may not look for trains at a crossing. Further, many train movements are unscheduled and would not be known even to drivers who are familiar with the crossing and with scheduled train traffic.

The driver's perception that a train is not likely to be at the crossing is reinforced each time that driver passes the crossing without seeing a train. Researchers have reported that a driver's response to a potential hazard is a function of both the perceived probability of the

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[7] AASHTO (1990, page 842).

[8] Berthelon, C. 1993. Curvilinear approach to an intersection and visual detection of a collision. Human Factors 35(3): 521–534 (page 522).

[9] (a) AASHTO (1990, page 842). (b) Superelevation is the technical term describing the angle at which a roadway is banked to enable a vehicle to operate smoothly around a curve at the design speed.

[10] Wigglesworth, E.C. [Royal Australasian College of Surgeons, Melbourne]. 1976. Report on human factors in road-rail crossing accidents. Melbourne, Victoria, Australia: Ministry of Transport. [Inclusive pages not known] (page 83).

adverse event occurring and of the driver's understanding of the severity of the consequence of the event.[11] A person's perception of the probability of a given event is strongly influenced by past experience,[12] and the frequency with which the driver encounters a train at a crossing will influence the likelihood of that driver stopping.

Personal circumstances also cause a driver to associate certain costs with the outcome of a decision to stop or not to stop. Stopping might make the driver late, or result in a collision with the highway vehicle behind; conversely, not stopping might result in an accident with a train. Research in signal detection theory has shown that because the frequency of trains at grade crossings is so low, drivers tend to bias their behavior toward not stopping.[13] The FRA has used signal detection theory models to predict which crossings are likely to have accidents and has found that a low train frequency at crossings is associated with a higher rate of accidents.

Driver Perception of
Train Speed and Distance

Even when a driver looks for a train, it may be difficult to accurately gauge the speed and arrival time of an approaching train. Once the train is detected, a driver must decide whether it is safe to proceed across the tracks and then take appropriate action. Guiding this decision will be the driver's perceptual judgments of train velocity and distance. The difficulty of making this judgment is illustrated by the following accidents.

About 10:40 p.m. on August 12, 1996, in Columbus, Ohio, a truckdriver was hauling trash to a nearby lot (case 58). As he approached a private passive crossing, he observed a Conrail train that appeared to be standing still near the crossing. According to the Conrail police department incident report, the locomotive headlight was illuminated; auxiliary lighting use is unknown. According to the traincrew, the train horn was not sounded prior to the accident. As the truckdriver reached the crossing, he realized the train was moving. His realization came too late to avoid the collision.

On March 20, 1996, a tanker truckdriver was leaving a company lot in Clairton, Pennsylvania, heading toward a two-track crossing (case 15). As he approached the crossing, he had an unobstructed view of the tracks. Looking down the tracks, he saw a Conrail freight train in the distance and decided it was safe to cross. According to the locomotive event recorder, the train horn was sounded prior to the accident; according to the traincrew, the locomotive headlight

[11] Schoppert, D.W.; Hoyt, D.W. 1968. Factors influencing safety at highway-rail grade crossings. National Cooperative Highway Research Program Report 50. Washington, DC: National Academy of Sciences; National Academy of Engineering. 113 p. (page 96).

[12] Schoppert and Hoyt (1968, page 97).

[13] Raslear, Thomas. 1996. Driver behavior at rail-highway grade crossings: A signal detection theory analysis. In: Safety of highway-railroad grade crossings: research needs workshop. Vol. II: Appendices. DOT/FRA/ORD-95/14.2; DOT-VNTSC-FRA-95-12.2. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration: F-9 through F-56 (page F-22). [Workshop held at and in conjunction with Volpe National Transportation Systems Center, Cambridge, MA.]

was illuminated. However, the driver misjudged how fast the train was moving, and as the truck crossed the tracks, it was struck by the freight train.

