vices that require active devices to be installed in conjunction with CWT systems.

6. The characteristics of the independent variables used in the discriminant function reveal that there are significant operational differences between the group of crossings with CWT and that without CWT devices. This indicates that although specific installation criteria in use by the railroads could not be identified, operational abnormalities do exist that prompt the use of CWT systems.

REFERENCES

1. R.L. Monroe, D.K. Munsell, and J. Rudd. Constant Warning Time Concept Development for Motorist Warning at Grade Crossings. Final Report FRA/ORD-81/07. FRA, U.S. Department of Transportation, May 1981.
2. Motion Sensor/Grade Crossing Predicator Application Guidelines. Safetran Systems Corporation, Louisville, Ky., March 1982.

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The Safety, Economic, and Environmental Consequences of Requiring Stops at Railroad-Highway Crossings

BRIAN L. BOWMAN, KEVIN P. McCARTHY, and GARY HUGHES

ABSTRACT

The purpose of this study was to determine the safety, economic, operational, and environmental consequences of requiring hazardous materials transporters, school buses, and passenger buses to stop at railroad crossings with active warning devices when the devices are not activated. The study included an assessment of the positive and negative impacts on accidents involving trains and those in which trains are not involved, traffic operations, fuel consumption, delay, pullout-lane construction and maintenance costs, and environmental degradation. Results indicate that not mandating stops at railroad crossings with active devices when the devices are not activated would reduce both train and nontrain accidents annually for all three classes of vehicles; the net annual decrease in train-involved accidents would be 2.6, 10.8, and 17.4 percent for hazardous materials transporters, school buses, and passenger buses, respectively. The annual economic savings resulting from not requiring stops were estimated as $328,000 in accident costs; $1,241,000 in pullout-lane construction and maintenance costs; $12,267,000 in excess fuel consumption; and $1,510,000 in delay.

The actions of drivers of hazardous materials haulers, school buses, and passenger buses at railroad-highway grade crossings are governed by regulations of the Bureau of Motor Carrier Safety (BMCS) through the Federal Motor Carrier Safety Regulations (FMCSR) and by individual state and local regulations. The state and local regulations are adapted, either entirely or partially, from the FMCSR or from recommendations of the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO) contained in the Uniform Vehicle Code (UVC).

Principal differences exist between the FMCSR and the recommendations of the UVC regarding mandatory stops at railroad-highway grade crossings. These differences include no exemptions in the UVC for mandatory stops at streetcar crossings, tracks used exclusively for industrial switching purposes, and abandoned tracks. In addition, stops are not required in the UVC at crossings with train-activated gates

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B.L. Bowman, Goodell-Grivas, Inc., 17320 W. Eight Mile Road, Southfield, Mich. 48075. K.P. McCarthy, City of Farmington Hills, 31555 Eleven Mile Road, Farmington Hills, Mich. 48018. G. Hughes, FHWA, 708 S. Third Avenue, Portland, Oreg. 97204.

or flashing lights or both when these devices are not activated (1). This is the major difference between the UVC and the FMCSR. Because individual states have the option to adopt all or portions of the UVC or the FMCSR, there are wide variations in state rules regarding stops at crossings.

The variations among the UVC recommendations, the FMCSR, and state laws have led to questions of which version has the greatest potential for reducing accidents. The primary issue of concern is whether trucks transporting hazardous materials, school buses, and passenger buses should be required to stop at crossings with active warning devices. The National Transportation Safety Board (NTSB), on the basis of results of a special study, recommended that the FMCSR be amended to be consistent with the UVC (2). This recommendation, plus similar recommendations of several states, prompted an Advance Notice of Proposed Rulemaking (ANPRM) (3) by FHWA that requested comments and information to determine whether the FMCSR should be modified to exclude crossings protected by active devices from the mandatory-stop requirement. The ANPRM requested additional data or information on crossing accidents in which trains were not involved and that were attributable to mandatory stopping by certain vehicles, cost savings to be derived from the FMCSR change, and the environmental effects of the proposed rule change.

STUDY OBJECTIVES AND SCOPE

The purpose of this study was to provide much of the information requested in ANPRM 82-10. The study was designed to determine the difference between the potential consequences of requiring and not requiring certain vehicles to stop at crossings with active warning devices. To assess the positive and negative aspects of the proposed FMCSR changes, the probable increases and decreases in train-involved and non-train-involved accidents, fuel consumption, cost of delay, and environmental degradation had to be determined.

The research approach provides an unbiased view of the consequences of the proposed changes to the FMCSR mandatory-stop requirement. This approach involved an investigation of

- Nationwide train-involved accident data for accidents occurring from 1975 through 1983;
- Non-train-involved accidents from Washington, California, Illinois, and North Carolina that were attributable to regulated vehicles stopping at crossings with active devices when the devices were not activated;
- The historic rate of nonoperation of crossing signals;
- The minimum amount of advance warning required for different combinations of roadway vehicles to clear the crossing zone after coming to a complete stop;
- The conflicts of following vehicles caused as a result of mandatory stops;
- The violation rate of the regulated vehicles; and
- The fuel consumption, noxious emissions, and delay caused by regulated vehicles that stop at all crossings with active warning devices.