Moving with traffic, merging into traffic, and turning left or right in front of traffic are daily tasks that require a driver to judge the speed and distance of other highway vehicles. Similarly, a driver must judge the speed and distance of an oncoming train to gauge the train's arrival at a grade crossing. However, visual illusions can interfere with the driver's perception of train velocity and distance. For example, an illusion of perspective can mislead a driver about the train's distance:

> Viewed from the crossing, railroad tracks produce the illusion of a great distance. That is because the parallel lines of the rails converge toward the horizon. (It is the same illusion used in art classes to create perspective.) The apparent convergence of the rails give the impression that the train is farther from the crossing than it is.[14]

Research describes illusions regarding train size that can mislead a motorist about the train's velocity.[15] First, the larger an object, the more slowly it appears to be moving; thus, because the train locomotive is a large object, it may appear to be moving more slowly than it is, causing the driver to overestimate the amount of time available to safely clear the crossing. Second, when a car and train are approaching each other at constant speeds, or when a vehicle is stopped at a crossing and looking down the tracks, the principal perceptual cue available to the driver is the rate of growth of the train's apparent size in the visual field. This apparent rate of growth is not linear but hyperbolic. When the train is at a distance, the apparent rate of growth for the object is slow, thereby giving the impression of slow speed. However, as the train gets closer, the increase in the size of the object in the visual field accelerates. For example, a 10-foot-wide by 15-foot-tall locomotive will occupy a visual angle of 0.43° when it is 2,000 feet from the observer. As the train reaches 1,000 feet, the locomotive's visual angle has doubled to 0.86°. When the train is even closer to the observer, the visual angle also doubles even though the train traverses less distance: the visual angle grows from 3.43° to 6.84° when the train travels from 250 feet to 125 feet from the observer. Drivers tend to be effective at estimating the speed of the train when it is closest because the change in visual angle is rapid. However, drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances, when the change in visual angle is slow and they are more likely to underestimate the train's speed.

Night also adds to the difficulty in perceiving train speed and distance. Drivers can determine train speed by comparing the train movement with that of the background. However, at night the background is not visible and drivers lose this important cue. The driver in case 58, described previously, who believed a slow moving train was standing still was observing the train at night.

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[14] Operation Lifesaver, Inc. 1997. School bus driver presentation. In: Operation Lifesaver Presenter Guide. Alexandria, VA. [Section 7, page 15].

[15] Liebowitz, H.W. 1985. Grade crossing accidents and human factors engineering. American Scientist 73: 558-562.

Driver Distractions

Objects or events both inside and outside a vehicle can provide competing stimuli or distractions that reduce driver attentiveness to the task of looking for a train. For example, as the driver in case 37 approached a passive crossing, she was reaching into the back seat to get some food for her child. Prior to entering the crossing, she looked up, saw a train, and hit the brakes. The driver was unable to stop the vehicle before striking the train.

Of the 18 interviewed drivers, 8 indicated they had been distracted by at least one source.[16] Stereo systems and passengers were the internal sources of distraction most frequently cited by these drivers; highway traffic was the external source most frequently identified. Two other drivers indicated that they might have been distracted, but they could not identify the source of distraction. The Safety Board cited distraction as the primary probable cause or contributing factor in 12 of the 60 study accidents: 2 nonfatal accidents, and 10 fatal accidents.

Passengers, particularly passenger conversation, was a common source of distraction. Three interviewed drivers stated that they were talking with passengers in their vehicles at the time of the accident, and in a fourth instance (case 6), witnesses stated they saw the driver talking with his passenger (both the driver and the passenger in the highway vehicle were fatally injured in the accident). Research indicates that passenger distraction accounts for the second biggest source of distraction in accidents; objects in the vehicle is the biggest source.[17]

Another source of driver distraction was highway traffic. Three interviewed drivers were distracted by oncoming traffic, and in two of the fatal accidents (cases 41 and 50), distraction attributed to highway traffic was cited in the accident's probable cause. In two of the study accidents, the drivers apparently were preoccupied with vehicles directly in front of them: the fatally injured driver in case 53 followed closely behind a vehicle that cleared the crossing just before the train arrived, and the fatally injured driver in case 41 stopped his vehicle on the tracks to wait for a vehicle in front of him to clear a nearby highway intersection. Even other drivers' attempts to warn of an oncoming train can distract drivers. In one accident (case 40), a driver was focused on another car flashing its headlights. The driver reported that he believed the flashing headlights indicated an impending speed trap; the driver continued into the path of a train.

Intersecting roads and traffic may also distract a driver from looking for a train. When another road intersects with the driver's roadway just before or after the grade crossing, it may increase the number of decisions the driver must make and distract the driver from looking for a train. Similarly, a driver may also be presented with multiple decisions when encountering a grade crossing immediately after turning off of an intersecting roadway onto a road with a grade crossing.

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[16] One of the eight drivers was not in the highway vehicle at the time of the accident: the vehicle had stalled while traversing the tracks and the driver had time to get out before the train arrived.