ANALYSIS OF ACCIDENT DATA

Accidents were analyzed by accident type and roadway vehicle speed to estimate the impacts of proposed changes to the mandatory-stop rule. If vehicles were not required to stop at crossings with active warning devices, then it could be expected that both train-involved and non-train-involved accidents at such crossings would be affected by this change. The direction and magnitude of this change were estimated by comparing the accidents occurring between trains and regulated vehicles (hazardous materials transporters, school buses, and passenger buses) with accidents occurring between trains and the general truck population (excluding hazardous materials transporters). This comparison was chosen because the driver and vehicle-operating characteristics of the general truck population closely resemble those of the regulated vehicles being analyzed in the study. Use of the accident characteristics of the total vehicle population, which includes automobiles, would not provide this similarity.

The analysis of accident data was performed in two distinct phases, train-involved and non-train-involved accidents. The identification of train-involved accidents was performed by using the FRA accident data base, whereas the non-train-involved accidents were identified through state accident record systems. Each phase (train-involved and non-train-involved accidents) was further divided into separate analysis steps for hazardous materials transporters, school buses, and passenger buses. Separate analyses were performed on the different vehicle types because each type had different length and acceleration characteristics and, in some cases, driver-proficiency and training requirements. In addition, separate analyses were required because of the different accident costs associated with each vehicle type.

Train-Involved Accidents

Analysis

The overall analysis of train-involved accidents was an extension of a special study performed by NTSB (2) in which accidents occurring between trains and hazardous materials haulers from 1975 through 1979 were used. The data collected for the NTSB study were expanded to include accidents through 1983 and accidents involving both school and passenger buses. A flowchart of this analysis methodology is shown in Figure 1.

Train-involved accidents were first identified through the FRA accident/incident reports. This information was then checked with other reports available from federal, state, and local agencies to verify vehicle type and accident characteristics. For example, some accidents involved vehicles that were coded as hazardous materials transporters but were actually pickup trucks carrying campers with propane tanks. A summary of the results of the verification process is shown in Figure 2.

The National Railroad-Highway Crossing Inventory of the U.S. Department of Transportation (DOT) and the Association of American Railroads (AAR) was used to ascertain (a) whether the crossing at which the accident occurred was public or private and (b) the type of warning device present at the time of the accident. Those accidents occurring at private crossings were eliminated from further analysis because the mandatory-stop regulation is not applicable to them. Although the regulation can be interpreted to provide recommended practices at private crossings, in the majority of states it is not enforceable at private crossings.

The type of warning device present was determined because (a) the UVC requires different driver actions on the basis of whether the crossing has active or passive devices and (b) any envisioned changes to the regulation would be to differentiate between appropriate driver action for active or passive

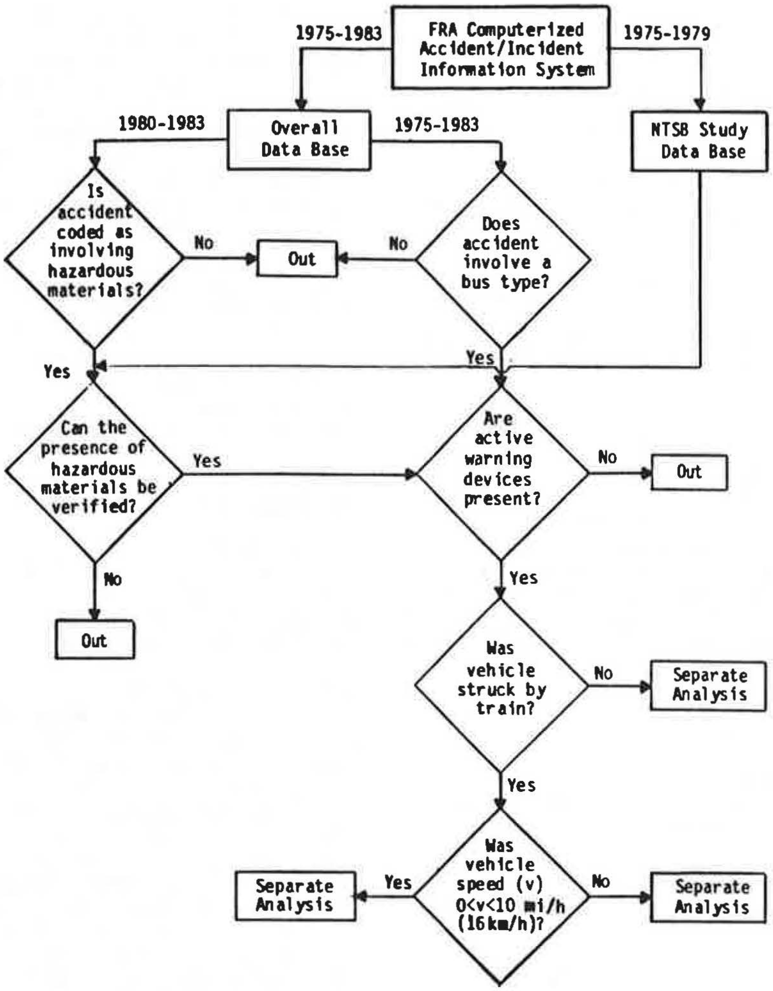

FIGURE 1 Flowchart of the train-involved accident identification procedure.