[17] Tijerina, Louis; Kiger, Steven M.; Rockwell, Thomas H.; Tornow, Carina. 1995. Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. In: Proceedings, 39th annual meeting of the Human Factors and Ergonomic Society, Vol. 2; 1995 October 9-13; San Diego, CA. Santa Monica, CA: Human Factors and Ergonomics Society: 1117-1121.

In the afternoon of June 21, 1996, the driver of a Buick Park Avenue approached a grade crossing in Pickerington, Ohio (case 41). About 22 feet beyond the tracks was an intersection with another city street. A car traveling in the same direction as the Buick had just crossed the tracks and was stopped at the intersection. According to witnesses, the driver of the Buick, who appeared to be using a cellular phone, was stopped on the tracks waiting for the vehicle in front of him to clear the intersection. While stopped, the Buick was struck by an arriving Conrail freight train, and the driver was killed.

For the purposes of this study, the Safety Board defined a nearby intersection to be one that lay within 75 feet of the crossing.[18] Twenty-nine of the grade crossings in the study cases had nearby highway intersections: on the far side of the crossing in 12 of the study cases, on the side of the crossing from which the accident-involved highway driver approached in 13 cases, and on both sides of the crossing in 4 cases.

A nearby highway intersection may present a distraction to the driver simply because the driver is aware of it. If a highway intersection on the departure side of the crossing is visible to an approaching driver, the driver's attention may be drawn toward that intersection and away from the crossing. This may be particularly hazardous in urban areas, where the driver's concern for traffic at the upcoming intersection may result in stopping directly on the tracks, as was the case in Pickerington, Ohio. In other situations, the driver of a vehicle turning off a parallel roadway may come upon the crossing before being able to direct attention away from negotiating the turn; at four study crossings, the highway intersection was less than 25 feet from the crossing (cases 1, 15, 44, and 58). In addition, if a train comes from the same direction as a highway vehicle on the parallel roadway, it will come from behind the vehicle, and a driver turning onto the road with the grade crossing may have few moments to react.

The presence of nearby intersections increases the risk at passive crossings. In an Australian study, it was discovered that at a crossing with a nearby intersection, "driver head movements and [train] search at Stanhope [the location of the crossing] were directed firstly at determining the presence of other road users and secondly at assessing the possible development of conflict situations."[19] The drivers observed in that study were more concerned with the dangers presented by other highway traffic and considered the grade crossing only secondarily.

Because nearby intersections could present problems for motorists at passive grade crossings, the Safety Board examined the FRA databases to determine how common nearby intersections are. Of the study accident crossings, 46.7 percent (28 of the 60) qualify as having a nearby intersection on either the approach or the departure side of the crossing, whereas 37.7 percent of all public passive crossings have such nearby intersections. The higher percentage of grade crossings with nearby intersections in the study sample than in the FRA inventory database

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[18] The measurement of 75 feet is not intended to indicate an absolute boundary. Intersections farther from (or closer to) a crossing than 75 feet may still present the opportunity for driver distraction. The FRA inventory database indicates the presence of nearby highway intersections within 75 feet of the crossing; therefore, the Safety Board selected a cutoff point of 75 feet to facilitate comparison between the study data and data in the FRA inventory database.

[19] Wigglesworth (1976, page 80).

suggests that nearby intersections may be a factor associated with passive grade crossing accidents.

The Safety Board concludes that the physical characteristics described above (sight distances, angle of intersection, roadway or track curvature, and nearby roadway intersections) can affect the level of safety at passive grade crossings. Roadway and/or track conditions, which include all these characteristics, were determined to be the primary probable cause or a contributing factor in 20 of the 60 study accidents.

Although the Federal Highway Administration's *Railroad–Highway Grade Crossing Handbook*[20] and the AASHTO's Greenbook provide guidance to assist highway engineers in the physical and geometric design of safe roadway systems, the characteristics at 55 of the 60 study crossings failed to adhere to at least one of these guidelines.

Driver Education

The Safety Board's study indicates that the motoring public does not clearly understand the level of risk at passive crossings and the need for full driver attention each time a crossing is used. Further, in a 1988 survey conducted by the University of Tennessee, researchers asked drivers what motorists should do when approaching a crossing that does not have railroad signals. In response, 24.3 percent of the drivers said that the driver should slow down and be prepared to stop (which was determined by the researchers to be the correct response), 69.6 percent declared that one should "stop, look, and listen at the crossing for a train," and 6.1 percent stated that the question was "not applicable, because all crossings have railroad signals."[21] The Safety Board examined material from various driver educational programs to determine if passive crossings, the inherent risk at these crossings, and the driver's tasks were adequately addressed.