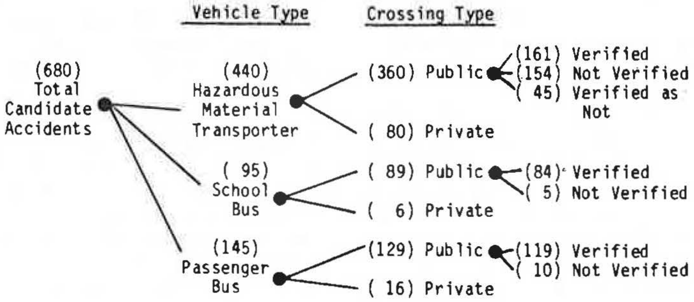

FIGURE 2 Verification of the train-involved accident data collection activities (1975-1983).

warning devices. Any electronic or mechanical signal device indicating the immediate approach of a train was considered an active device with the exception of highway traffic signals. Highway traffic signals were separated from the active category because the FMCSR and UVC currently exempt crossings equipped with highway traffic signals from the mandatory-stop regulation. A breakdown of the accident stratification is summarized in Figure 3.

Results

Comparative analysis of train-involved accidents (at public crossings with active warning devices) between the general truck population and the verified regulated vehicles revealed that (a) regulated vehicles have a significantly higher proportion of accidents in which the train strikes the vehicle and (b) the general truck population has a significantly higher proportion of accidents in which the vehicle strikes the train. These differences are summarized in Table 1.

If the mandatory-stop regulation is changed to exclude stops at crossings with active warning devices when the devices are not activated, this would place the responsibility of recognizing the presence of a train on the detection system. If the regulation is changed and the active warning system fails for any reason, train-involved accidents will in-

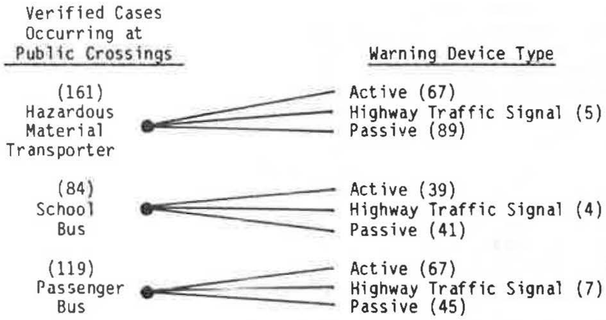

FIGURE 3 Breakdown of verified-accident stratification based on crossing warning device type.

crease. Therefore, the estimates were adjusted by the anticipated increase in accidents due to signal malfunction. The magnitude of this increase will depend on the frequency with which the signal system malfunctions in the actual presence of a train.

The magnitude of the expected increase was estimated by expanding prior analyses performed separately by Crawford and Johnston (4,5). This process resulted in an estimated increase due to signal malfunction of 0.70 percent per year. Applying this increase to the previously estimated change in train-involved accidents (Table 1) results in the following net percent change:

Category	Hazardous Materials Transporter	School Bus	Passenger Bus
Estimated change in accident totals from Table 1	-3.3	-11.5	-18.1
Estimated increase due to signal malfunction	0.70	0.70	0.70
Net change in accidents	-2.6	-10.8	-17.4

A stringent verification process was used to ascertain whether vehicles involved in train accidents were hazardous materials transporters, school buses, or passenger buses. After this process, only 161 hazardous materials transporter, 84 school bus, and 119 passenger bus accidents were sufficiently verified and remained in the analysis. This verified subset was tested to determine whether it represented a random sample of the entire possible population of mandatory-stop accidents. The chi-square test of independence indicated, with a 99 percent level of confidence, that the accident characteristics of the verified accident sample were a good representation of the total possible population. The sample therefore provided a reliable description of the total population of regulated-vehicle accidents. It can also be assumed that determinations of prevalent accident characteristics and of the proportions of total accidents in which the vehicle is struck by or strikes the train made by using the sample represent those of the total population. However, estimates of accident magnitude based on the verified sample will provide lower-limit estimates.

The net percent change in accidents given in the previous paragraph indicates that changing the mandatory-stop regulation so that stops at crossings with active warning devices are not required when the devices are not activated would result in a net decrease in train-involved accidents for hazardous materials transporters, school buses, and passenger buses of 2.6, 10.8, and 17.4 percent, respectively.

Non-Train-Involved Accidents

The accident records of four states--California, Illinois, North Carolina, and Washington--were searched to identify accidents that did not involve a train and were directly or indirectly caused by a regulated vehicle stopping at a railroad crossing. The procedure used in selecting the accidents is summarized in Figure 4.

The selection criteria were very stringent. It was not necessary for the accident reports to involve a regulated vehicle directly, but it was required that the accident description mention a mandatory-stop vehicle stopping at a railroad crossing with no train present or approaching. Therefore, a rear-end accident involving two passenger vehicles would have been included only if the verbal description of the accident mentioned a truck or bus stopping with no train or no flashers activated. Because of the liberal initial and restrictive final selection processes, a large quantity of records were searched to obtain a limited number of cases. A total of 18,814 accidents were initially selected by the computer searches, but only 264 cases satisfied the selection criteria. The number of accidents identified as part of this task do not therefore represent the true magnitude of the non-train-involved accidents resulting from the actions of mandatory-stop vehicles.

It may be expected that many accidents involving a regulated vehicle and the vehicles queued behind it were not reported as involving a regulated vehicle, a railroad crossing, or the presence or absence of a train. In addition, the accident type typically expected to result from the actions of a mandatory-stop vehicle is often characterized by low speed and minimal damage. These accidents are often not re-

TABLE 1 Analysis of Train-Involved Accidents

		Verified Cases					
		Hazardous Materials Transporter		School Bus		Passenger Bus	
Accident Type	General Truck Population[a] (%)	Percent[b]	Difference[c]	Percent[b]	Difference[c]	Percent[b]	Difference[c]
Vehicle struck by train							
Vehicle speed ≤10 mph	14.0	17.4	-3.4	33.3	-19.3	31.3	-17.3
Vehicle speed ≥10 mph	11.9	16.8	-4.9	9.5	2.4	16.0	-4.1
Train struck by vehicle	12.5	7.5	5.0	7.1	5.4	9.2	3.3
Total differences			-3.3		-11.5		-18.1

[a] Percent of total.
[b] Percent of total verified accidents.
[c] Difference between regulated-vehicle and general-truck accidents.

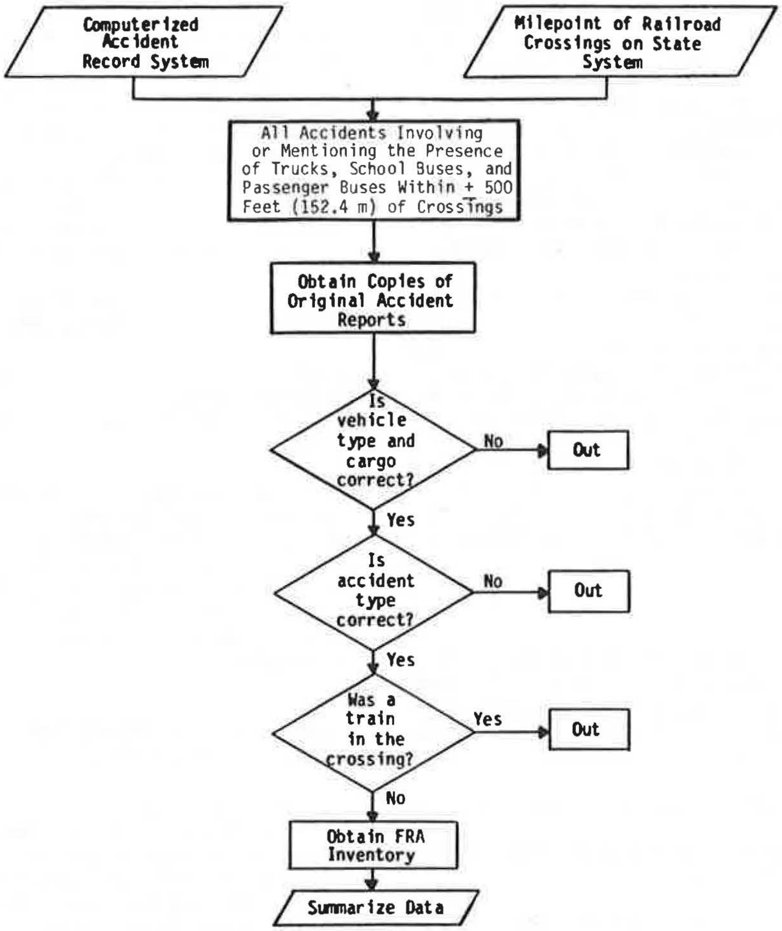

FIGURE 4 Flowchart of the non-train-involved accident identification procedure.

ported. Also, the record-keeping capabilities and policies of each state influence the accidents selected. Only one state maintained records back to 1975, one to 1976, and the remaining two states did not maintain records before 1978.

The average nationwide estimates of non-train-involved accidents for the analysis period were 40 involving hazardous materials transporters, 122 involving school buses, and 31 involving passenger buses. These represent the annual reduction in non-train-involved accidents that could be achieved if regulated vehicles were not required to stop at crossings with active devices when the devices were not activated. These estimates of non-train-involved accident frequencies appear inordinately low. It can be reasonably expected, for example, that during 1983 there were more than 40 accidents nationwide resulting from stops by hazardous materials transporters at crossings with active devices that were not activated.

COLLECTION AND ANALYSIS OF OPERATIONAL DATA

Data Collection

Data related to traffic conflicts, erratic maneuvers, compliance, and lane use were collected at 12 sites to obtain information on the operational effects of, and the rate of compliance with, the mandatory-stop regulation.

The initial data collection plan was to use six sites with and six sites without pullout lanes (also termed truck and bus stopping lanes). In addition to the consideration of pullout lanes, characteristics such as high traffic volumes, relatively high numbers of mandatory-stop vehicles, and two-lane roadways were desired to increase observational opportunities. Difficulties were encountered, however, in locating sites with pullout lanes.

A total of 79 sites identified by the national inventory as having truck pullout lanes were visited in Michigan, Ohio, and Illinois. Only two of these sites, located in Michigan, were determined to actually have pullout lanes, but they were not appropriate because of low volumes of mandatory-stop vehicles. The remaining 77 sites had been miscoded and did not have lanes that had been constructed for the primary purpose of reducing delay and congestion from stops by regulated vehicles in the traveled way. In urban areas a common error was that four-lane facilities with parking permitted were often erroneously coded as having pullout lanes when the parking was prohibited in advance of the crossing. The result of the site-selection process was six sites without pullout lanes, two each in Michigan, Ohio, and Illinois, and six sites with pullout lanes in Washington.

The difficulty in identifying sites with pullout lanes resulted in changes in both the magnitude and the interpretation of the data. The difference in magnitude resulted from using sites in Washington that had four lanes plus a pullout lane. It was originally planned to only use two-lane sites to increase the number of conflicts and erratic maneuvers observed. For example, erratic maneuvers or conflicts related to passing maneuvers would not be expected to occur on four-lane roadways. Changes in data interpretation resulted from the difference that exists in the state regulations pertaining to mandatory stops. Both Washington and Illinois are in basic agreement with the UVC recommendation, which does not require stops at crossings with active devices that are not activated. Variations exist, however, in that Illinois requires stops only by school buses and Washington requires stops by hazardous materials transporters. To help ensure compatibility among the hazardous materials transporters, data collected in different study areas were only obtained from trucks that were placarded.

Data were collected simultaneously for 9 hr on each approach by two data collectors. Each data collector observed one approach and manually collected data pertaining to driver action, placard type, directional volumes, number of following vehicles, position on the roadway, traffic conflicts, and erratic maneuvers. The frequency of observed traffic conflicts and erratic maneuvers, however, was not sufficiently large to permit any conclusions. To obtain a sufficiently large data set, a much larger data collection effort would need to be undertaken.

Results

Although the states chosen for study varied in their mandatory-stop regulations, there were sufficient similarities to permit a comparative analysis. This analysis was concerned with providing insights into two issues:

1. What is the overall compliance or violation rate?
2. Do the differences in state regulations result in different driver reactions?

The first issue was addressed by combining driver actions for each vehicle type on the basis of similarities in the state laws. Table 2 indicates that trucks and tank trucks have a violation rate of 97.5 and 70.1 percent, respectively. The violation rate for school buses was 36.4 percent. The tank-truck category was the only one with a number of observations sufficiently large for statistical analyses to be performed.

TABLE 2 Summary of Driver Compliance Data

Vehicle Type	No. of Observations by Driver Action: Full Stop	Rolling Stop	No Stop	Total	Violation Rate (%)
Trucks[a]	1	3	36	40	97.5
Tank trucks[a]	83	59	136	278	70.1
School bus[b]	28	16	0	44	36.4

[a] Placarded trucks from Michigan, Ohio, and Washington.
[b] Data from Michigan, Ohio, and Illinois.

If the compliance rate were higher, there would be a good possibility that observed differences between the characteristics of train-involved accidents of the general truck population and those of the regulated vehicles would be even more pronounced. This would be especially true in those accidents in which vehicles traveling less than 10 mph were struck by a train. Similarly, an increase in non-train-involved accidents could also be expected with an increase in the compliance rate.

The second issue regarding driver actions in the different states was analyzed by using the chi-square test. The observations on trucks and tank trucks were combined for Michigan, Ohio, and Washington, which are in basic agreement with the FMCSR in that stops are required by placarded vehicles at crossings with active devices. These data were compared with those from Illinois, where such stops are not required. The null hypothesis tested was that the frequency of truck and tank-truck driver actions (e.g., full stop, rolling stop, or no stop) is the same for Michigan, Ohio, and Washington as it is for Illinois. The data are as follows (chi-square = 6.03, df = 2, 95 percent critical value = 5.99):

State	No. of Observations by Driver Action: Full Stop	Rolling Stop	No Stop	Total
Michigan, Ohio, and Washington	84	62	172	319
Illinois	7	16	21	44

With the chi-square value of 6.03, the chances are less than 5 in 100 that the observed driver actions of mandatory-stop vehicles are similar in Michigan, Ohio, and Washington to those observed in Illinois. The different state laws therefore influenced driver behavior even though the violation rate was very high in the three states that require stops at active crossings.

DETERMINATION OF DELAY, FUEL CONSUMPTION, AND POLLUTION CONSEQUENCES

Estimates of delay, fuel consumption, and air pollution resulting from the mandatory-stop requirement at active crossings were obtained by using the NETSIM model, which was developed by FHWA as a generalized tool to analyze the impact of different traffic control strategies for roadway networks. Because the NETSIM model does not have provisions for modeling vehicles stopping at a railroad crossing, it was necessary to modify the model and use surrogates.

The modeling effort involved estimating the impact of regulated vehicles when the active devices were not activated. The presence of trains was therefore not a concern and the crossings were treated as two-way stop controlled intersections. The stop signs controlled the traffic on the low-volume surrogate railroad approaches. This permitted the main-street traffic to flow unimpeded unless intentionally stopped at the crossing. Although this strategy provided a dependable simulation of a railroad crossing, it inherently assumed that vehicles slow down at a crossing only for the arrival of a train. The actual speed of vehicles over a crossing is, however, dependent on the defensive driving behavior of the motorists and the condition of the crossing surface. Assuming that the vehicles slow down only for a train does not, however, affect the accuracy of the results because comparisons are being performed between conditions with and without the mandatory-stop regulation. The same basic assumptions are therefore being applied in both situations.

The vehicles making a stop at the crossings are creating short-term blockages analogous to a bus stopping to load or discharge passengers. This analogy was used to model bus stops before the railroad node. The vehicle, acting as a bus, is required to stop for an amount of time assumed equivalent to the time it takes to stop and check the tracks for oncoming trains. The effect of these stops on traffic and associated operational and environmental impacts were analyzed.

The primary purpose of the NETSIM analysis was to estimate the savings or differences in delay, fuel consumption, and noxious emissions between vehicles governed and not governed by the mandatory-stop regulation at crossings with active devices. This was accomplished by expanding the NETSIM simulation results to yearly estimates by categories of facility type, average daily traffic (ADT), and percent truck mix. The expansion was performed by using the number of working days (260) in a year, which provides a better representation of the decreased truck volumes occurring on weekends and holidays than that provided by the total number of days in a year.

These differences were expanded to nationwide estimates by determining the stratification of active crossings by the number of roadway lanes, ADT, and percent truck mix. The estimate of the number of crossings in each category was obtained by performing a stratification of 2,974 crossings randomly selected from the total of 53,207 crossings with active devices (excluding highway signals). The nationwide estimates of the annual delay, fuel consumption, and noxious emissions conserved by not requiring stops at crossings with active devices when not activated are as follows:

Excess Delay (hr/yr)	Excess Fuel Consumption (gal/yr)	Excess Noxious Emissions (tons/yr)		
		HC	CO	NOx
1,483,000	12,267,000	9,000	144,000	19,000

The NETSIM simulation indicates that if vehicles are not required to stop at crossings with active devices when the devices are not activated, there would be an annual nationwide savings of 1,483,000 hr of delay, 12,267,000 gal (46,614,000 L) of fuel, 9,000 tons (8,000 tonnes) of HC, 144,000 tons (130,000 tonnes) of CO, and 19,000 tons (17,000 tonnes) of NO_x.

The simulation results were expanded to yearly totals on the basis of the number of working days (260) in a year. Because there is truck movement on weekends and school bus and passenger bus movements were not simulated, the NETSIM results are conservative.

ECONOMIC CONSEQUENCES OF THE MANDATORY-STOP RULE

The economic consequences of the mandatory-stop rule result from its impact on accidents, pullout-lane installation and maintenance, fuel consumption, and delay. Estimates of each of these cost categories were made on an average annual basis.

Accident Costs

Costs associated with collisions between trains and hazardous materials transporters, school buses, or passenger buses have a higher total than those costs associated with other vehicle types. This is particularly true with regard to property damage costs for hazardous materials transporters. A study performed by NTSB for accidents from 1975 through 1979 determined that the average cost for property-damage-only accidents involving trucks carrying hazardous materials and trains was $27,007 (2). This is a conservative estimate of the actual costs. Factors such as potential train damage, cleanup of environmentally damaging pollutants, emergency response actions, litigation, and in some cases evacuation of citizens in danger can dramatically raise the property damage costs. Accidents that occurred after the NTSB study emphasize how conservative this estimate is. These accidents included four separate truck-train accidents occurring during a 10-day period in 1980 that resulted in nine fatalities, nine injuries, and $718,000 in property damage. In this 10-day period, the property damage costs amounted to 43 percent of the expected entire annual costs. Another truck accident, which was investigated in 1981, resulted in the derailment of 5 locomotive units and 24 cars, incurring $2,748,000 in property damage alone (2).

Several insurance companies and insurance service corporations were contacted to obtain information on the actual costs of accidents involving trains and trucks transporting hazardous materials, passenger buses, and school buses. These organizations stated that the costs of environmental cleanup, litigation, and property damage claims were either not available or considered proprietary information. Accident costs were therefore based on information from the NTSB study and the National Safety Council (NSC).

The costs and sources in Table 3 were used to determine the overall cost of the accident consequences. Note that the 1983 NSC costs were used in all accident and severity categories except property-damage-only and personal-injury accidents for hazardous materials transporters. This was done because, although accidents between trains and buses or school buses are often catastrophic in terms of fatalities and personal injury, bus accidents typically do not incur property damage losses comparable with those incurred by hazardous materials transporter accidents.

Estimating the overall accident cost savings for train-involved accidents required a breakdown by accident severity. This breakdown, presented in Table 4, included only accidents that had been previously verified. The data, for example, reveal that 0.38 of the 161 train-hazardous material transporter accidents involved a personal injury. For every personal-injury accident that occurred, an average of 1.8 persons was injured.

The estimated net reduction in train-involved accidents given earlier was applied to the severity breakdown of accidents that were verified over the 9-year analysis period. The annual savings in train-involved accidents resulting from not requiring vehicles to stop at crossings with active warning devices when unactivated is $106,000.

Estimates of the annual reduction in non-train-involved accidents were obtained by applying the cost of property-damage-only accidents to the previously determined 40, 122, and 31 annual reductions

TABLE 3 Accident Cost Estimates

	Train-Involved Accidents			Non-Train-Involved Accidents		
Vehicle Type	PDO ($)	PI ($)	F ($)	PDO ($)	PI ($)	F ($)
Hazardous materials transporters	27,007[a]	34,457[b]	210,000	1,150	8,600	210,000
School buses	1,150	8,600	210,000	1,150	8,600	210,000
Passenger buses	1,150	8,600	210,000	1,150	8,600	210,000

Note: Except as noted, 1983 NSC accident cost estimates were used. PDO = property damage only, PI = personal injury, F = fatality.

[a] Based on NTSB study (*2*, p. 2).

[b] The sum of NTSB PDO costs and NSC PI costs.

TABLE 4 Breakdown of Severity for Verified Train-Involved Accidents, 1975-1983

	Accidents Between Trains and		
Component of Accident Severity	Hazardous Materials Transporters	School Buses	Passenger Buses
Total no. of accidents	161	84	119
Property-damage only accidents	70	51	71
Personal-injury accidents			
No. of accidents	61	30	40
No. of persons	111	126	210
Fatal accidents			
No. of accidents	30	3	8
No. of persons	54	4	21
Personal-injury ratio	0.38	0.36	0.34
Persons injured per personal-injury accident	1.80	4.20	5.30
Fatality ratio	0.19	0.04	0.07
Persons killed per fatal accident	1.80	1.30	2.60

in accidents involving hazardous materials transporters, school buses, and passenger buses, respectively. The result was an annual non-train-involved accident cost reduction of $222,000. The property-damage-only cost was applied to the non-train-involved accidents because they are typically accidents of low severity.

The estimated total annual train-involved and non-train-involved accident cost savings resulting from not requiring stops at crossings with unactivated active devices is therefore $328,000 ($106,000 + $222,000). It should be realized that this estimate is a conservative, lower-bound estimate. It is based on only accidents positively identified as involving hazardous materials transporters, school buses, and passenger buses. In both the train-involved and non-train-involved accident categories there are additional accidents that could not be verified and in the case of non-train-involved accidents, that were not identified or reported.

Pullout-Lane Construction and Maintenance Costs

Pullout lanes permit vehicles to come to a stop without presenting major disruptions to through traffic. They are primarily constructed on two-lane facilities with relatively high vehicle and truck volumes. In addition to costs associated with the pullout lane itself, there are also costs associated with maintaining and extending the crossing surface over the rails; extending the gate arms, when present; and often converting the mast-mounted flashing lights to cantilevered lights.

The overall costs associated with each of these changes are dependent on their frequency of occurrence and the number of tracks involved. Efforts were extended in three steps to determine the costs associated with pullout lanes: (a) estimating the total number of pullout lanes, (b) estimating yearly installations, and (c) obtaining cost estimates.

Estimating the Total Number of Pullout Lanes

A nationwide search of the FRA national inventory, with no restrictions, revealed that 2,581 crossings were coded as having truck pullout lanes. The difficulties, however, in locating sites with pullout lanes for the data collection indicated that this figure was not accurate. To increase the accuracy, another search was performed with the restriction that only crossings on two-lane roadways be eligible for pullout-lane identification. This assumption resulted in the identification of 664 crossings as existing on two-lane facilities with truck pullout lanes. This estimate will probably be lower than the actual amount of pullout lanes because some multiple-lane roadways have pullout lanes. This was found to be the case in the state of Washington. It is likely, however, that the majority of installations will be on two-lane, two-way facilities that pose passing restrictions without a pullout lane.

Estimating Yearly Installations

An estimate of the annual number of new pullout-lane installations was obtained by searching the historic and current records of the FRA national inventory. This process revealed that an average of 17 crossings per year are equipped with new pullout lanes.

Estimating Pullout-Lane Costs

Estimates of construction and maintenance costs were obtained from an investigation of literature and a survey of the states and railroads. The primary source for the maintenance costs was a 1982 technical paper presented by Bryant (6) to the Communications and Signal Division meeting of AAR. Bryant studied 400 crossings, stratified them by warning-device type and number of tracks, and determined the average yearly maintenance cost.

Construction costs were obtained from a survey forwarded to the railroads and states as part of this study. These costs were applied to the number of crossings with each warning device and crossing-surface type, which were also obtained from the FRA national inventory. The average annual construction cost was estimated to be $596,000 and annual pullout-lane maintenance cost was $645,000. The estimated maintenance cost does not include the cost of maintaining the surface condition of the pullout lanes themselves.

Fuel Consumption Costs

Results from the NETSIM analysis indicate that 12,267,000 gal/year (46,614,600 L/year) are consumed at active crossings because of the mandatory-stop provision. Applying a conservative estimate of $1 per gallon results in $12,267,000 in excess fuel expenditure per year.

Delay Costs

The NETSIM analysis yielded estimates of delay to the total traffic stream in addition to the delay experienced by the vehicles required to stop. In determining the associated cost of delay, the NETSIM estimates were separated into truck and following-vehicle delay. This was done to apply the cost estimates based on vehicle type.

The value-of-time estimates were obtained from 1977 estimates provided in a publication by the American Association of State Highway and Transportation Officials (AASHTO) (7). All of the following vehicles were assumed to be automobiles that experienced delays of less than 5 min. Applying the AASHTO estimates for occupancy rate and value of time for an average traveler trip resulted in a delay cost of $0.33 per hour. For trucks, the delay cost was assumed to represent market costs rather than the value of personal user time, as was used for automobiles. This approach was taken because the lost productivity of the truck driver's time represents, in most cases, an actual monetary outlay by the shipper. The value used for truck delay was therefore $8 per hour. It should be noted that the values used for both automobile and truck delay represent 1975 values and were not updated by the Consumer Price Index to yield current values; therefore they present a lower-than-actual cost. The total cost of delay resulting from requiring vehicles to stop at active crossings when the devices are not activated is as follows:

Vehicle Type	Annual Delay (hr)	Hourly Time Value ($)	Delay Cost ($)
Automobile	1,350,000	0.33	446,000
Truck	133,000	8.00	1,064,000
Total			1,510,000

The results of the economic consequences of proposed changes in the mandatory-stop requirement are as follows:

Cost Category	Annual Cost ($)
Train- and non-train-involved accidents	328,000
Pullout-lane construction	596,000
Pullout-lane maintenance	645,000
Fuel consumption	12,267,000
Delay	1,510,000
Total	15,346,000

CONCLUSIONS

The project activities resulted in the following conclusions:

- Higher proportions of hazardous materials transporters, school buses, and passenger buses were struck by a train at crossings with active devices than was the case for trucks not transporting hazardous materials. This difference was found to be significant at the 99 percent confidence level.
- The percentage of accidents involving the vehicle hitting the train was smaller for the population of mandatory-stop vehicles than it was for the population of trucks not transporting hazardous materials. This difference was large enough to be significant at the 99 percent confidence level.
- If the mandatory-stop rule did not require stops at crossings with active warning devices when the devices were not activated, the primary responsibility of recognizing the presence of a train was placed on the train-detection system. It was conservatively estimated that this would result in an increase in train-involved accidents of 0.70 percent due to the malfunction of the warning system.
- Requiring vehicles to stop at crossings with activated devices when no train is present or approaching results in an increased number of vehicle-to-vehicle accidents. The annual nationwide estimate of such non-train-involved accidents was 40, 121, and 31 for hazardous materials transporters, school buses, and passenger buses, respectively.
- If the mandatory-stop regulation did not require stops at crossings with activated devices when not activated, there would be a net annual decrease in train-involved accidents for hazardous materials transporters, school buses, and passenger buses of 2.6, 10.8, and 17.4 percent, respectively. The net decrease would occur even though there was an increase in accidents where the train was struck by the vehicle and in accidents due to warning-device malfunction.
- Requiring vehicles to stop at crossings with active devices when not activated results in 1,483,000 hr of excess delay and 12,267,000 gal of excess fuel consumption. Truck pullout lanes at railroad crossings, necessitated indirectly by the mandatory-stop regulations, result in an estimated annual expenditure of $596,000 for construction and $645,000 for maintenance.
- Requiring vehicles to stop at crossings with active devices when not activated results in excess annual expenditures of $328,000 in accident costs, $12,267,000 in fuel, and $1,510,000 in the value of time lost due to delay.
- The rate of the violation in which drivers of regulated vehicles did not come to a full stop was high with regard to trucks (97.5 percent) and tank trucks (70.1 percent). School buses and passenger buses had consistently lower violation rates than trucks and tank trucks.

REFERENCES

1. Uniform Vehicle Code, Section 11.703. National Committee on Uniform Traffic Laws and Ordinances, Chicago, Ill., 1975.
2. Special Study: Railroad/Highway Grade Crossing Accidents Involving Trucks Transporting Bulk Hazardous Materials. Bureau of Technology Report NTSB-HZM-81-2. National Transportation Safety Board, U.S. Department of Transportation, Sept. 1981.
3. Advance Notice of Proposed Rulemaking 82-10. Federal Register, Vol. 47, No. 223, Nov. 18, 1982.
4. M.G. Crawford. Nonoperation of Railroad-Highway Train Activated Automatic Grade Crossing Warning Devices, 1975-1976. Office of Rail Systems Analysis and Information, Federal Railroad Administration, Washington, D.C., Aug. 1977.
5. A.W. Johnston. Special Safety Inquiry: Rail-Highway Grade Crossing Safety. FRA Docket RSSI-84-3, Notice 1, Washington, D.C., July 1984.
6. T. Bryant. Cost Survey of Highway-Rail Warning Devices. Presented at AAR Communications and Signal Division 22nd Annual Meeting, St. Louis, Mo., Oct. 1982.
7. A Manual on User Benefit Analysis of Highway and Bus Transit Improvements, 1977. American Association of State Highway and Transportation Officials, Washington, D.C., 1977.

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