Highway safety education is provided to motorists by several organizations. The American Association of Motor Vehicle Administrators (AAMVA), founded in 1933, is a voluntary, not-for-profit educational organization representing the State and provincial officials in the United States and Canada who are responsible for the administration and enforcement of motor vehicle laws. The AAMVA serves as an "information clearinghouse" for motor vehicle administration, police traffic services, and highway safety.[22] The Professional Truck Drivers Institute of America (PTDIA) develops curriculum and certification standards for training entry-level truck drivers. Operation Lifesaver (OL) is a not-for-profit organization that provides information about grade crossing safety to motor vehicle operators through safety educational

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[20] U.S. Department of Transportation, Federal Highway Administration. 1986. Railroad-highway grade crossing handbook. 2nd ed. FHWA-TS-86-215. Washington, DC. 261 p.

[21] Richards, Stephen H.; Heathington, K.W. 1988. Motorist understanding of railroad-highway grade crossing traffic control devices and associated traffic laws. In: Traffic control devices 1988. Transportation Research Record 1160. Washington, DC: Transportation Research Board, National Research Council: 52-59.

[22] Information obtained on May 4, 1998, from the Web site of the American Association of Motor Vehicle Administrators: http://www.aamva.org/aboutaamva.html.

programs.[23] The American Automobile Association (AAA) has been involved in driver education since the mid-1930s. The AAA writes and provides driver education materials for use in high school and in professional driver's schools, conducts programs to assist driver education teachers with their preparations, and also conducts driver improvement programs for the general population.[24]

A review of the driver education material developed by the above organizations found that very little information is provided on the dangers of passive grade crossings or what actions are required of drivers at passive crossings. The AAA materials reviewed by the Board specify that passive grade crossings require more care on the part of the driver but do not discuss physical characteristics at grade crossings that can affect the driver's ability to see an approaching train. The PTDIA course outline material reviewed by the Board makes no mention of grade crossings.

Further, a review of the OL *Presenter Trainer's Manual* found that the section on school bus driver presentation addresses the visual illusions to which a driver is subject. However, the manual does not contain information about the unique problems present at passive grade crossings that require full driver attention, nor does it discuss how the physical characteristics of the crossing may affect the driver's ability to see a train approaching. Attendees at OL courses may not be aware of the unique dangers present at passive grade crossings because OL presentations do not address issues specific to passive grade crossings.

The Safety Board is also concerned that the States' written driver examinations may not always address issues specific to the dangers of passive grade crossings. According to one witness at the Safety Board's public forum, the motor vehicle administration in his State has five versions of the written driver's examination, only two of which contain a single question about grade crossings.[25] The Safety Board concludes that the dangers of passive grade crossings are not adequately addressed in current driver education material or in the States' written driver examination tests. The Safety Board is recommending, therefore, that the States ensure that questions on safety at passive grade crossings are included in every version of the State's written driver examinations. Further, the Safety Board believes that Operation Lifesaver, the American Association of Motor Vehicle Administrators, the American Automobile Association, and the Professional Truck Drivers Institute of America should include in their training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. The Safety Board also believes that OL, the AAMVA, the AAA, and the PTDIA should develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs.

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[23] OL volunteers give speeches at schools and community associations, and prepare exhibits for regional fairs, in addition to other activities.

[24] Telephone conversation with staff at the national office of the AAA, May 13, 1997.

[25] Remarks by a representative of the Missouri State Police. In: Transcript of the NTSB public forum on safety at passive grade crossings (page 96).

Therefore, the National Transportation Safety Board recommends that the American Association of Motor Vehicle Administrators:

> Include in training manuals, presentations, and printed educational material information about (1) the need for full driver attention at passive grade crossings, (2) the fact that trains are often moving faster than they appear to be from a distance, and (3) the ways in which the physical characteristics of the crossing affect the driver's ability to see an approaching train at a passive crossing. (H-98-38)

> Develop, in conjunction with the U.S. Department of Transportation, an appropriate training module specific to safety at passive grade crossings to be included in the organizations' highway safety education programs. (H-98-39)

Also as a result of this study, the Safety Board issued recommendations to the U.S. Department of Transportation, the Federal Railroad Administration, the National Highway Traffic Safety Administration, the Federal Highway Administration, the States, Operation Lifesaver, Inc., the American Automobile Association, the Professional Truck Drivers Institute of America, the Advertising Council, Inc., the American Association of State Highway and Transportation Officials, the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transit Association.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility ". . . to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-98-38 and -39 in your reply.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman