CONSEQUENCES OF MANDATORY STOPS AT RAILROAD-HIGHWAY CROSSINGS

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Research, Development, and Technology
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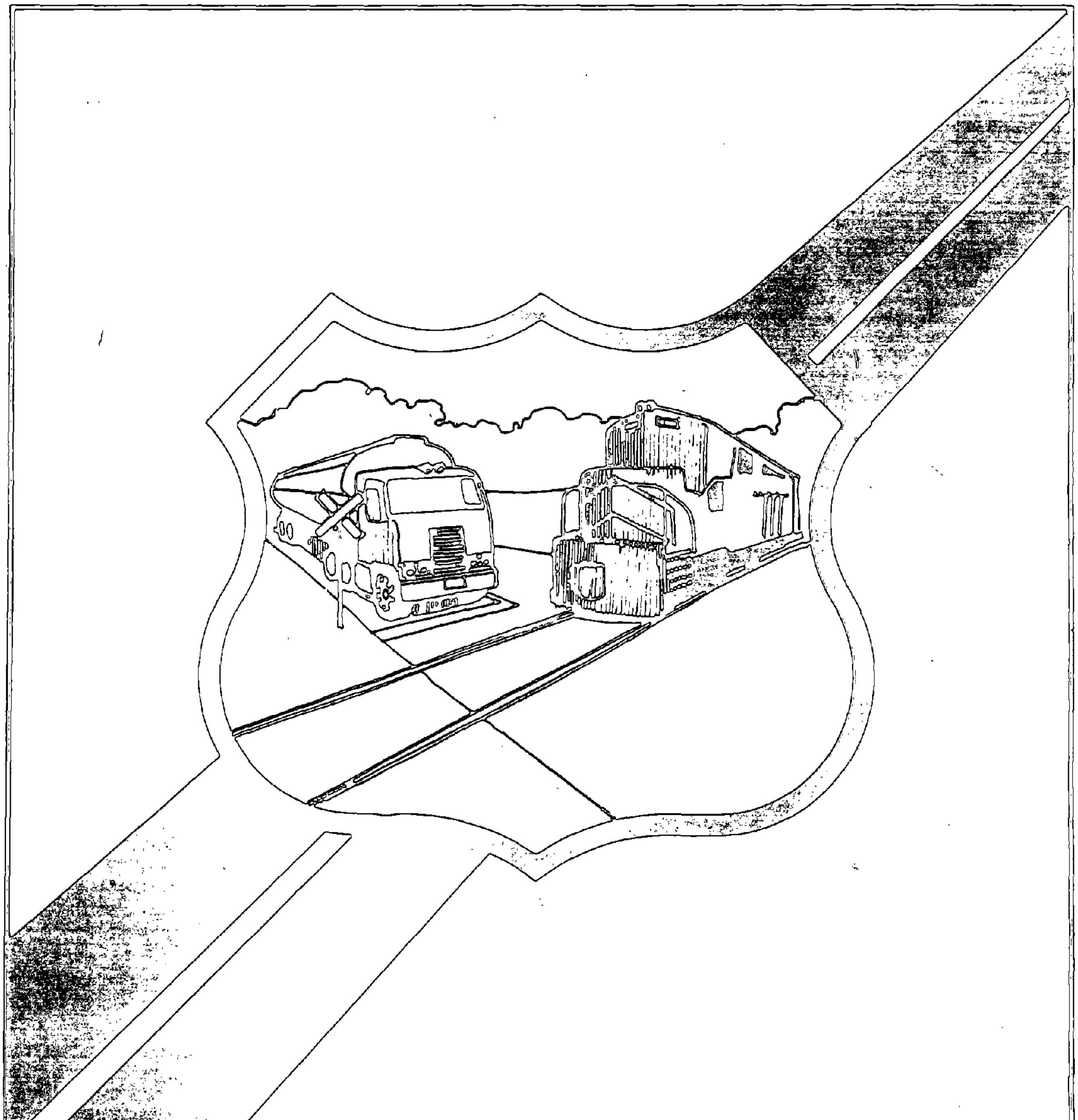

FOREWORD

This report will be of interest to policy makers concerned with regulations governing the movement of hazardous materials, school buses and passenger buses. The research was initiated to provide information regarding a proposed rule change in the Federal Motor Carrier Safety Regulation which would exempt the hazardous material transporters, school buses and passenger buses from having to stop at railroad grade crossings with active warning devices when the devices are not activated. The research clearly indicates safety and cost benefits would result with the proposed rule change.

The report is from a contractual effort as part of FCP Project 1A "Safety and Traffic Control Devices." Mr. Gary Hughes of Region 10 served as the Contracting Officer's Technical Representative.

One copy of the report is being sent to each region and division office and one copy for each State highway agency. The division and State copies are being sent directly to the division offices.

Stanley R. Byington
Director, Office of Safety and
Traffic Operations R&D

NOTICE

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16. Abstract

The purpose of this study was to determine the safety, economic, operational, and environmental consequences of requiring certain types of vehicles 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 train and nontrain-involved accidents, traffic operations, fuel consumption, delay, pullout-lane construction/maintenance costs, and environmental degradation.

Results of the study indicate that not mandating stops at railroad crossings with active devices when the devices are not activated would result in an annual reduction of both train and nontrain accidents for hazardous material transporters, school buses, and passenger buses. Not requiring stops would result in a net annual decrease in train-involved accidents for hazardous material transporters, school buses, and passenger buses of 2.6, 10.8, and 17.4 percent, respectively. The annual economic savings resulting from not requiring stops were estimated as $454,000 in accident costs, $1,241,000 in pullout-lane construction/maintenance costs, $12,267,000 in excess fuel consumption, and $1,510.000 in delay.

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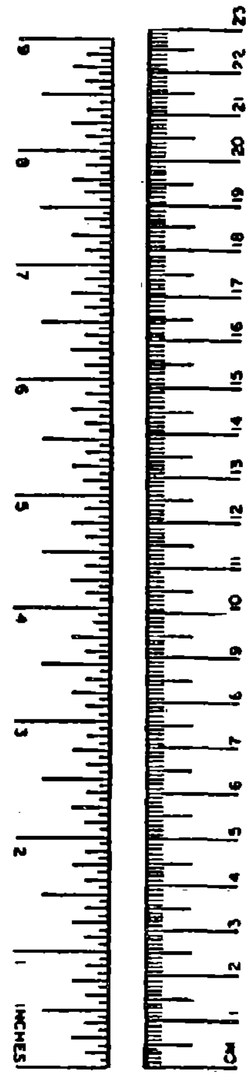
METRIC CONVERSION FACTORS

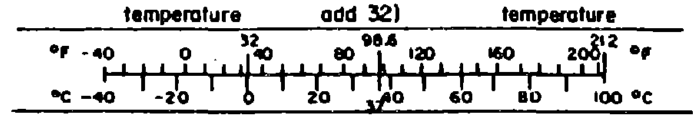
APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Introduction

Collisions between trains and vehicles transporting either hazardous materials, or a relatively large number of passengers, have potential for catastrophic consequences. Accidents involving hazardous materials can affect not only the vehicle occupants but also other motorists, bystanders, nearby occupied buildings, and, in some instances, entire communities. Recognition of the potential consequences prompted the enactment of regulations requiring certain vehicles to stop at railroad highway crossings and only proceed when it is deemed safe to do so. These regulations are commonly referred to as "mandatory stop requirements."

There are two primary sources for regulations governing the actions of drivers at railroad highway crossings. These are regulations promulgated by the Bureau of Motor Carrier Safety (BMCS), through the Federal Motor Carrier Safety Regulations (FMCSR), and those promulgated by individual States and local jurisdictions. The regulations adopted by the States and local jurisdictions consist primarily of adaptations, either in their entirety or portions thereof, of the FMCSR or the 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 contained in the UVC. Included in these differences are that the UVC provides no exemptions for streetcar crossings, tracks used exclusively for industrial switching purposes, and abandoned tracks. In addition, in the UVC, stops are not required at crossings with train-activated gates and/or flashing lights, when these devices are not activated.[1] Not requiring a stop at crossings with active warning devices is the major difference between the UVC recommendations and the FMCSR. Since individual States adopt all or portions of the UVC or the FMCSR, there are wide variations in State rules regarding stops at crossings.

The variations between the recommendation of the UVC, the FMCSR and State laws has led to questions of which version has the greatest potential for reducing accidents. The primary issue of concern is whether to require vehicles to stop at crossings with active warning devices. The National Transportation Safety Board (NTSB), based on the 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). This notice (No. 82-10), issued in the Federal Register (Volume 47, No. 223, November 18, 1982) by the Federal Highway Administration, requested comments and information to determine if 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 non-train-involved crossing accidents attributable to mandatory stopping by certain vehicles, cost savings to be derived from a change to the FMCSR mandatory stop requirement, and the environmental effects of the proposed rule change.

Study Scope and Objectives

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. Assessing the positive and negative aspects of proposed changes to the FMCSR, required a determination of probable increases and decreases in train and nontrain-involved accidents, fuel consumption, costs, and environmental degradation.

The study utilized information available from the Federal Railroad Administration (FRA), the National Highway Traffic Safety Administration, the Bureau of Motor Carrier Safety (BMCS), the Federal Highway Administration (FHWA), individual States, railroad operating authorities, and available literature, in addition to site-specific operational data. Only data pertaining to public railroad highway crossings were included in the analysis.

The specific objectives of the study were:

To determine the safety, economic, operational, and environmental consequences of:

- The current FMCSR requirement for certain classes of vehicles to stop at all railroad highway crossings.
- Requiring stopping only at all railroad highway crossings with passive warning devices and at crossings with active warning devices when the devices are activated.
- Elimination of pullout lanes at crossings with active warning devices, with and without the requirement that certain classes of vehicles are required to stop.

Research Approach

The research approach was structured to provide an unbiased view of the consequences of the proposed changes to the FMCSR mandatory stop law. This approach involved an investigation of:

- Nationwide train-involved accident data for accidents occurring from 1975 through 1983.
- Nontrain-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 crossing signal malfunction.
- 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 following vehicle conflicts caused by stopping.
- The violation rate of the regulated vehicles.
- The fuel consumption, noxious emissions, and delay caused by regulated vehicles stopping at all crossings with active warning devices.

Conclusions

The project activities resulted in the following conclusions:

- The stringent verification process used in this study, resulted in a relatively small number of both train and nontrain-involved accidents being selected for analyses. There were 169 accidents that could not be verified as either involving or not involving the specific vehicle types or accident characteristics required for analysis. If more of these accidents could have been verified and included in the analysis, the accident frequencies would have been much higher. Therefore, accident frequencies and associated accident costs contained in this report represent a lower limit on the actual values.

- There were higher proportions of hazardous material transporters, school buses, and passenger buses being struck by a train at crossings with active devices than that which occurs for trucks not transporting hazardous materials. This difference was found to be significant at the 0.01 significance level.

- The percentage of accidents involving the vehicle impacting 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 0.01 level.

- If the mandatory stop requirement did not require stops at crossings with active warning devices when the devices are not activated, the primary responsibility of recognizing the presence of a train would be placed on the train detection system. It was conservatively estimated that this would result in train-involved accidents increasing 0.70 percent, due to nonoperation of the warning system. This estimate for accidents due to nonoperating warning systems would, however, decrease to 0.33 percent if accidents involving insulated railroad equipment could be eliminated. Train detection systems are not designed to automatically detect the presence of insulated equipment.

- 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 nontrain-involved accidents was estimated to be 40, 121, and 31 for hazardous material transporters, school buses, and passenger buses, respectively. These estimates appear to be inordinately low for nationwide totals. It can be reasonably expected, therefore, that these estimates represent a lower limit on the actual values.

- If the mandatory stop regulation did not require stops at crossings with active devices when not activated, there would be a net annual decrease in train-involved accidents for hazardous material transporters, school and passenger buses of 2.6, 10.8, and 17.4 percent, respectively. The net decrease would occur even though there would be an increase in accidents where the train was struck by the vehicle and in accidents due to warning device non-operation.

- Requiring vehicles to stop at crossings with active devices when not activated results in 1,483,000 hours of excess delay and 12,267,000 gallons of excess fuel being consumed. Truck pullout lanes at railroad crossings, necessitated indirectly by the mandatory stop regulations, results 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 $454,000 in accident costs, $12,267,000 in fuel, and $1,510,000 in the value of time lost due to delay.

- A higher percentage of school and passenger bus accidents occur at crossings with active control devices. This may be due to exposure. A larger proportion of bus trips can be expected to occur in urban areas with higher population densities and vehicular traffic. Urbanized roadways with high ADT are more likely to have active warning devices than low volume rural roadways.

- A higher percentage of hazardous material transporter accidents occurred at crossings with passive warning devices. This may be a function of exposure since the hazardous material depots, warehouses, and shipping points are often located in low density rural areas.

- The violation rate, where 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 and passenger buses had consistently lower violation rates than trucks and tank trucks.

- The increased use of double and triple bottom truck trailers results in the minimum MUTCD advance warning of 20 seconds, being insufficient at many railroad grade crossings.

CHAPTER 1 - INTRODUCTION

Statement of the Problem

Collisions between trains and vehicles transporting either hazardous materials, or a relatively large number of passengers, have potential for catastrophic consequences. Accidents involving hazardous materials can affect not only the vehicle occupants but also other motorists, bystanders, nearby occupied buildings, and, in some instances, entire communities. Recognition of the potential consequences prompted the enactment of regulations requiring certain vehicles to stop at railroad highway crossings and only proceed when it is deemed safe to do so. These regulations are commonly referred to as "mandatory stop requirements."

There are two primary sources for regulations governing the actions of drivers at railroad-highway crossings. These are regulations promulgated by the Bureau of Motor Carrier Safety (BMCS), through the Federal Motor Carrier Safety Regulations (FMCSR), and those promulgated by individual States and local jurisdictions. The regulations adopted by the States and local jurisdictions consist primarily of adaptations, either in their entirety or portions thereof, of the FMCSR or the recommendations of the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO).

FMCSR in title 49CFR section 392.10 requires every bus transporting passengers and placarded or marked vehicles transporting specified hazardous materials (whether loaded or empty) to stop at every railroad-highway grade crossing with the exception of those crossings that 1) are streetcar crossings or railroad tracks used exclusively for industrial switching purposes; 2) have traffic controlled by a police officer or crossing flagman; 3) control traffic movement by a stop and go traffic light; 4) are abandoned; or 5) are posted with an "Exempt Crossing" sign.[3] The FMCSR applies to vehicles and operating authorities involved in interstate commerce.

The NCUTLO has compiled recommendations, in the form of model legislation, that can be adopted as State motor vehicle and traffic laws. These recommendations are compiled in the UVC which has contained a section requiring drivers of school buses and vehicles carrying dangerous cargos to stop at railroad crossings since 1930.[4] The UVC was revised in 1971 to eliminate some problems that were deemed, by proponents of change, to make the existing code unreasonable. These problems centered on definitions of "flammable liquids," hazardous cargo quantities, designation of regulated vehicles and treatment of exempt crossings.[5] The revisions that were made to the UVC addressed these deficiencies but differences exist between the UVC recommendation and the FMCSR. One principal difference is that the UVC provides no exemptions for streetcar crossings, tracks used exclusively for industrial switching purposes, and abandoned tracks. In addition, in the UVC, stops are not required at crossings with train-activated gates and/or flashing lights when these devices are not activated.[1] Not requiring a stop at crossings with active warning devices is a major difference between the UVC recommendation and the FMCSR.

Since individual States adopt all or portions of the UVC recommedations or the FMCSR there are wide variations in State rules regarding stops at crossings. Kearney compiled the State laws and compared them to the recommended regulations of the UVC.[4] In analyzing 51 jurisdictions, (50 States and the District of Columbia), Kearney determined that two have laws encompassing the 1971 UVC recommendation, two had no section in their code requiring certain vehicles to stop at grade crossings, and 47 described the types of vehicles and the crossings at which stops are required. Eight States have more than one law requiring mandatory stops, one for buses and school buses, and another for trucks carrying hazardous materials.

Kearney further ascertained that 36 States comply with the FMCSR rule requiring drivers to stop at crossings equipped with gates and/or flashing lights even when they are not activated. Seven States are in partial agreement with the UVC's recommendation to not require stops when the devices are not activated. These States differ from the UVC by not requiring stops by some vehicle types or by exempting only those crossings equipped with gates. Another 12 States exempt mandatory stops at crossings with official traffic control devices, but differ from the UVC recommendation by not requiring an "exempt" sign, by limiting the exemption to certain crossings, (abandoned, in a residential or business district, etc.), or by exempting certain vehicles.[4]

The variations between the recommendation of the UVC, the FMCSR and the State laws has lead to questions of which version has the greatest potential for reducing accidents. The primary issue of concern is whether to require vehicles to stop at crossings with active warning devices when they are not activated. The National Transportation Safety Board (NTSB), based on the 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). This notice (No. 82-10), issued in the Federal Register (Volume 47, No. 223, November 18, 1982) by the Federal Highway Administration, requested comments and information to determine if the FMCSR should be modified to exclude crossings protected by certain active devices from the mandatory stop requirement. The ANPRM requested additional data or information on nontrain-involved crossing accidents attributable to mandatory stopping by certain vehicles, cost savings to be derived from a change in the FMCSR mandatory stop requirement, and the environmental effects of the proposed rule change.

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The study utilized information available from the FRA, FARS, BMCS, FHWA, individual States, railroad operating authorities, and available literature, in addition to site-specific operational data. Only data pertaining to public railroad highway crossings were included in the analysis.

The specific objectives of the study were:

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- Requiring stopping only at all railroad highway crossings with passive warning devices and at crossings with active warning devices when the devices are activated.
- Eliminating pullout lanes at crossings with active warning devices, with and without the requirement that certain classes of vehicles are required to stop.

Research Approach

The research approach was structured to provide an unbiased view of the consequences of the proposed changes to the FMCSR mandatory stop law. This was accomplished by looking at both the negative and positive aspects of the tasks presented in figure 1. For example, when analyzing train-involved accidents, it was assumed that certain accident types could possibly be reduced by adopting the proposed change while other types, such as the regulated vehicle striking the train, could be increased.

The individual tasks performed and their sequence of performance is shown in figure 1. These tasks encompassed an investigation of:

- Nationwide train-involved accident data for accidents occurring from 1975 through 1983.
- Nontrain-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

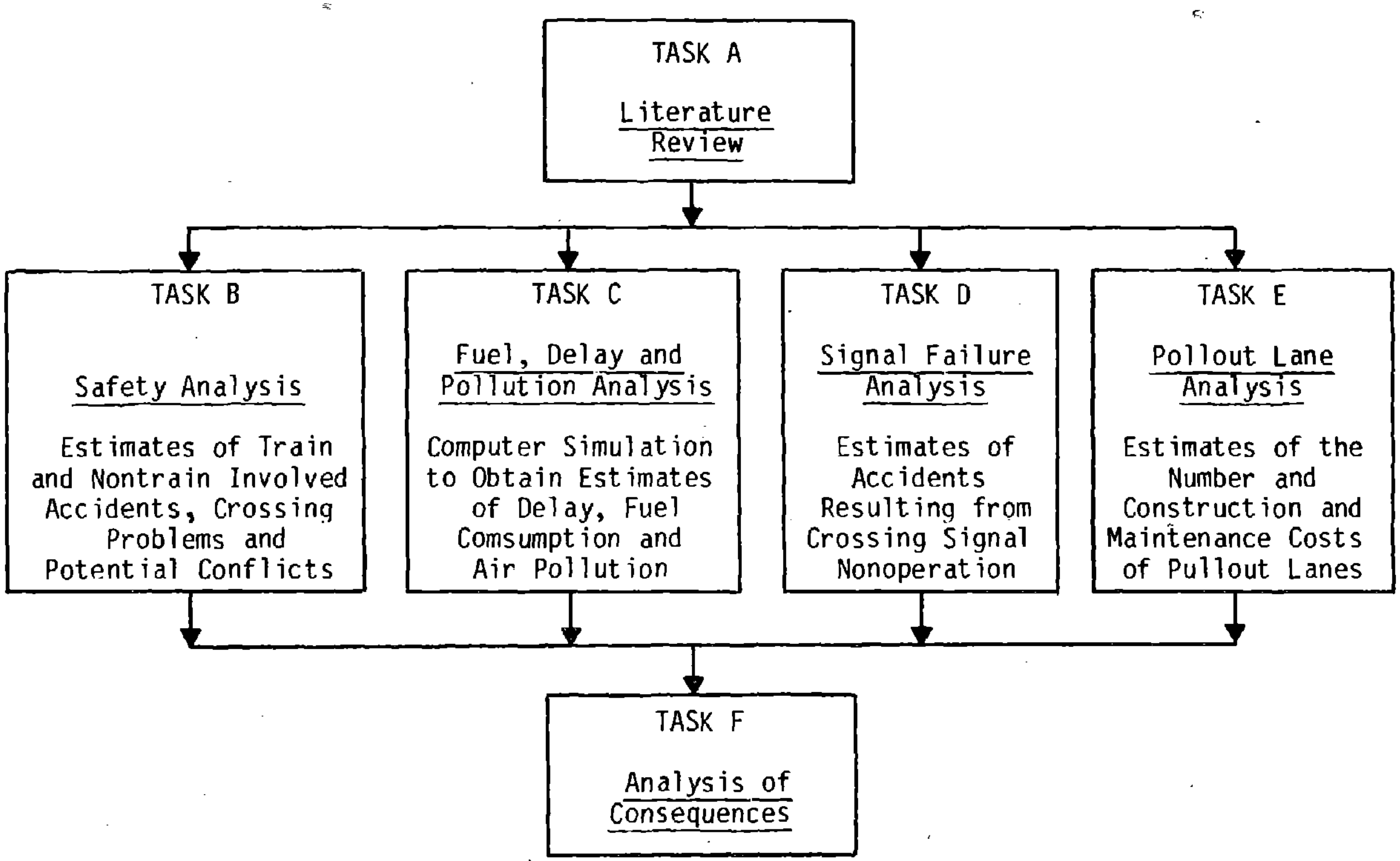

Figure 1. Flow diagram of project tasks.

not activated.

- The historic rate of crossing signal nonoperation.
- The minimum amount of advance warning required for different combinations of roadway vehicles to clear the crossing zone after coming to a complete stop.
- Following vehicle conflicts caused by stopping.
- Violation rate of the regulated vehicles.
- Fuel consumption, noxious emissions, and delay caused by regulated vehicles stopping at all crossings with active warning devices.

Background and Literature Review

One of the first activities of this project was a review of available literature on the mandatory stop regulation. This review consisted of identifying literature that addressed the following specific issues of concern:

- The Reliability of Train-activated Devices.

  The original mandatory stop regulation, established prior to 1940, was based on the level of equipment reliability utilized at that time. Have advancements in railroad crossing protection devices and carrier operating characteristics eliminated the need for vehicles to stop at crossings with active control?

- Adequacy of Advance Warning.

  When a vehicle stops at a railroad crossing the total time in the hazard zone is dependent upon the drivers perception/reaction time, acceleration characteristics of the vehicle, length of the hazard zone, and vehicle length. Does the minimum time of 20 seconds advance warning provide sufficient time for vehicles of different lengths to clear the hazard zone when the driver initiates the crossing action from a full stop?

- Analysis of Train-involved Accidents.

  The characteristics of train-involved accidents are a function of driver action. Those incidents where the vehicle impacts the train indicates that the driver had no prior intention of stopping at the crossing or did not begin to decelerate in sufficient time to avoid the accident. Conversely, those accidents in which the vehicle is impacted by the train indicate a situation where the driver may have followed the mandatory stop rule but had insufficient time to clear the hazard zone. Changes in the mandatory stop requirement will have a different impact on these two accident types. What proportion of train and regulated vehicle accidents would be affected by changes in the mandatory stop requirement?

- Analysis of Nontrain-involved Accidents.
  The stopping of vehicles at railroad crossings presents an obstruction to following vehicles. What is the magnitude of nontrain-involved accidents at railroad crossings that either directly or indirectly involve mandatory stop vehicles?

- Economic Consequences.
  The economic consequences of the mandatory stop regulation include construction, fuel, delay, and maintenance costs in addition to accident costs. What are the potential economic consequences of the different versions to the mandatory stop requirement?

- Environmental Consequences.
  Requiring vehicles to stop and then accelerate to free flow speed increases exhaust emissions. What is the magnitude of the additional noxious emissions resulting from requiring stops at crossings with active warning devices?

The following is a discussion of the major findings from the literature review.

Reliability of Train-activated Devices

The reliability of train-activated devices will have a direct impact on train-involved accidents if the current FMCSR is changed to not require stops at crossings with active devices when the devices are not activated. The specific reasons for the initial 1930's regulation and recommendations requiring stops at all active crossings was not found in the literature. It is unknown whether this was due to a single or series of catastrophic incidents at active crossing sites, or if equipment reliability was so poor that the potential for a catastrophic incident was high. It may have been that the proportion of crossings with active devices was so small that the impact of requiring stops was miniscule.

While the reasons for including crossing with active devices in the initial regulation is unknown, it is known that the proportion of crossings with active devices is greater today than it was in the early 1930's. For example, in fiscal years 1935 through 1942, 3,844 grade crossings were eliminated, 655 grade separations were constructed, and traffic control devices were installed at 4,652 crossings.[6] In addition, advances in hardware and train detection technology have resulted in current systems being more dependable than when the regulation was enacted. The increased numbers and dependability of train-activated warning devices may influence the need for requiring regulated vehicles to stop at crossings with active devices.

While the FMCSR requires stops at crossings with active devices, the regulation does not require stops at crossings equipped with a highway traffic signal; when showing green. This may be interpreted to mean that flashing grade crossing signals are not as reliable as highway traffic signals. The problem with this contention is that highway traffic signals installed at, or in the vicinity of, railroad crossings are designed to be preempted by an approaching train. The recognition that a train is approaching is accomplished by the same train detection circuitry that is used for the railroad flashers. If that circuitry is nonoperative for the flashers, it will be inoperative for the traffic signal as well.

Failed circuitry was found to be a factor in a study performed by the National Transportation Safety Board (NTSB) investigating the contributing causes to a collision between a commuter train and a gasoline tanker truck. [7] This incident occurred in 1982 at a location which was equipped with traffic signals interconnected with the railroad train detection circuitry. The railroad's automated grade crossing warning system was designed to provide a normally open contact to the highway traffic signal system. The open circuit would be lost when an approaching train shunted the track circuitry, thereby closing a contact which provided a continuous electrical circuit activating the traffic signals and crossing flashers. One of the probable causes of the accident was identified as a loss of shunting which deactivated the circuit and caused the traffic signal to show green. The shunting loss was determined to have occurred because of the light weight of the commuter train, the nonuse of the track during the day before the accident, and the possibility of a film of dirt and rust building on the rails.

The train detection systems of modern crossing hardware are designed to be failsafe. The train detection logic is designed to recognize train presence by the shunting action or change in impedance resulting from a railroad unit (railroad consist) occupying the tracks. Alternative power supplied by backup batteries provide necessary current in case of a commercial power outage. If there is a power failure or if the train detection circuitry fails, the flashers and the highway traffic signals, when present, revert to the active mode. The motorists are, therefore, instructed to stop and visually verify that it is safe to proceed.

A search of the literature did not reveal any evidence that traffic signals were more dependable than flashers at railroad crossings. Since 1) both use the same control circuitry and 2) traffic signals require additional electrical and mechanical components, it is reasonable to assume that crossings equipped with highway traffic signals in addition to flashers may be more prone to malfunction than crossings equipped only with flashers. No studies, however, were found that supported this diametric contention.

Crawford analyzed 261 accidents which occurred during 1975 and 1976 that were reported as involving malfunction of warning devices.[8] Only 50 of these accidents were classified as actually involving signal malfunction. The remaining accidents involved cases that were miscoded, had signals that were actually working, did not have active devices present, or involved insulated equipment that was not designed to activate the signals. Of the 50 which were classified as signal nonoperation, 24 were attributable to equipment malfunction, 19 were alleged to be human errors, and 7 were caused by vandalism.

Johnston carried the work of Crawford one step further by extending accidents involving nonoperating signals resulting from equipment failure to nationwide data.[9] Johnston determined that 12 percent and 16 percent of the alleged accidents involving equipment malfunction during 1975 and 1976, respectively, were valid. Johnston increased these estimates to 20 percent and applied this estimate to the total yearly train-involved accidents. The result was that only 0.3 percent of the yearly accidents that occur at crossings with active warning devices were attributable to a signal malfunction. The 20 percent estimate used by Johnston was conservative. If 15 percent, which corresponds more closely with the 1975 and 1976 findings, was used the annual incidence of equipment failure accidents would drop to 0.2 percent during the period of 1978 to 1983.

In summary, no references could be found in the current literature to support the contention that traffic signals at railroad crossings are more reliable in warning of the presence of a train than crossing flashing lights alone. In addition, only a small percentage (0.3 percent) of all accidents at railroad crossings are caused by equipment malfunction. Accidents which actually occurred during conditions of signal nonoperation were found to be attributable to human error, insulated equipment and vandalism in addition to actual equipment malfunction.

Adequacy of Advance Warning

In addition to requiring regulated vehicles to stop at railroad crossings, the FMCSR prohibits manual gear shifting on the tracks to reduce the possibility of stalling. Due to the slow acceleration characteristics of trucks while in low gears, it takes some 55-foot(16.8m) trucks 18 seconds to clear the crossing hazard zone. The required time to clear the hazard zone is even greater if multiple tracks, sharp angle of intersection, or rough crossing surfaces exist. This clearance time does not consider the the additional time that the driver needs to look in both directions, shift into gear and accelerate. Warning signals are required by the Manual on Uniform Traffic Control Devices (MUTCD), to provide at least 20 seconds advance warning of an approaching train.[10] If it takes nearly 20 seconds for a truck to clear a crossing, and a warning is provided for only 20 seconds, there is a possibility that the trailer will be struck by the train, even if the driver complies with the law.

Messiter concluded from his research that, due to the unusually high frequency of low speeds in the accidents he studied, "the act of stopping or negotiating crossing at very low speeds may magnify the hazard or introduce additional ones."[11]

An NTSB study also revealed a large number of train-involved accidents in which train speeds as well as truck speeds were low.[2] The study estimated that truck and train speeds were in the range of 0 to 10 mi/h (0 to 16 km/h) in 68.1 and 46.4 percent, respectively, of the accidents studied. In addition, 81.4 percent of the accidents occurred with the train striking the truck. This accident type combined with the low truck speeds suggests that the trucks had come to a full or rolling stop at the crossing in response to either a poor crossing surface or the mandatory stop requirement.

Included in the NTSB's report on their study is a summary of the Southern Railway System's pilot grade crossing safety program. As part of this program, the train operators were to report any near collisions they viewed as they proceeded through the crossing.[2,12] During this 14-month program, 48 near-collisions between trains and hazardous material haulers were reported. As a result of these findings, the Southern Railway System estimates that for every reported accident at a railroad crossing, there are at least 12 near-collisions.

Using information from previous studies, Richards concludes that the probability of a collision between a train and a vehicle is very small, since, under normal operating conditions, vehicles are in the hazard zone of the crossing for only small increments of time. Requiring vehicles to stop and then proceed through the crossing without changing gears increases the crossing time and, hence, the possibility of an accident. [13]

In summary, negotiating crossings at low speeds can be attributable to full or rolling stops resulting from the mandatory stop requirement or to poor crossing surfaces. Whatever the cause, a low crossing speed increases the amount of time that the vehicle spends in the hazard zone. Since the potential for an accident is a function of exposure, any increase in hazard zone time results in an increased accident potential. Thus, the legal requirement that a vehicle must stop at every crossing, regardless of the type of crossing control, may increase rather than decrease collision risk.

In addition, if the vehicles are stopping at crossings with active control devices and the crossings are equipped with only a 20-second advance warning, the possibility of an accident may be higher than if they had not stopped. This is especially true if poor crossing geometrics or sight restrictions exist.

Train-Involved Accidents

The literature review revealed only one comprehensive multiyear study on train-involved accidents involving trucks transporting hazardous materials. The study, performed by NTSB, was conducted on accident summaries provided by the Federal Railroad Administration (FRA).[2] The initial data provided by the FRA was determined to include vehicles other than trucks classified as carriers of hazardous materials. Some automobile accidents, for example, were coded as hazardous material accidents if their gasoline tanks ruptured. This necessitated that each accident be verified by examining information available from the files of other agencies. Each FRA accident report from 1975 through 1979 was examined individually by NTSB personnel, resulting in 288 verified accidents being used in the study. The study included accidents occurring at crossings with active and passive warning devices.

The data for the 288 incidents indicated that hazardous material accidents tended to occur at single track crossings (57.3 percent) where average daily traffic was either very low (less than 500 vehicles -- 25.4 percent) or relatively high (greater than 5,000 vehicles -- 26.2 percent). The accidents occurred primarily on two-lane (82.0 percent), paved roadways (85.8 percent) where the crossing intersected the highway at 60 to 90 degrees (78.1 percent). The crossings were equipped with gates and/or flashers in 38.2 percent of the accidents and 81.4 percent of the accidents involved the train striking the truck.

A number of studies developed conclusions or recommendations that were applicable to mandatory stop vehicles. One of these studies, performed by Sanders, collected and analyzed observational data of driver behavior at railroad crossings.[14] The study concluded that the mandatory stop regulations are both "unobserved and unenforced." Approximately 53 percent of the school buses and 88 percent of the buses-for-hire did not stop at the crossings, as required by law. He further concluded that since the average speed of these vehicles at the crossing was 25.4 mi/h (40.6 km/h), they never intended to stop.

Comments included in the final report of the NTSB's study support Sanders' findings.[2] The data revealed that 30 percent of all the truck accidents studied occurred as a result of driver disobedience of the warning signal.

Hopkins states that "if the motorist perceives and understands the warning, but does not believe it, the signal has lost all its value."[15] This is supported by NTSB which concluded that the frequent users of a crossing become aware that signals flash too long in advance of a train's arrival and proceed through a crossing when the warning device is activated. Also, if the crossing has a reputation of being blocked by trains for long periods of time, drivers are more likely to try to beat the train as opposed to waiting for it to pass. Recommendations of Hopkins include the provision that crossing signals should provide a uniform advance warning. [15] This would require specialized train detection circuitry when there is a mix of train speeds at a crossing.

From accident data used in Berg's study, it was observed that 53 to 71 percent of the driver-error type accidents occurred at railroad crossings equipped with flashers.[16] In 91 to 93 percent of these accidents, the driver had recognized the activated signal, but failed to stop. The predominate factor that contributed to these accidents was an excessive warning time. Even though the signals indicated an approaching train, the excessive warning time resulted in the driver disregarding the hazard and proceeding across the railroad tracks.

During a driver behavior study by Wilde many driver-judgmental errors were observed at railroad grade crossings.[17] While none of these observations resulted in a collision, all could be classified as a "critical incident" or an action that significantly increased the opportunity for an accident. In all of these incidents, the vehicles crossed the tracks while the flashers were activated. These activated signals involved an excessively long warning in advance of a train's arrival or activations without a train approaching. He concludes that by eliminating false warning and unnecessarily long warning times, the rate of disobedience towards crossing signals will be reduced, thus reducing train-involved accidents at crossings.

In summary, observations made at railroad crossings by Sanders indicate that a large percentage of school and for-hire buses violate the mandatory stop regulations.[14] Berg determined that 53 to 71 percent of accidents at crossings with active devices are the result of driver error. [16] Accidents involving driver error require countermeasures such as education and strict driver selection criteria for drivers of certain vehicle types. In addition to driver competency, possible causes of train-involved accidents include both insufficient and excessively long warning times at crossings with active devices and increased dwell time in the hazard zone.

Nontrain-Involved Accidents

The stopping of regulated vehicles for railroad crossings poses a physical obstruction that has the potential for increasing accidents and disrupting traffic flow. The result can be an increase in rear end, head-on, sideswipe, and run-off-road accidents.

Hopkins found that accidents in which trains are present but not involved, or not present at all are far less severe than vehicle/train collisions, but they occur twice as often.[15] Many such accidents are associated with evasive maneuvers to avoid a train or collision with vehicles stopped for a train, or collision with vehicles stopped due to legal requirements.

Reference to the increased probability of nontrain-involved accidents due to the mandatory stop requirements was also made by Burnett in his response to the ANPRM (Docket No. MC-105).[18, 19] His response recognizes that active devices are installed where there are visibility restrictions or where heavy traffic volumes exist. If high traffic volumes exist, a requirement for vehicles to stop when trains are not present could result in potential conflicts between following vehicles, and, consequently, rear end or sideswipe accidents. Burnett also suggested that FHWA should make an effort to document this type of accident history. This documentation will enable comparisons between the frequency and risk of nontrain-involved versus train-involved accidents.

An accident based study by Schoppert found that vehicles required to stop at crossings accounted for 13.3 percent of the accidents that occurred when a train was not present at the crossings.[20] From a sample of 3,627 accidents, 17 percent were of the rear end collision type and occurred when no train was present.

A study by Burnham, using accident data from the State of Georgia, found that 88.2 percent of the near-the-crossing accidents for trucks and buses were vehicle-to-vehicle collisions (15 percent higher than the statewide trends for the same type accidents).[18] Even though the data used was very limited, the results still identify an abnormally high occurrence for these accident types.

The trucking industry recognizes the problem of nontrain-involved accidents at railroad crossings. Forman indicates that, from the motor carrier's point of view, the grade crossing problem is greater in terms of vehicle-to-vehicle collisions than from vehicle-train collisions.[21] He states that one of the primary results of the mandatory stop regulation is vehicles colliding with the rear of vehicles while stopping, stopped, or accelerating away from a grade crossing. To alleviate the problem, drivers have been instructed to begin slowing down well in advance of the crossing, to turn on their simultaneous four-way hazard flashers, and to make the stop off the traveled portion of the highway, if possible. The trucking industry believes that each time a stop can be eliminated, an accident-producing situation can also be eliminated.

In summary, the potential for increased vehicle-to-vehicle accidents due to the mandatory stop requirement has been recognized as a problem by researchers, practitioners, and motor carriers. There have not been many studies, however, which have quantified the magnitude of this accident problem.

One impediment to such a quantification is that many of these accidents are low cost or, as in the case of run-off-road and fixed-object accidents, are single vehicle accidents. Such accident types are often unreported, or if reported, have a dollar value below the minimal reporting threshold. Analysis of nontrain-involved accidents resulting from compliance to the mandatory stop regulations will, therefore, result in an analysis of only a small sample of the total accident population. The sample size will, however, increase in those accidents which involve school buses. Many school districts have a directive requiring accident reports, regardless of accident magnitude.

Economic Consequences

The economic consequences of changes in the mandatory stop requirement will be primarily related to fuel consumption, delay, construction, maintenance, and accident costs. The increased fuel costs are incurred by both the regulated and following vehicles due to the increased frequency of deceleration and acceleration resulting from the mandated stops. The construction costs are primarily the result of pullout lanes installed to accommodate heavy volumes of regulated vehicles. These costs include the construction and maintenance costs of the lane itself, plus the cost of extending the gate arms and cantilevering the flashing lights, when appropriate. Costs associated with fuel and construction, after obtaining estimates of consumption and number of installations, are available from current market prices and input from States and railroads. In addition, information on railroad hardware costs are available from railroads, manufacturers, and a prior survey conducted by Bryant.[22]

Costs that can be applied to the value of time associated with delay are available from an American Association of State Highway and Transportation Officials (AASHTO) publication.[23] These costs are primarily 1975 costs but can be updated to current costs by using the Consumer Price Index (CPI). It is recommended that costs associated with automobile delay be calculated separately from costs associated with truck delay. Delay savings for trucks can be considered as representing actual monetary outlays for the drivers' wages and for nonproductive equipment usage. The unit value of time for automobile delay is dependent upon the trip purpose and average vehicle occupancy.

Determining appropriate cost figures to use for accident costs required an investigation of the current literature. Costs incurred by train-truck or train-bus accidents have a much higher total than those typically associated with other accidents. A nationwide NTSB study determined that over a 5-year period, 1975 through 1979, accidents involving hazardous material transporters and trains resulted in an average of $1,670,000 in annual property damage.[2] However, some accidents, such as a 1981 train-truck accident which resulted in the derailment of 5 locomotive units, 24 cars and 1 fatality, are considerably higher than the average. This accident was assessed property damage of $2,748,000, not including the cost associated with the fatality. This was 1.6 times the average annual property damage stated above. There is, therefore, a wide variation in costs associated with mandatory stop vehicle and train accidents.

A number of accident cost estimates are available, including those from the National Highway Traffic Safety Administration (NHTSA) and the

National Safety Council (NSC).[24, 25] A study by the Granville Corporation summarized and assessed available research on motor vehicle accident costs.[26] The assessment included the identification of the sources of cost variations and made a determination on which components have been satisfactorily estimated. Their analysis concluded that NHTSA (1983) estimates were preferrable to the NSC estimates.

In summary, estimates of average costs for these accident types are best obtained from investigations conducted by NTSB. Costs related to non-train-involved accidents can be obtained from both NHTSA and NSC, but the study by Granville Corporation indicates that the NHTSA estimates are more realistic.

Environmental Consequences

Requiring vehicles to stop at all railroad crossings, regardless of the type of crossing control devices, will have a different environmental impact than only requiring stops at crossings without active devices. Therefore, an assessment of the total impact of changes to the regulation requires an analysis of fuel consumption and pollution levels. This can best be obtained by computer simulation. Many simulation models have been developed and utilized to evaluate consumption, pollution, and delay.[27,28,29] This literature review identified two models, the NETSIM and TEXAS models, as the best candidates for this study.

The NETSIM model evolved from the Urban Traffic Control System (UTCS) network simulation modeling efforts. The inputs to the model include target speeds, discharge rates, flow rates, frequency of rare events, turning percentages, bus data, traffic composition, pedestrian flows, amber phase behavior, network geometry and channelization, signal timing, detection location, vehicle generating distributions, gap acceptance distributions, and car-following and lane-switching parameters. Model outputs include miles traveled (VMT), volumes, travel time, delay time, ratio of moving time to total travel time, average delay per vehicle, average traffic speed, average occupancy, average stops, percent saturation, and number of cycle failures. The model can be used for simulation of various traffic control strategies, bus preemption options, and network optimization.

The TEXAS computer simulation model developed by Lee et al. can be utilized for examining intersection traffic flow on a microscopic scale. [28] This model can be used to evaluate the operational effects of various traffic demands, types of traffic control, vehicle characteristics, signal timing plans, geometric configurations, and lane control.

The measures of performance derived from the TEXAS model include, but are not limited to, the following: (a) average queue delay, (b) average stopped delay, (c) percent of vehicles required to stop, (d) percent of vehicles required to slow to less than 10 mi/h (16 km/h) and (e) other level of service indicators. Key features of this simulation model also include lane change decision logic, and roadway geometrics and checking of sight distance restrictions.

In summary, two primary models are available for adaptation to the simulation of mandatory stop vehicles at railroad crossings. The NETSIM model has had wider use and acceptance than the TEXAS model and appears easier to adapt to project needs.

CHAPTER 2 - ANALYSIS OF ACCIDENT DATA

Analysis Overview

The analysis of accident data was performed in two distinct phases, train and nontrain-involved accidents. The identification of train-involved accidents was performed using the FRA accident data base while the nontrain-involved accidents were identified through State record systems. Each phase (train and nontrain-involved accidents) is further divided into separate analysis steps for hazardous material transporters, school buses, and passenger buses. Separate analyses were performed on the different vehicle types because they each exhibit different vehicle lengths, acceleration characteristics, and, in some cases, driver proficiency and training. In addition, separate analyses were required due to the different accident costs associated with each vehicle type.

Train-Involved Accidents

Analysis Approach

The overall train-involved accident analysis was an extension of a special study performed by NTSB.[2] This study analyzed accidents occurring between trains and hazardous material haulers that occurred from 1975 through 1979. The accidents were first identified from the FRA reports and then verified through reports available from other agencies.

The data collected for the NTSB study was used for the study contained in this report. It was expanded to include accidents through 1983 and accidents involving both school and passenger buses. A flowchart of the analysis methodology is presented in figure 2.

In addition to including buses in the analysis, the methodology presented in figure 2 differs from the NTSB study by separating the accidents into three distinct accident types: 1) roadway vehicle struck by the train with vehicle speeds less than a speed threshold value; 2) roadway vehicle struck by the train with vehicle speeds greater than or equal to the speed threshold value; and 3) roadway vehicle striking the train. The

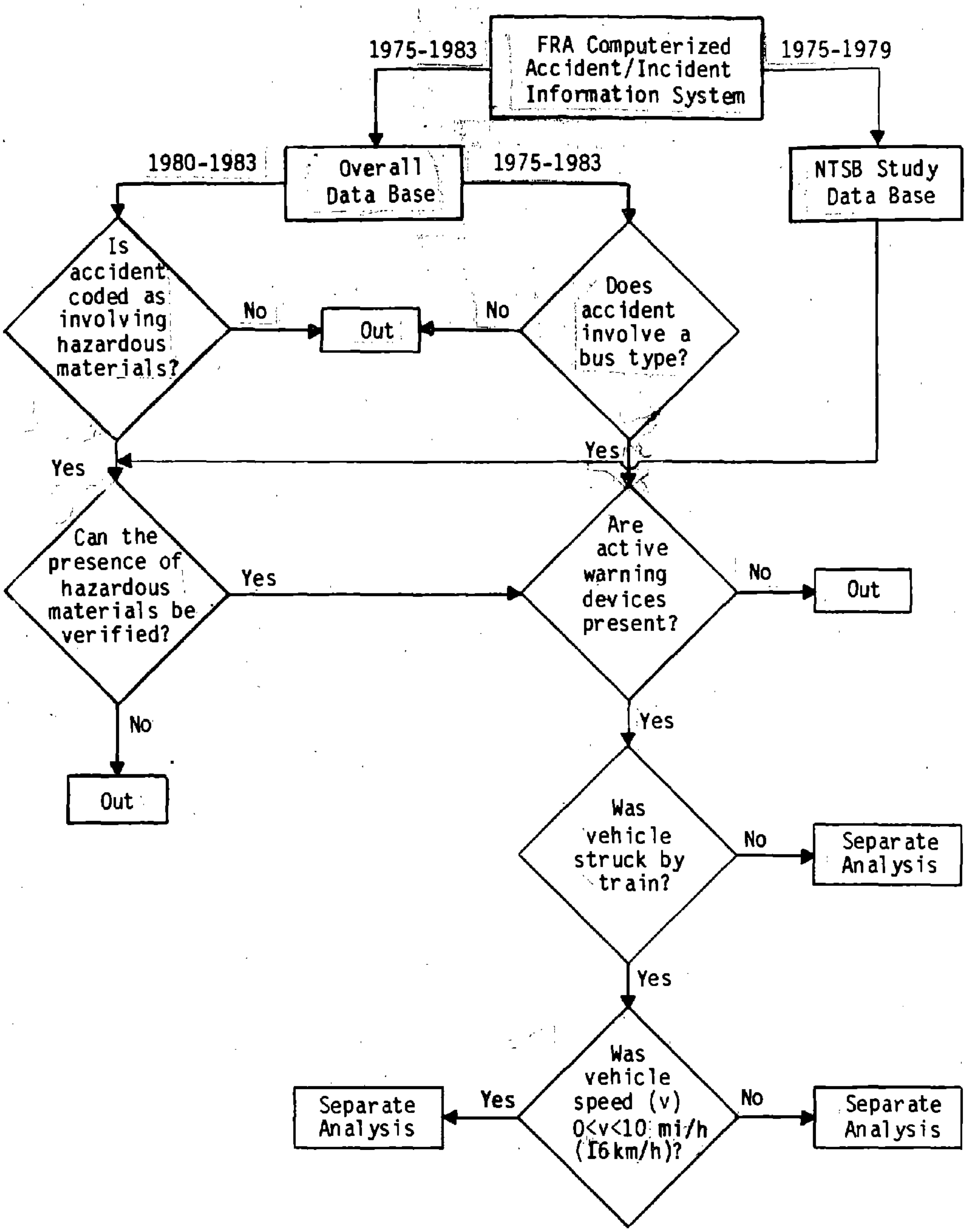

Figure 2. Flowchart of the accident analysis procedure.

reason for this stratification is that any changes to the mandatory stop law can be expected to have a different impact on each analysis category. For example, if mandatory stop vehicles are no longer required to stop at all crossings with active devices when not activated then accidents where the vehicles strike the train could conceivably increase. Conversely, accidents where vehicles are traveling less than the speed threshold, and impacted by the train could be expected to decrease. The magnitude of the expected increase and decrease would also differ. The rationale for determining the magnitude and direction of change is explained more fully in the respective sections of this report.

Determination of Speed Threshold

The concept of using a certain speed as an accident classification variable is based on the realization that requiring vehicles to stop at a crossing inherently results in lower speeds. Theoretically, if the posted speed is 40 mi/h (64 km/h) and vehicles are not required to stop, their speed over the crossing would be approximately 40 mi/h (64 km/h). Their actual speed would, of course, be influenced by additional factors, such as the condition of the crossing surface, roadway environment, congestion, grade, environmental conditions, and both upstream and downstream traffic control devices. Train accidents with vehicles above the shown threshold speed could be expected to continue, and maybe even increase. Accidents with vehicles below the speed could be expected to decrease or remain the same. If the chosen threshold speed was too low, the number of accidents identified as being reducable by a change in the mandatory stop law would be missed. Alternatively, if the threshold speed was set too high, the estimated affect of changes in the law would be exaggerated.

The desirable speed for the threshold value is the maximum speed that each vehicle type could be expected to attain upon reacting to the mandatory stop provision. However, the determination of this speed is complicated by variations in weight/power ratios, gear ratios, driver characteristics, site and crossing characteristics, environmental conditions, and driver reaction.

Operational studies conducted, as part of this study, at crossings with a high number of mandatory stop vehicles revealed that 36.4 percent of the drivers came to a rolling stop in lieu of a full stop. To determine the threshold speed based only on the acceleration capabilities from a full stop would, therefore, create an unrealistically low estimate. A two-dimensional effort, consisting of an accident analysis and a speed study, was used to determine the threshold speed.

The accident analysis consisted of analyzing the speeds recorded on the accident report forms for trucks and truck-trailers that were struck by a train. Only trucks and truck-trailers were used in the analysis because distinct categories of these vehicles exist that are and are not required to stop at crossings. This distinction, in conjunction with the traffic control device at the crossing, permits a comparative analysis of vehicle speeds at the time of the accident between vehicles required and not required to stop. No such clear distinction exists with school or passenger buses. According to the majority of State laws, school and passenger buses are required to stop at all crossings.

Only those accidents occurring at crossings with active devices were used in the analysis. Drivers approaching crossings with passive devices will often slow down to visually verify that no train is approaching. This visual verification is less likely to occur where the driver can rely on automatic devices to detect and provide warning of an approaching train. The use of crossings with active warning devices, therefore, provides a better estimate of any inherent accident speed differential between vehicles required and not required to stop at railroad crossings. There were instances where accidents occurred at crossings that had both active warning devices and stop signs. The presence of the stop signs results in a change in the accident characteristics inherent to crossings with active devices. These accidents were, therefore, removed from the analysis. A flowchart of the accident categorization procedure is presented in figure 3 and discussed below.

1. The FRA accident/incident reports were searched to obtain accidents involving trucks and truck-trailers not carrying hazardous

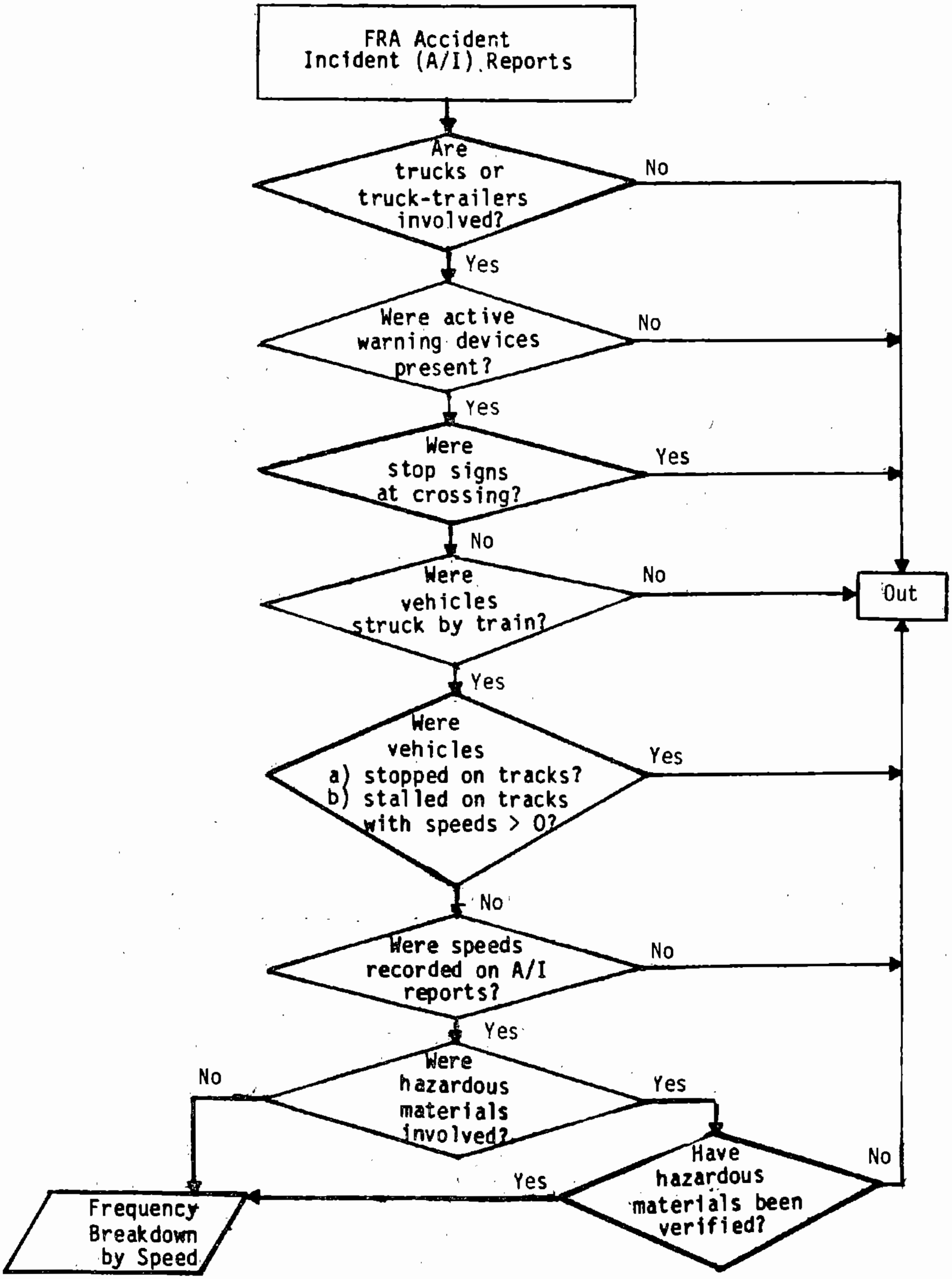

Figure 3. Flowchart of the accident categorization procedures to determine the threshold speed.

materials that were struck by a train. Both truck and truck-trailers were used since both were present in the verified hazardous material accidents used in the comparative analysis.

2. The accident file resulting from the previous step was searched to eliminate those incidents that 1) had unknown speeds; 2) were coded as stalled on the tracks with a speed greater than zero mi/h; 3) were coded as stopped on the tracks; and 4) were coded as having a supplemental stop sign. The reports with unknown speeds and stalled on the tracks with speeds greater than zero were eliminated because they represented data errors. Incidents where the vehicle was stopped on the tracks were eliminated because the reason for stopping could be the result of traffic abnormalities or vehicle breakdown. These accidents could, therefore, be the result of extraneous factors and not characteristic of speed-versus-accident frequency relationships. The accidents remaining after this step were considered as representing a population of vehicles that "are not required to stop at railroad crossings."

3. The accidents that had been verified as involving vehicles transporting hazardous materials were used as the base for a representative population of vehicles that are required to stop at railroad crossings. This base was modified by eliminating accidents that were coded as unknown, stalled with speeds greater than zero, and stopped on the tracks.

The result of this procedure was the two groups of accident frequencies presented in table 1. The groups are similar with regard to vehicle type, driver characteristics, and elimination of detectable errors. This data was then analyzed using the procedure presented below:

1. The differences in the cumulative accident percentages, by vehicle speed, were analyzed to 1) determine if there was a significant difference in the cumulative accident frequencies between the two distributions; and 2) discover where shifts in accident

Table 1. Accidents categorized by speed for trucks struck by a train and required and not required to stop (1975-1983).

Speed	Stopping Required			No Stopping Required		
	Freq.	Percent of Total	Cumulative Percent	Freq.	Percent of Total	Cumulative Percent
0	13	23.6	23.6	680	16.0	16.0
1	1	1.8	25.5	43	1.0	17.1
2	2	3.6	29.1	142	3.3	20.4
3	3	5.5	34.5	157	3.7	24.1
4	1	1.8	36.4	83	2.0	26.1
5	7	12.7	49.1	697	16.4	42.5
6	-	-	49.1	20	0.5	43.0
7	1	1.8	50.9	17	0.4	43.4
8	-	-	50.9	52	1.2	44.6
9	-	-	59.9	5	0.1	44.7
10	6	10.9	61.8	723	17.1	61.8
11	-	-	61.8	1	0.02	61.8
12	-	-	61.8	22	0.5	62.3
13	-	-	61.8	5	0.1	62.4
14	-	-	61.8	3	0.1	62.4
15	6	10.9	72.7	400	9.4	71.9
16	-	-	72.7	-	-	71.9
17	-	-	72.7	-	-	71.9
18	-	-	72.7	11	0.3	72.2
19	-	-	72.7	3	0.1	72.3
20	6	10.9	83.6	323	7.6	79.9
>20	9	16.4	100.0	853	20.1	100.0
Total	55			4,240		

1 mi/h = 1.6 km/h

frequency occurred. The result of the Kolmogorov-Smirnov (K-S) test, presented at the bottom of table 2, indicates that the maximum difference in the cumulative distributions is not large enough to conclude that the two populations are significantly different. Visual inspection of the differences, however, shown in table 2 indicates that trucks required to stop at crossings have a higher cumulative percentage of accidents at speeds below 10 mi/h (16 km/h) than trucks that are not required to stop. Above 10 mi/h (16 km/h) the cumulative accident percentage is essentially identical between the two populations.

2. The cumulative frequencies were plotted as presented in figure 4. Inspection of figure 4 indicates that relatively low measures in accident frequency occur at intervals of 5 mi/h (8 km/h). Between these 5-mi/h (8-km/h) steps the cumulative frequencies remain relatively constant until the next 5-mi/h (8-km/h) speed increment. The only exception to this is the interval from 0 to 5 mi/h which had an increase of 26.5 percent for trucks which are not required to stop and 25.5 percent for trucks which are required to stop. This graph indicates that caution must be exercised in taking the speeds recorded on the accident reports at face value. They are estimates, often based on judgments of witnesses or train crew members, and can be expected to have a certain amount of error. The data indicates that the witnesses, accustomed to the decimal system, are rounding their estimates to the nearest 5 mi/h (8 km/h). Similar round off errors were discovered by Council with regard to accident milepost values. [30] Analyzing by individual speed groupings of 1 or 2 mi/h will not, therefore, be any more reliable than those formulated by 5-mi/h (8-km/h) increments.

The previous analysis led to a preliminary conclusion that 10 mi/h (16 km/h) was a suitable threshold speed. The failure to establish any statistically valid differences between the two distributions, however, indicated that additional substantiative data was required.

Table 2. Difference in the cumulative accident frequency between trucks that are required and not required to stop at railroad crossings.

Speed	(1) Stopping Required	(2) No Stopping Required	Difference (1 - 2)
0	23.6	16.0	7.6
1	25.5	17.1	8.4
2	29.1	20.4	8.7
3	34.5	24.1	10.4
4	36.4	26.1	10.3
5	49.1	42.5	6.6
6	49.1	43.0	6.1
7	50.9	43.4	7.5
8	50.9	44.6	6.3
9	50.9	44.7	6.2
10	61.8	61.8	0
11	61.8	61.8	0
12	61.8	62.3	-0.5
13	61.8	62.4	-0.6
14	61.8	62.4	-0.6
15	72.7	71.9	0.8
16	72.7	71.9	0.8
17	72.7	71.9	0.8
18	72.7	72.2	0.5
19	72.7	72.3	0.4
20	83.6	79.9	0.4
>20	100.0	100.0	3.7

(1 mi/h = 1.6 km/h)

K-S Statistic = 0.104
Critical Value (95%) = 0.185

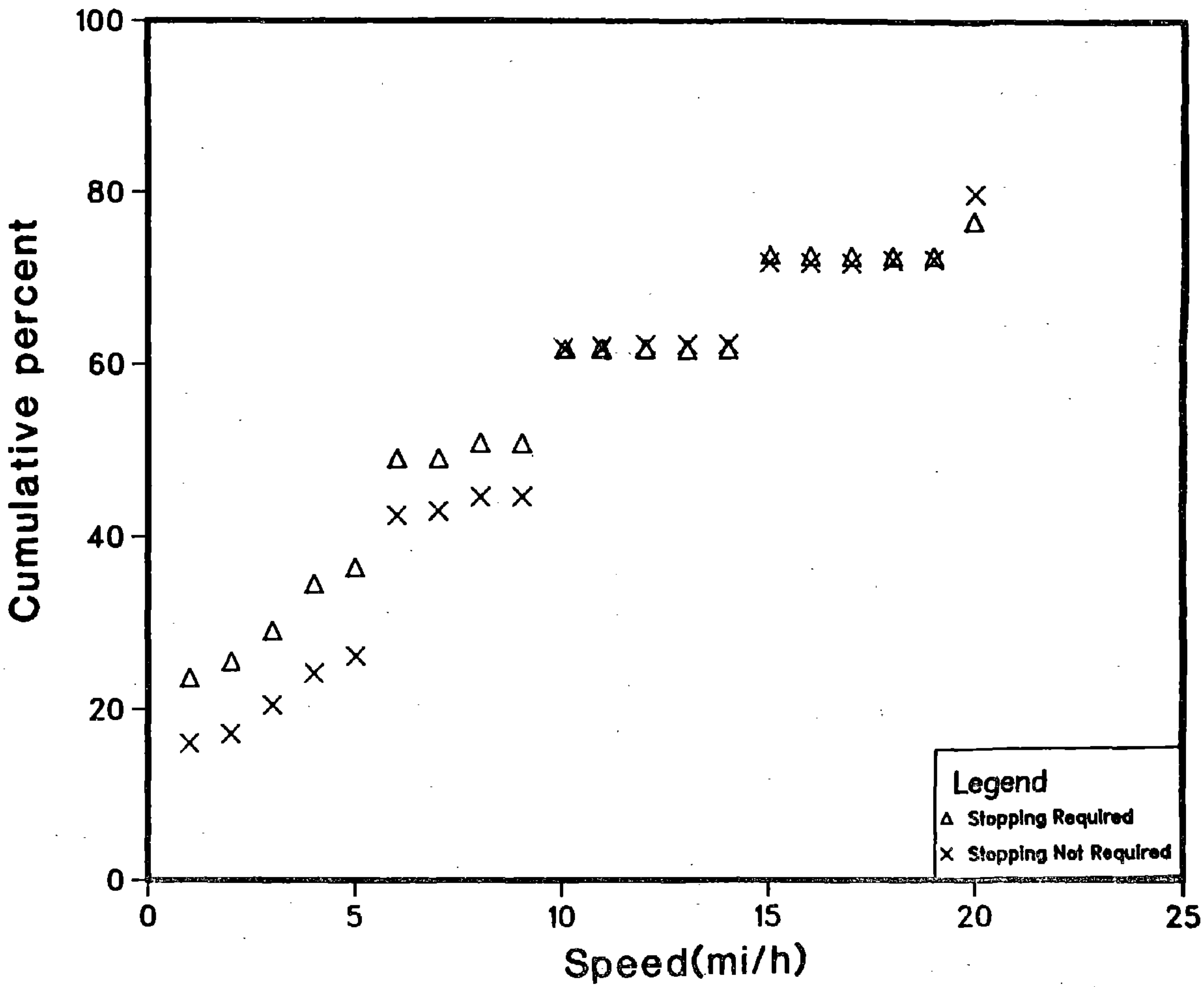

Figure 4. Cumulative accident frequency by speed of trucks required and not required to stop at railroad crossings. (1 mi/h = 1.6 km/h)

The substantiative data were obtained by measuring speeds of placarded[1] trucks and truck-trailers that came to a rolling stop at four different crossings in Michigan. Each crossing had an elastometric crossing surface in excellent condition with no, or negligible, deceleration discernable by tractor-trailer units not governed by the mandatory stop rule. The reason for the deceleration of the observed vehicles was, therefore, assumed to be due to the mandatory stop rule. Observations on rolling stop vehicles were used because it yielded a realistic upper limit on the speed effects of the rule. The mandatory stop vehicles that were in blatant violation of the rule (i.e., slowing very little or not at all) or in compliance with the rule were not included in the observations. These speed data, presented in figure 5, indicate an average speed of 8.3 mi/h (13.3 km/h) with approximately 62 percent of the observed vehicles crossing at a speed of 9 mi/h (14.4 km/h) or less.

Similar speed data were obtained for school and passenger buses. Due to the relatively small number of buses, and the added requisite of observing them approaching a railroad crossing at a rolling stop, only 48 observations were obtained. The data, summarized in figure 6, shows an average speed of 8.6 mi/h (13.8 km/h) with 72.9 percent of the observations at or below 9 mi/h (14.4 km/h).

The speed studies, coupled with the accident-speed relationship, led to the adoption of 10 mi/h (16 km/h) as the threshold speed value for transporters of hazardous materials, school buses, and passenger buses. Those incidents where the vehicle is struck by the train while traveling below 10 mi/h (16 km/h) were analyzed separately from those incidents occurring at or above 10 mi/h (16 km/h). Note that the 10-mi/h (16-km/h) speed was not included in the lower speed group. This is due to the results shown in figure 4 which indicate that the accident frequency occurring at 10 mi/h (16 km/h) is more representative of the higher speed group. Including accidents at 10 mi/h (16 km/h) would essentially result in add-

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1 Placards are diamond-shaped markers. The color and message of the placard indicates the classification type of material being transported.

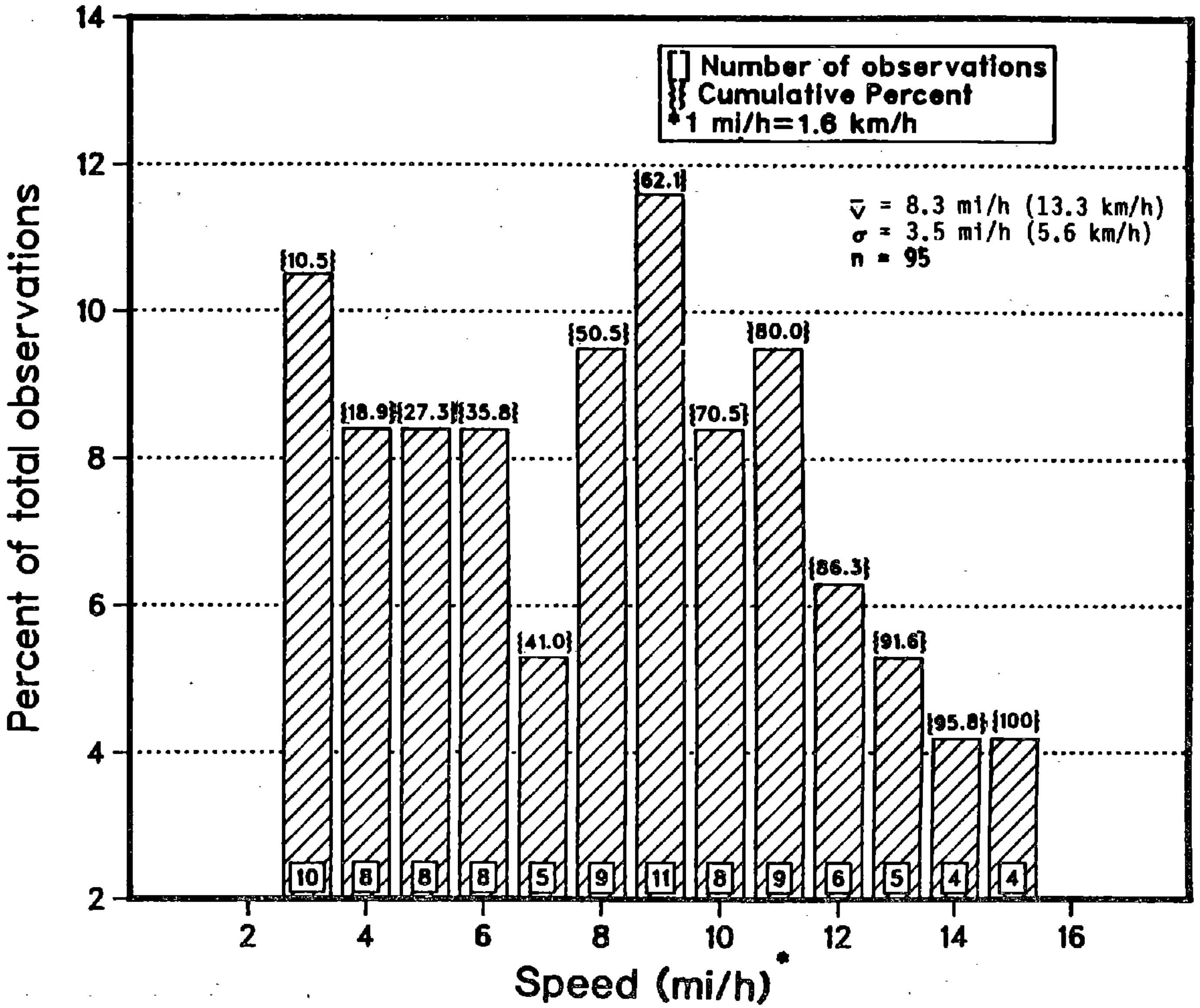


Figure 5. Speed data summary of hazardous material haulers at railroad crossings after performing a rolling stop.

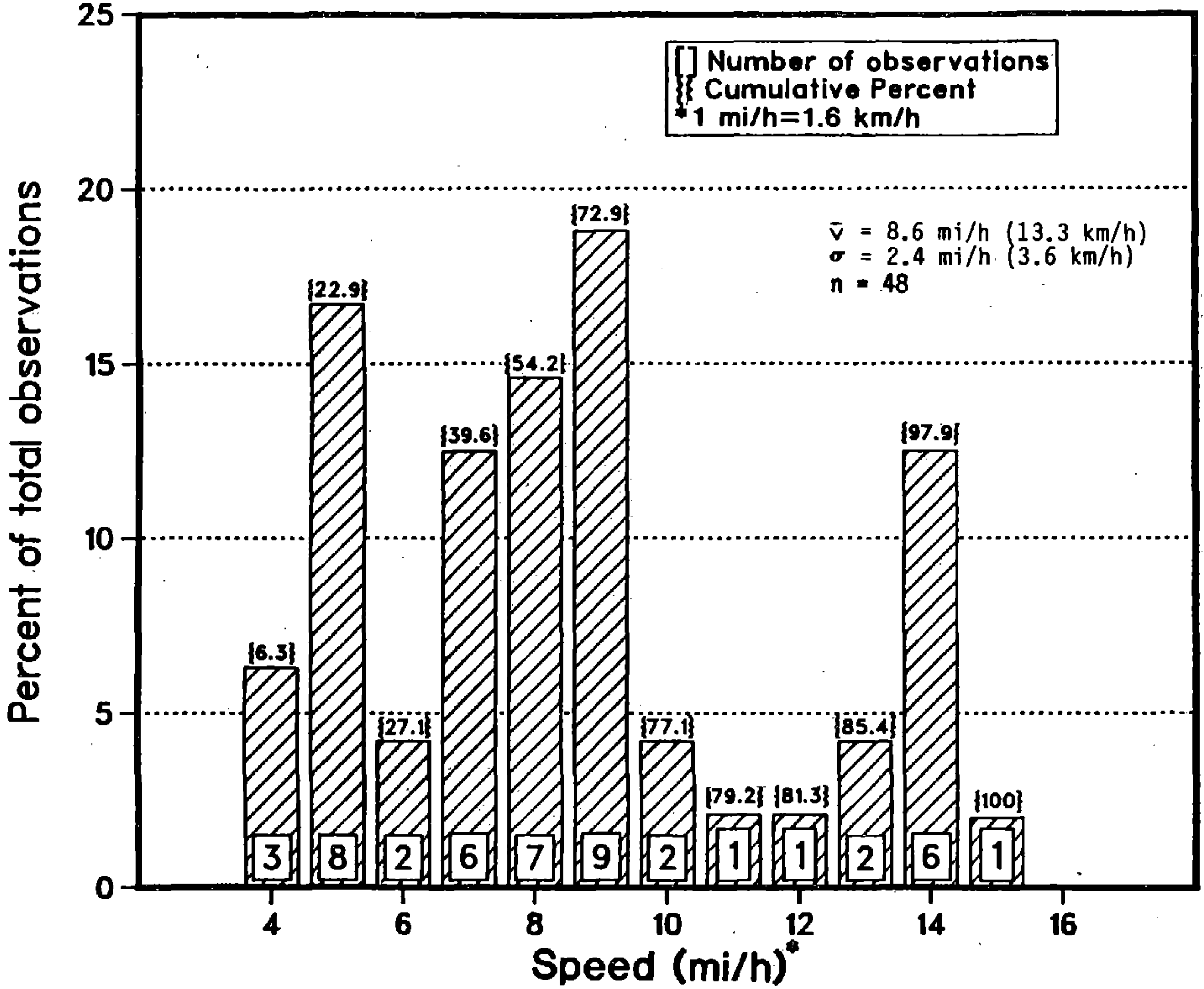


Figure 6. Speed data summary of school and passenger buses at railroad crossings after performing a rolling stop.

ing accidents that actually occurred from 11 mi/h (17.6 km/h) to 15 mi/h (24.0 km/h) that were rounded off to 10 mi/h (16 km/h). This would over emphasize the probable effect of any changes in the mandatory stop regulation.

Verification Process

Candidate train-involved accidents were selected from the FRA accident/incident file based on highway user type and the involvement of hazardous materials. The initial identification of school and passenger buses was accomplished by identifying the vehicle type from the accident/incident report.(figure 7) The initial identification of hazardous material haulers was performed by identifying the vehicle type as either truck or tractor-trailer while simultaneouly indicating that hazardous materials were being transported by either the highway user or both the highway user and/or the railroad.(figure 7) This information was then checked with other reports to verify that hazardous materials were actually being transported by an appropriate highway user. Some instances, coded as trucks with hazardous materials, for example, were actually determined to be pickup trucks carrying campers with propane tanks. The verification process for train accidents with hazardous material transporters, school and passenger buses, consisted of analyzing reports from the following agencies:

- Federal Railroad Administration (FRA) crossing accident/incident reports, coded as involving a truck transporting a hazardous material, school or passenger buses; supplementary railroad injury and illness summaries; rail equipment accident/incident reports; and crossing inventory forms.

- Federal Highway Administration (FHWA)/Bureau of Motor Carrier Safety (BMCS) accident reports.

- Research and Special Programs Administration (RSPA)/Materials Transportation Bureau (MTB) reports of accidents involving hazardous materials.

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

RAIL-HIGHWAY GRADE CROSSING ACCIDENT/INCIDENT REPORT

FORM APPROVED
OMB NO 04R4033

1 NAME OF REPORTING RAILROAD — Amtrak / Autotrain — 1a Alphabetic Code — 1b Railroad Accident/Incident No.

2 NAME OF OTHER RAILROAD INVOLVED IN TRAIN ACCIDENT/INCIDENT — 2a Alphabetic Code — 2b Railroad Accident/Incident No.

3 NAME OF RAILROAD RESPONSIBLE FOR TRACK MAINTENANCE (single entry) — 3a Alphabetic Code — 3b Railroad Accident/Incident No.

4. U.S. DOT-AAR GRADE CROSSING IDENTIFICATION NUMBER — 5 DATE OF ACCIDENT/INCIDENT (month, day, year) — 6 TIME OF ACCIDENT/INCIDENT (am / pm)

LOCATION

7. NEAREST RAILROAD STATION — 8 COUNTY — 9 STATE (use state code) — CODE

10 CITY (if in a city) — 11. HIGHWAY NAME OR NUMBER (if private crossing, so state)

ACCIDENT/INCIDENT SITUATION

HIGHWAY USER INVOLVED — RAILROAD EQUIPMENT INVOLVED

12 TYPE: 1. Auto 2. Truck 3. Truck Trailer 4. Bus 5. School Bus 6. Motorcycle 7. Pedestrian 8. Other (specify) — CODE

16 EQUIPMENT: 1. Train (units pulling) 2. Train (units pushing) 3. Train (standing) 4. Car(s) (moving) 5. Car(s) (standing) 6. Light loco(s) (moving) 7. Light loco(s) (standing) 8. Other (specify) — CODE

13 SPEED (estimated mph at impact) — 14 DIRECTION (geographical) 1 North 2. South 3. East 4. West — CODE — 17 POSITION OF CAR/UNIT IN TRAIN — CODE

15 POSITION 1. Stalled on crossing 2. Stopped on crossing 3. Moving over crossing — CODE — 18. CIRCUMSTANCE 1. Train struck highway user 2. Train struck by highway user — CODE

19. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway user 2. Rail equipment 3 Both 4 Neither — CODE

ENVIRONMENT

20 TEMPERATURE (specify, if minus) °F — 21. VISIBILITY (single entry) 1 Dawn 2. Day 3 Dusk 4 Dark — CODE — 22. WEATHER (single entry) 1. Clear 2 Cloudy 3. Rain 4 Fog 5. Sleet 6 Snow — CODE

TRAIN AND TRACK

23 TYPE OF TRAIN 1. Freight 2 Passenger 3. Mixed 4 Work 5 Yard/Switching 6. Light Locomotive(s) — CODE — 24 TRACK TYPE USED BY TRAIN INVOLVED 1. Main 2 Yard 3 Siding 4 Industry — CODE

25. TRACK NUMBER OR NAME — 26. FRA TRACK CLASSIFICATION — 27. NUMBER OF LOCOMOTIVE UNITS

28 NUMBER OF CARS — 29. TRAIN SPEED (recorded speed, if available) MPH Est Recorded — 30 TIME TABLE DIRECTION 1. North 2. South 3. East 4. West — CODE

CROSSING WARNING

31. TYPE (place X in appropriate box(es)) 1 Gates 2 Cantilever FLS 3 Standard FLS 4 Wig Wags 5 Hwy. Traffic Signals 6 Audible 7 Crossbucks 8 Stop Signs 9 Watchman 10 Flagged by crew 11 Other (specify) 12 None

32 SIGNALED CROSSING WARNING — Was the signaled crossing warning identified in item 31 operating? 1. Yes 2 No — CODE

33 LOCATION OF WARNING 1. Both sides 2. Side of vehicle approach 3. Opposite side of vehicle approach — CODE — 34. CROSSING WARNING INTERCONNECTED WITH HIGHWAY SIGNALS 1. Yes 2. No 3 Unknown — CODE — 35 CROSSING ILLUMINATED BY STREET LIGHTS OR SPECIAL LIGHTS 1. Yes 2. No 3. Unknown — CODE

MOTORIST ACTION

36. MOTORIST PASSED STANDING HIGHWAY VEHICLE 1. Yes 2. No 3. Unknown — CODE — 37. MOTORIST DROVE BEHIND OR IN FRONT OF TRAIN AND STRUCK OR WAS STRUCK BY SECOND TRAIN 1. Yes 2. No 3. Unknown — CODE

38 MOTORIST 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Other (specify) 5. Unknown — CODE

39. VIEW OF TRACK OBSCURED BY (primary obstruction) 1. Permanent structure 2. Standing railroad equipment 3. Passing train 4 Topography 5 Vegetation 6 Highway vehicles 7. Other (specify) 8 Not obstructed — CODE

HIGHWAY VEHICLE PROPERTY DAMAGE/CASUALTIES

40 HIGHWAY VEHICLE PROPERTY DAMAGE (est. dollar damage) — 41. DRIVER WAS 1. Killed 2. Injured 3. Uninjured — CODE — 42. WAS DRIVER IN THE VEHICLE? 1. Yes 2. No — CODE

43 TOTAL NUMBER OF OCCUPANTS KILLED — 44 TOTAL NUMBER OF OCCUPANTS INJURED — 45 TOTAL NUMBER OF OCCUPANTS (include driver)

46. IS A RAIL EQUIPMENT ACCIDENT/INCIDENT REPORT BEING FILED? 1. Yes 2. No — CODE

47 TYPED NAME AND TITLE — 48 SIGNATURE — 49 DATE

FORM FRA F 6180-57 (12-78) REPLACES FORM FRA F 6180-13 (10-67) WHICH IS OBSOLETE

Figure 7. Rail-highway grade crossing accident/incident report.

- National Highway Traffic Safety Administration (NHTSA)/Fatal Accident Reporting System (FARS).
- Individual States, usually through the Federal highway safety coordinator, when verification could not be obtained through existing reports.

The applicability of each of the above verification sources was dependent upon the circumstances of each incident. For instance, FARS reports were not available unless a fatal accident occurred; BCMS reports only include trucks involved in interstate commerce; and the FRA rail/equipment report requires a reportable loss to the railroad of at least $4,500 (since 1982). Figure 8 presents the number of times that each of these verification methods was used in the validation process. When a candidate incident could not be verified as having the characteristics required for the study, it was either eliminated from further analysis or analyzed separately.

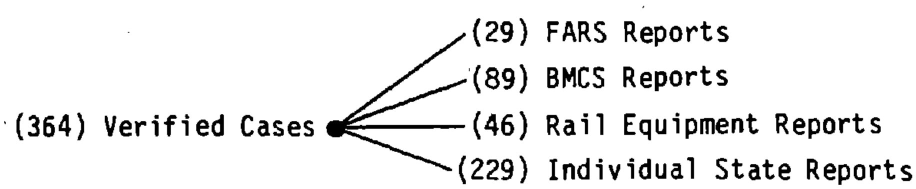


Figure 8. The usage of reports from various agencies in the accident verification process.

A summary of the train-involved accident collection activities is presented in figure 9. Of the total 680 candidate accidents identified through the initial selection process, 161 involving the transportation of hazardous materials, 84 involving a school bus, and 119 involving a passenger bus were verified as occurring at a public highway crossing.

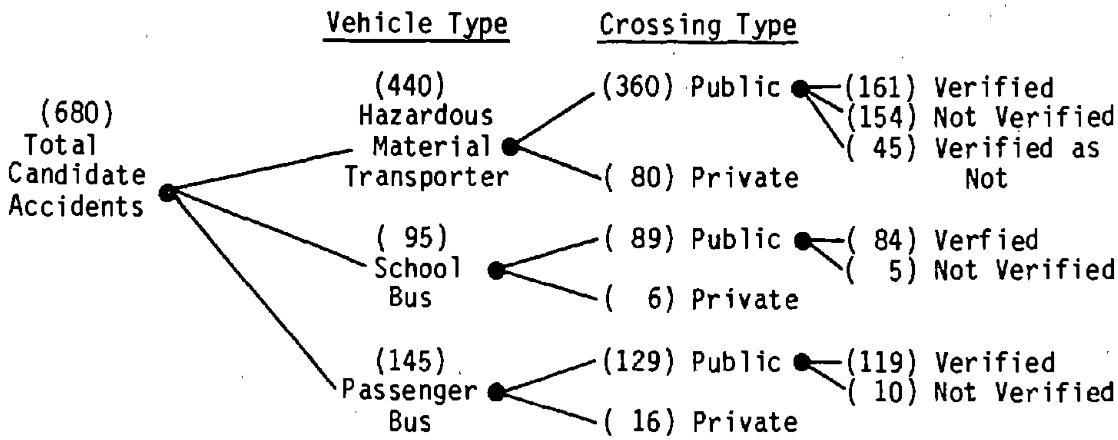


Figure 9. Breakdown of the train-involved accident data collection activities (1975-1983).

Locational Characteristics

The U.S. DOT/AAR National Crossing Inventory was used to determine the type of crossing and warning device that was present at each location that experienced an accident. In most cases, the information was obtained by searching the inventory file on the crossing number recorded on the accident/incident reports. In some instances, due to errors in recording the crossing number on the accident/incident reports, the information either could not be located or other identifiers, such as street name, city, and county, did not correspond. When this occurred, the inventory file was searched by specifying the railroad, geocodes of the city, county and the street name. The total process resulted in the information being located for all but 61 of the accidents. Those accidents for which information could not be verified were eliminated from further analysis.

The inventory was used to ascertain two specific items 1) whether the crossing at which the accident occurred was public or private; and 2) 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 regulations are applicable to public and not private crossings. While the regulations can be interpreted to provide recommended practices at private crossings, they are not, in the majority of States, enforceable at private crossings.

The determination of the type of warning device that is present was performed because 1) the present code of the UVC requires different driver actions based on whether the crossing has active or passive devices and 2) any envisioned changes to the regulations would be to differentiate between appropriate driver action at crossings depending on whether there were active or passive warning devices. Active devices were considered as any electronic or mechanical signal device that was designed to give an indication of the immediate approach of a train, with the exception of highway traffic signals. Highway traffic signals were separated from the active category because the current versions of the FMCSR and UVC recommendations exempt crossings equipped with highway traffic signals from the provision of the mandatory stop regulation. A breakdown of the accident stratification is summarized in figure 10.

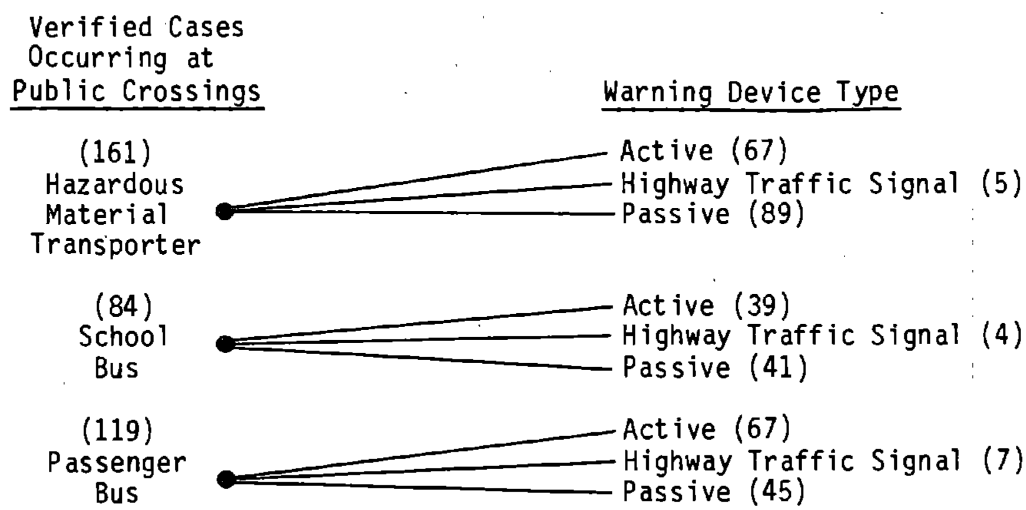


Figure 10. Breakdown of accident stratification based on crossing inventory analysis.

Reliability of Verified Cases

The verification process used in the study was stringent. If supporting criteria could not be obtained that provided credence to the vehicle or cargo type, or if ambiguities or contradictions existed in the available data, the cases were not included in the primary analysis. The result was that 154 hazardous material transport, 5 school bus and 10 commercial bus accidents remained unverified and not included in the analysis. These were cases where the appropriate information could not be obtained to verify that they were the correct type of accident. The possibility exists, however, that they were actually accidents of interest to the study.

The verified accidents are a subset of the total mandatory stop accidents. Since this subset was not obtained by considering any specific accident type or characteristic it should represent a random sample of the entire population. This was determined to be the case by performing a chi-square test of independence on relevant sample and population characteristics. The results of these tests, presented in table 3 indicate that there is no significant difference between the verified cases and the entire possible population. The verified cases can, therefore, be used to make statistically valid inferences of relevant accident characteristics for the entire population.

Table 3. Chi-square test for independence

Accident Characteristics	Verified Sample	Verified and Unverified Population	Chi-Square Statistic (95% Critical Value)
Warning Device Type			
Active	67	136	1.28
Highway Signal	5	8	df=3
Stop Sign	7	21	(7.82)
Passive	82	150	
Accident Type and Vehicle Speed			
Struck by Train	132	261	1.44
Striking Train	29	54	df=3
Less than 10 mi/h	78	171	(7.82)
Greater than 10 mi/h	83	144	
Driver Action			
Did not Stop	103	195	
Stopped then Proceeded	17	23	1.91
Obstructed View	5	11	df=5
Unknown	13	25	(11.07)
Drove Around Gates	5	10	
Other, Stopped, Stalled	17	41	

While the use of verified cases will provide valid inferences of accident characteristics, it remains a subset of the total population. Determinations of accident magnitude based only on the verified accidents will, therefore, provide a lower limit to the actual accident frequencies. The actual values would be higher if all, or a portion, of the unverifiable accidents could have been verified and included in the analysis.

Analysis of Total Train-involved Accidents

Analysis of the total number of accidents between trains and hazardous material transporters, school and passenger buses was performed to obtain an overview of yearly accident trends. This analysis was primarily performed to discern any variations in accident trends exhibited by the general (nonhazardous material) truck population, verified hazardous material transporters, school buses, and passenger buses. The only stratification used in the analysis was type of vehicle.

The analysis of total train-involved accidents was performed by using accident rates determined from the number of yearly registered vehicles. The yearly registrations were obtained from the Highway Statistics reports published annually by the U.S. Department of Transportation.[31] The data summarized in table 4 represents total nationwide vehicle registrations, with the exception of Hawaii. Vehicle registrations in Hawaii were excluded because there are only 6 railroad crossings in the State.

It is realized that total vehicle registrations are not the optimal measure of exposure. The probability of an accident occurring with a train is a function of numerous variables. Included in these variables are the number of crossings, number of trains per day, train and vehicle length, speed and time of day for train and roadway vehicle movements, and number of truck or bus movements. Using total vehicle registration does, however, provide an acceptable basis for comparison if certain assumptions are made. The assumptions made for this analysis are:

Table 4. Yearly vehicle registrations.

	Total Trucks Registered (1, 2, 6)	Placarded Hazardous Material Transporter (1, 2, 3)	General Truck Population (1, 2)	Total School Bus (1, 2, 4)	Total Passenger Bus (1, 2, 5)
1975	25,710.6	282.8	25,427.8	365.4	94.5
1976	27,649.2	304.1	27,345.1	378.5	97.3
1977	29,487.0	324.4	29,162.6	390.7	98.4
1978	31,622.5	347.8	31,274.7	395.4	102.0
1979	33,297.1	366.3	32,930.8	410.3	106.9
1980	33,585.2	369.4	33,215.8	417.1	108.4
1981	34,397.6	378.4	34,019.2	431.7	109.0
1982	35,198.0	387.2	34,810.8	440.9	114.9
1983	36,492.9	401.4	36,091.5	469.5	112.4

(1) - Thousands
(2) - Excludes Hawaii
(3) - Based on 1.1% of Total Trucks
(4) - Includes some church, industrial, and other private buses.
(5) - Includes private, commercial, and federal.
(6) - Includes pickups, panel, and walk-in trucks.

- The number of crossings with each warning device type remained constant over the study period. It was initially planned to perform an overall analysis based on both vehicle and warning device types. Information was not available, however, on the number of crossings equipped with a specific type of warning device for each year since 1975. Analysis was performed, therefore, without consideration of the total number of crossings or warning device type.

- The percent mix of trucks transporting hazardous materials remains constant. The percentage of vehicles transporting hazardous materials was estimated from the 1977 Truck Use and Inventory Survey. [32] This survey estimated that there were approximately 309.8 thousand vehicles transporting hazardous materials in sufficient quantities to require a placard under the Code of Federal

Regulations, Title 49, Transportation. Applying this estimate to the total 1977 truck registrations, contained in table 4, yields a 1.1 percent mix of trucks transporting hazardous materials. It should be noted that this estimate is based on all registered trucks, including pickups, panels, and walk-ins. It does not represent the mix of hazardous material vehicles with regard to the medium to heavy truck weight classifications. The percent of total truck registrations was used to determine accident rates because all truck types are included in the yearly registration estimates of the Highway Statistics reports; which were used to obtain the yearly registration estimates.[33]

- Estimates of total registrations from the annual highway statistics publications provide a reasonable estimate of the vehicle types being analyzed. This assumption is relatively reliable when analyzing school and passenger buses. It is not as accurate when analyzing truck accidents. The total truck registrations, presented in table 4, include vehicle types, such as pickup trucks, which have a low probability of transporting hazardous materials in sufficient quantities to warrant a placard. Since 1) the total vehicle registration is used throughout the analysis period; and 2) the number of hazardous material trucks is also based on total vehicle registration, this assumption provides a reasonably reliable basis for yearly comparisons.

The estimates of yearly vehicle registrations were applied to the accident frequencies to obtain the rates presented in table 5. It should be noted that these rates were obtained to provide an analysis of yearly trends, not to estimate the magnitude of the difference between vehicle types. The yearly accident rates for hazardous material transporters was obtained by only using cases that were verified. Since there were a large number of cases for which no verification could be obtained, the hazardous material rates presented in table 5 represent a subset of the true population. Because it is a subset, the rates are lower than those which actually exist. Comparisons between groups (such as the accident rates exhibited by hazardous material transporters and the general truck population) are not valid. Comparisons within groups, such as yearly accident rates of the general truck population or long term trends, are, however, valid observations.

Table 5. Accident frequency and rate for various vehicle categories at public railroad crossings.

	General Truck Population		Placarded Hazardous Material Transporter		School Bus		Passenger Bus	
	Acc. Freq.	Acc. Rate (2)	Acc. Freq. (1)	Acc. Rate (2)	Acc. Freq. (1)	Acc. Rate (2)	Acc. Freq. (1)	Acc. Rate (2)
1975	2,599	102.2	12	42.4	7	19.2	7	74.1
1976	2,989	109.3	17	55.9	11	29.1	20	205.5
1977	3,195	109.6	24	74.0	8	20.5	21	213.4
1978	3,469	110.9	33	94.9	10	25.3	10	98.0
1979	3,290	99.9	32	87.4	14	34.1	15	140.3
1980	2,781	83.7	10	27.1	10	24.0	19	175.3
1981	2,462	72.4	17	44.9	11	25.5	15	137.6
1982	2,074	59.6	10	25.8	8	18.1	8	69.6
1983	N/A	N/A	6	14.9	4	8.5	4	35.6

(1) - Includes only verified accidents.
(2) - Accidents per million registered vehicles.

Graphs of the accident rates are presented in figure 11 with relevant statistics presented in table 6. All of the vehicle types are experiencing negative trends which indicate an overall reduction in accidents. The yearly accident experience for school buses is relatively constant. The general truck population, hazardous material transporters, and passenger buses, however, experience wide fluctuations in their yearly accident rate with respective standard deviations of 19.3, 28.3, and 62.8. The accident rate for passenger buses increased from 1975 to 1977 and from 1978 to 1980. After 1980 the passenger bus accident rate experienced a steady decline to a 1983 rate of 35.6 accidents per million registered vehicles.

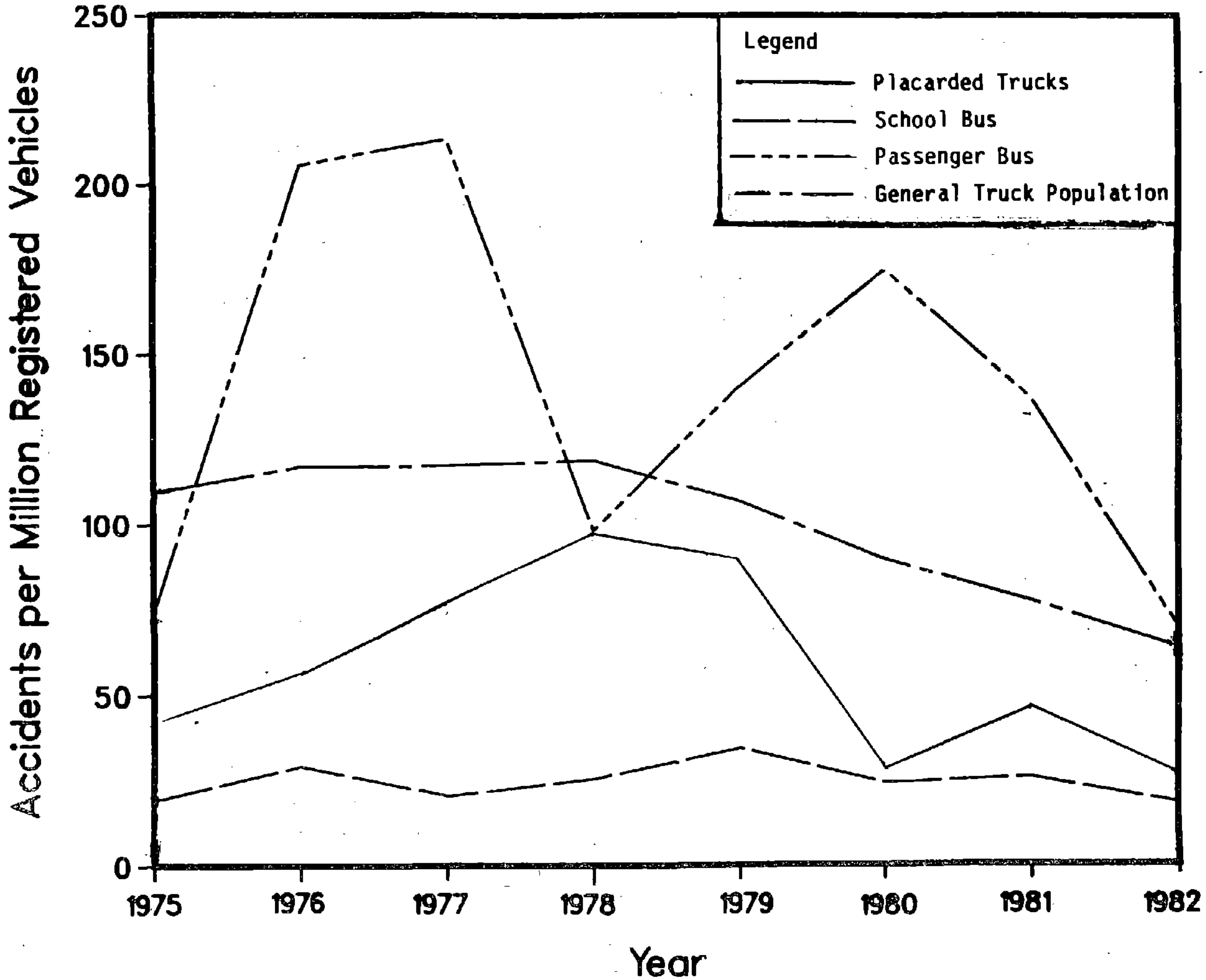


Figure 11. Respective accident rate for different vehicle types. (Note: Hazardous material transporter, school bus, and passenger bus rates are derived from verified accidents only.)

Table 6 - Statistics of yearly accident rate analysis.

Vehicle Type	Trend	Standard Deviation
General Truck Population	-6.8	19.3
Hazardous Material Transporters	-5.4	28.3
School Buses	-1.1	7.3
Passenger Buses	-10.3	62.8

Pertinent characteristics of the verified accidents have been summarized in table 7. Following are some observations based on this summary:

- The majority of hazardous material accidents (50.9 percent) occurred at crossings with passive warning devices (excluding stop signs). The greatest number of accidents for school and passenger buses occurred at crossings with active warning devices.
- In all three vehicle categories, the largest percentage of accidents involved the vehicle being struck by the train. In each instance the majority of struck-by-train accidents involved vehicle speeds below 10 mi/h (16 km/h).
- Monday had the largest percentage (26 percent) of hazardous material accidents. The largest percentage of school (26.7 percent) and passenger bus (21.8 percent) accidents occurred on Wednesday.
- The majority of accidents for all three vehicle types occurred from 1300 to 1500 hours. The school bus accidents peaked (39.3 percent) during this time period with hazardous material (24.2 percent) and passenger bus (17.6 percent) accidents peaking during 1000 to 1200 and 0700 to 0900 hours, respectively.
- The majority of both hazardous material and school bus accidents occurred on rural roadways. Urban roadways accounted for the majority of passenger bus accidents.

Table 7. Accident characteristics of verified accidents at public railroad crossings.

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Warning Device Type						
Active	67	41.6	39	46.4	67	56.3
Traffic Signal	5	3.1	4	4.8	7	5.8
Stop Sign	7	4.3	6	7.1	4	3.4
Passive (excluding stop sign)	82	50.9	35	41.7	41	34.5
Accident Type						
Struck by Train V<10	71	44.1	55	65.5	59	49.6
Struck by Train V≥10	61	37.9	20	23.8	34	28.6
Striking Train	29	18.0	9	10.7	26	21.8
Month of Year						
January	15	9.3	16	19.0	10	8.4
February	11	6.8	11	13.1	13	10.9
March	10	6.2	8	9.5	7	5.9
April	20	12.4	6	7.1	9	7.6
May	7	4.3	6	7.1	4	3.4
June	14	8.7	2	2.4	11	9.2
July	10	6.2	1	1.2	7	5.9
August	14	8.7	1	1.2	8	6.7
September	7	4.3	4	4.8	11	9.2
October	16	9.9	8	9.5	11	9.2
November	20	12.4	13	15.6	15	12.6
December	17	10.6	8	9.5	13	10.9
Day of Week						
Monday	26	16.1	17	20.2	15	12.6
Tuesday	17	10.6	13	15.5	21	17.6
Wednesday	20	12.4	22	26.2	26	21.8
Thursday	22	13.7	12	14.3	16	13.4
Friday	20	12.4	14	16.7	19	16.0
Saturday	8	5.0	1	1.2	16	13.4
Sunday	5	3.1	4	4.8	6	5.0
Unknown	43	26.7	1	1.2	0	0.0

Table 7. Accident characteristics of verified accidents at public railroad crossings (continued).

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
Hour of Day						
0100 - 0300	3	1.9	1	1.2	9	7.6
0400 - 0600	15	9.3	6	7.1	19	16.0
0700 - 0900	35	21.7	24	28.6	21	17.6
1000 - 1200	39	24.2	11	13.1	11	9.2
1300 - 1500	37	23.0	33	39.3	20	16.8
1600 - 1800	20	12.4	8	9.5	20	16.8
1900 - 2100	9	5.6	1	1.2	12	10.1
2200 - 2400	3	1.9	0	0	7	5.9
Functional Classification						
Urban Roadway	69	42.9	40	47.6	87	73.1
Rural Roadway	84	52.2	44	52.4	30	25.2
Unknown	8	5.0	0	0	2	1.7
Severity (Persons)*						
Fatal	30(54)	18.6	3(4)	3.6	8(21)	6.7
Personal Injury	61(111)	37.9	30(126)	35.7	40(210	33.6
Property Damage Only	70	43.5	51	60.7	71	59.7
Visibility						
Dawn	7	4.3	5	6.0	10	8.4
Day	124	77.0	71	84.5	66	55.5
Dusk	2	1.2	3	3.6	5	4.2
Dark	28	17.4	5	6.0	38	31.9
Weather						
Clear	112	69.6	55	65.5	80	67.2
Cloudy	35	21.7	13	15.5	29	24.4
Rain	6	3.7	10	11.9	6	5.0
Fog	3	1.9	1	1.2	1	0.8
Snow	5	3.1	5	6.0	3	2.5

*Numbers in parentheses represent persons killed or injured.

Table 7. Accident characteristics of verified accidents at public railroad crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Crossing Angle						
0 - 29	8	5.0	7	8.3	2	1.7
30 - 59	25	15.5	8	9.5	17	14.3
60 - 90	121	75.2	69	82.1	98	82.4
Unknown	7	4.3	0	0	2	1.7
Driver Action						
Did not Stop	103	64.0	35	41.7	70	58.8
Stopped then Proceeded	17	10.6	19	22.6	14	11.8
View of Track Obstructed	5	3.1	1	1.2	3	2.5
Drove Around Gates	5	3.1	2	2.4	6	5.0
Other, Stopped, Stalled	17	10.6	26	31.0	22	18.5
Unknown	14	8.7	1	1.2	4	3.4
Trains per Day						
<1	6	3.7	4	4.8	4	3.4
1 - 5	51	31.7	24	28.6	28	23.5
6 - 10	39	24.2	22	26.2	22	18.5
11 - 15	16	9.9	15	17.9	13	10.9
16 - 20	17	10.6	7	8.3	14	11.8
>20	32	19.9	12	14.3	38	31.9
Type of Development						
Open Spare	56	34.8	26	31.0	19	16.0
Residential	18	11.2	21	25.0	12	10.1
Commercial	47	29.2	22	26.2	51	42.9
Industrial	33	20.5	11	13.1	33	27.7
Institutional	0	0	4	4.8	2	1.7
Unknown	7	4.3	0	0	2	0.0
Percent Trucks						
0 - 5	67	41.6	35	41.7	42	35.3
6 - 10	58	36.0	36	42.9	54	45.4
11 - 15	21	13.0	8	9.5	13	10.9
>15	15	9.3	5	6.0	10	8.4

Table 7. Accident characteristics of verified accidents at public railroad crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Number of Tracks						
1	90	55.9	52	61.9	51	42.9
2	34	21.1	16	19.0	33	27.7
3	14	8.7	11	13.1	18	15.1
4 - 6	13	8.1	5	6.0	13	10.9
7 - 9	3	1.9	0	0	2	1.7
Unknown	7	4.3	0	0	2	1.7

- A total of 445 persons were injured and 79 fatalities resulted from accidents in all three vehicle categories. The highest percentage of accidents in each vehicle class were property-damage-only-accidents.

- The majority of all accidents occurred during daylight visibility conditions. The second highest percentage of hazardous material (17.4 percent) and passenger bus (31.9 percent) accidents occurred during dark conditions.

- Clear and cloudy weather conditions were present during a large majority of all accidents.

- A majority of the drivers either did not stop or stopped and then proceeded prior to the impact. The percentage of did not stop accidents was the highest of all driver action entries for each vehicle type.

Analysis of Train-Struck-Vehicle-Accidents With Vehicle Speed Less than 10 mi/h (16 km/h)

The primary purpose of analyzing accidents that were stratified by accident type and threshold speed was to estimate the impacts of proposed changes to the mandatory stop rules. If vehicles are no longer required to stop at crossings with active warning devices, then an impact can be expected on both train-involved and nontrain-involved accidents at crossings with active warning devices. The direction and magnitude of this change was estimated by comparing the accidents occurring between trains and regulated vehicles with those accidents occurring between trains and the general (nonhazardous material) truck population.

The number of yearly accidents that 1) occurred at public crossings with an active warning device; 2) involved a specified vehicle type traveling less than 10 mi/h (16 km/h) and 3) was struck by a train is presented in table 8. This information was used to determine the percentage of total accidents that occurred with vehicle speeds below 10 mi/h (16 km/h). The total for the general truck population was determined from the FRA accident/incident inventory. An accident was included if it involved a truck-train collision occurring at a public crossing from 1975 through 1982. Accidents that were coded as involving roadway vehicles or both the roadway vehicle and the train transporting hazardous materials were excluded from the total. The totals for hazardous material transporters, school and passenger buses were determined only from those cases that had been verified. The totals are presented in table 9.

Table 8 - Accidents at public crossings with active warning devices where the train struck the vehicle and the vehicle speed was less than 10 mi/h (1.6 km/h)

Year	General Truck Population	Verified Hazardous Material Transporter	Verified School Bus	Verified Passenger Bus
1975	219	3	3	4
1976	336	4	5	4
1977	364	3	2	5
1978	420	8	2	4
1979	473	2	5	6
1980	387	2	3	4
1981	352	3	4	5
1982	303	1	1	3
1983	Not Available	2	3	2

Table 9 - Total train-involved accidents.

	General Truck Population (1)	Verified Hazardous Material Transporter (2)	Verified School Bus (2)	Verified Passenger Bus (2)
Total Accidents	20,397	161	84	119

(1) - Accidents from 1975 through 1982.
(2) - Verified accidents from 1975 through 1983.

The percentages presented in table 10 indicate that 14.0 percent of all train-involved accidents with the general truck population occur below 10 mi/h (16 km/h). This is a smaller percentage than occurs with verified hazardous material transporters (17.4 percent). These results indicate that requiring vehicles to come to a stop at crossings with active warning devices increases the incidence of train-involved accidents at low vehicle speeds.

A summary of the accident characteristics for vehicles that were struck by the train, with vehicle speeds below 10 mi/h (16 km/h) is presented in table 11. Comparing this table with a summary of the total accidents presented in table 7 displays similarities in the percentages of almost all accident categories. Major deviations do occur, however, with regard to driver action. For all three vehicle types, hazardous material transporter, school bus, and passenger bus, the percentage of accidents where the driver either stopped and then proceeded or stalled on the tracks were higher for accidents under 10 mi/h (16 km/h).

The mandatory stop regulations are increasing the number of accidents where a regulated vehicle, traveling less than 10 mi/h (16 km/h) is struck by a train. This observation is based on 1) the high percentage of accidents where the driver stopped and then proceeded or was stalled on the tracks; and 2) the higher proportion of accidents involving regulated vehicles travelling less than 10 mi/h (16 km/h), being struck by a train, than that which occurs with the general truck population.

Analysis of Train Struck Vehicle Accidents with Vehicle Speed Greater Than or Equal to 10 mi/h (16 km/h)

The number of yearly accidents where a specified vehicle type, traveling at a speed equal to or greater than 10 mi/h (16 km/h), was struck by a train is presented in table 12. Only those accidents that occurred at public crossings with active warning devices were included.

Table 10. Percentage of total train-involved accidents occurring below 10 mi/h (16 km/h) where the train struck the vehicle at a crossing with active warning devices.

	General Truck Population		Verified Hazardous Material Transporter		Verified School Bus		Verified Passenger Bus	
	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent
1975	1.1	1.1	1.9	1.9	3.6	3.6	3.4	3.4
1976	1.6	2.7	2.5	4.3	6.0	9.6	3.4	6.7
1977	1.8	4.5	1.9	6.2	2.3	11.9	4.2	10.9
1978	2.1	6.6	5.0	11.2	2.3	14.2	3.4	14.3
1979	2.3	8.9	1.2	12.4	6.0	20.2	5.0	19.3
1980	1.9	10.8	1.2	13.6	3.6	23.8	3.4	22.7
1981	1.7	12.5	1.9	15.5	4.7	28.5	4.2	26.9
1982	1.5	14.0	0.6	16.1	1.2	29.7	2.5	29.4
1983	-	-	1.2	17.4	3.6	33.3	1.7	31.1

Table 11. Summary of verified accidents where the train struck the vehicle with a vehicle speed less that 10 mi/h (16 km/h) at public crossings.

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Warning Device Type						
Active	28	39.4	25	45.5	37	62.7
Traffic Signal	3	4.2	2	3.6	3	5.1
Stop Sign	3	4.2	4	7.3	3	5.1
Passive (excluding stop sign)	37	52.1	24	43.6	16	27.1
Month of Year						
January	5	7.0	10	18.2	1	1.7
February	3	4.2	7	12.7	6	10.2
March	3	4.2	5	9.1	3	5.1
April	11	15.5	5	9.1	4	6.8
May	3	4.2	5	9.1	3	5.1
June	5	7.0	1	1.8	5	8.5
July	8	11.3	1	1.8	3	5.1
August	4	5.6	1	1.8	6	10.2
September	3	4.2	2	3.6	10	16.9
October	9	12.7	5	9.1	3	5.1
November	7	9.9	8	14.5	9	15.3
December	10	14.2	5	9.1	6	10.2
Day of Week						
Monday	9	12.7	12	21.8	5	8.5
Tuesday	5	7.0	6	10.9	13	22.0
Wednesday	13	18.3	15	27.3	12	20.3
Thursday	9	12.7	7	12.7	7	11.9
Friday	7	9.9	10	18.2	10	16.9
Saturday	2	2.8	1	1.8	8	13.6
Sunday	3	4.2	3	5.5	4	6.8
Unknown	23	32.4	1	1.8	0	0

Table 11. Summary of verified accidents where the train struck the vehicle with a vehicle speed less than 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Hour of Day						
0100 - 0300	0	0	0	0	0	0
0400 - 0600	10	14.1	4	7.3	9	15.3
0700 - 0900	14	19.7	20	36.4	10	16.9
1000 - 1200	14	19.7	5	9.1	7	11.9
1300 - 1500	19	26.8	23	41.8	11	18.6
1600 - 1800	9	12.7	2	3.6	10	16.9
1900 - 2100	4	5.6	1	1.8	6	10.2
2200 - 2400	1	1.4	0	0	2	3.4
Functional Classification						
Urban Roadway	34	47.9	23	41.8	46	78.0
Rural Roadway	34	47.9	32	58.2	11	18.6
Unknown	3	4.2	0	0	2	3.4
Severity (Persons)*						
Fatal	10(21)	14.1	1(2)	1.8	6(19)	10.2
Personal Injury	27(51)	38.0	17(71)	30.9	15(78)	25.4
Property Damage Only	34	47.9	37	67.3	38	64.4
Visibility						
Dawn	4	5.6	4	7.3	5	8.5
Day	52	73.2	49	89.1	35	59.3
Dusk	1	1.4	0	0	3	5.1
Dark	14	19.7	2	3.6	16	27.1
Weather						
Clear	48	67.6	38	69.1	42	71.2
Cloudy	17	23.9	6	10.9	12	20.3
Rain	2	2.8	5	9.1	3	5.1
Fog	2	2.8	1	1.8	1	1.7
Snow	2	2.8	5	9.1	1	1.7

*Number in parentheses represents persons killed or injured.

Table 11. Summary of verified accidents where the train struck the vehicle with a vehicle speed less than 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
Crossing Angle						
0 - 29	5	7.0	5	9.1	1	1.7
30 - 59	13	18.3	6	10.9	8	13.6
60 - 90	50	70.4	44	80.0	46	78.0
Unknown	3	4.2	0	0	4	6.8
Driver Action						
Did not Stop	32	45.1	16	29.1	20	33.9
Stopped then Proceeded	12	16.9	13	23.6	10	16.9
View of Track Obstructed	1	1.4	0	0	1	1.7
Drove Around Gates	2	2.8	1	1.8	4	6.8
Other, Stopped, Stalled	15	21.1	25	45.5	21	35.6
Unknown	9	12.7	0	0	3	5.1
Trains per Day						
<1	0	0	4	7.3	0	0
1 - 5	23	32.4	16	29.1	8	13.6
6 - 10	19	26.8	14	25.5	9	15.3
11 - 15	6	8.5	8	14.5	10	16.9
16 - 20	9	12.7	6	10.9	9	15.3
>20	14	19.7	7	12.7	23	39.0
Type of Development						
Open Space	18	25.4	20	36.4	6	10.2
Residential	6	8.5	14	25.5	7	11.9
Commercial	25	35.2	13	23.6	31	52.5
Industrial	19	26.8	6	10.9	12	20.3
Institutional	0	0	2	3.6	1	1.7
Unknown	3	4.2	0	0	2	3.4
Percent Trucks						
0 - 5	31	43.7	23	41.8	23	39.0
6 - 10	22	31.0	22	40.0	30	50.8
11 - 15	10	14.1	8	14.5	2	3.4
>15	8	11.3	2	3.6	4	6.8

Table 11. Summary of verified accidents where the train struck the vehicle with a vehicle speed less than 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Number of Tracks						
1	31	43.7	34	61.8	21	35.6
2	22	31.0	11	20.0	20	33.9
3	6	8.5	6	10.9	9	15.3
4 - 6	7	9.9	4	7.3	6	10.2
7 - 9	2	2.8	0	0	1	1.7
Unknown	3	4.2	0	0	2	3.4

Table 12 - Accidents occurring at public crossings with active warning devices where the train struck the vehicle and the vehicle speed was greater than or equal to 10 mi/h (16 km/h).

Year	General Truck Population	Verified Hazardous Material Transporter	Verified School Buses	Verified Passenger Bus
1975	252	4	0	2
1976	314	2	1	3
1977	331	4	0	2
1978	337	7	2	2
1979	328	4	2	3
1980	336	0	1	4
1981	300	3	1	2
1982	227	3	1	0
1983	Not Available	0	0	1

The yearly accidents are presented as the percentage of total accidents in table 13. Inspection of the percentages reveals that there is a higher percentage of accidents occurring, in this analysis category, with hazardous material transporters (16.8 percent) and passenger buses (16 percent) than with the general truck population (11.9 percent). With the exception of school buses, therefore, the occurrence of regulated vehicles being struck by a train is higher than the general truck population in both speed groups. The significance of this difference was analyzed using the Z-test of proportions on the combined categories of regulated vehicles. The results of the analysis, presented in table 14, indicate that there is a significant difference, at 0.01 level of significance, in train-struck vehicle accidents between the general truck population and vehicles that are regulated by the mandatory stop regulations. This leads to a preliminary conclusion that the regulations are increasing the incidence of vehicles being struck by the train. It also suggests that train-involved accident analyses, stratified by vehicle speed, may not have been necessary.

Table 13. Percentage of total train-involved accidents occurring at or above 10 mi/h (16 km/h) where the train struck the vehicle at a crossing with active warning devices.

	General Truck Population		Verified Hazardous Material Transporter		Verified School Bus		Verified Passenger Bus	
	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent
1975	1.2	1.2	2.5	2.5	0	0	1.7	1.7
1976	1.5	2.8	1.2	3.7	1.2	1.2	2.5	4.2
1977	1.6	4.4	2.5	6.2	0	1.2	1.7	5.9
1978	1.7	6.0	4.3	10.6	2.4	3.6	1.7	7.6
1979	1.6	7.7	2.5	13.0	2.4	6.0	2.5	10.1
1980	1.6	9.3	0	13.0	1.2	7.1	3.4	13.4
1981	1.5	10.8	1.9	14.9	1.2	8.3	1.7	15.1
1982	1.1	11.9	1.9	16.8	1.2	9.5	0	15.1
1983	-	-	0	16.8	0	9.5	0.8	16.0

Table 14. Z-test of proportions on accidents where the vehicle was struck by a train.

Vehicle Type	Possible Occurrences (Total Accidents)	Struck by Train Occurrences	Proportion
Verified Regulated Vehicles	364	144	0.3956
General Truck Population	20,397	5,279	0.2588

Z = 5.89 99% Critical Value = 2.58

A summary of accident characteristics for this accident category is presented in table 15. Comparing this table with a summary of the total accidents presented in table 7, displays similarities in almost all accident categories. The only major deviation is in the category of driver action pertaining to stopped or stalled. This is expected since the table represents accidents occurring at vehicle speeds of 10 mi/h (16 km/h) or greater.

Analysis of Accidents Where the Vehicle Struck the Train

The number of yearly accidents where a specified vehicle type strikes a train is presented in table 16. Analysis of the resultant percentages, presented in table 17, indicate that all classes of regulated vehicles have a lower percentage of accidents than the general truck population. A Z-test of proportions performed on these differences, shown in table 18, indicates that there is a significant difference, at the 0.01 level of significance, in vehicles striking the train between the general truck population and vehicles that are regulated by the mandatory stop regulations. The mandatory stop regulations do, therefore, reduce the number of accidents where vehicles strike the train.

Table 15. Summary of total verified accidents where the train struck the vehicle with a vehicle speed greater than or equal to 10 mi/h (16 km/h) at public crossings.

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Warning Device Type						
Active	27	44.3	8	40.0	19	55.9
Traffic Signal	0	0	2	10.0	2	5.9
Stop Sign	3	4.9	1	5.0	0	0
Passive (excluding stop sign)	31	50.8	9	45.0	13	38.2
Month of Year						
January	6	9.8	4	20.0	4	11.8
February	5	8.2	4	20.0	5	14.7
March	4	6.6	2	10.0	4	11.8
April	6	9.8	1	5.0	3	8.8
May	3	4.9	1	5.0	0	0
June	7	11.5	1	5.0	2	5.9
July	2	3.3	0	0	2	5.9
August	5	8.2	0	0	1	2.9
September	2	3.3	1	5.0	1	2.9
October	4	6.6	2	10.0	4	11.8
November	11	18.0	3	15.0	3	8.8
December	6	9.8	1	5.0	5	14.7
Day of Week						
Monday	9	14.8	2	10.0	8	23.5
Tuesday	8	13.1	6	30.0	3	8.8
Wednesday	5	8.2	6	30.0	9	26.5
Thursday	6	9.8	3	15.0	2	5.9
Friday	8	13.1	2	10.0	3	8.8
Saturday	3	4.9	0	0	7	20.7
Sunday	2	3.3	1	5.0	2	5.9
Unknown	20	32.8	0	0	0	0

Table 15. Summary of total verified accidents where the train struck the vehicle with a vehicle speed greater than or equal to 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
Hour of Day						
0100 - 0300	1	1.6	1	5.0	1	2.9
0400 - 0600	2	3.3	2	10.0	7	20.6
0700 - 0900	12	19.7	2	10.0	5	14.7
1000 - 1200	17	27.9	3	15.0	4	11.8
1300 - 1500	13	21.3	8	40.0	4	11.8
1600 - 1800	9	14.8	4	20.0	8	23.5
1900 - 2100	5	8.2	0	0	3	8.8
2200 - 2400	2	3.3	0	0	2	5.9
Functional Classification						
Urban Roadway	30	49.2	15	75.0	27	79.4
Rural Roadway	28	45.9	5	25.0	7	20.6
Unknown	3	4.9	0	0	0	0
Severity (Persons)*						
Fatal	12(23)	19.7	2(2)	10.0	2(2)	5.9
Personal Injury	21(46)	34.4	11(53)	55.0	17(107)	50.0
Property Damage Only	28	45.9	7	35.0	15	44.1
Visibility						
Dawn	2	3.3	0	0	2	5.9
Day	50	82.0	16	80.0	17	50.0
Dusk	0	0	3	15.0	2	5.9
Dark	9	14.8	1	5.0	13	38.2
Weather						
Clear	38	62.3	12	60.0	24	70.6
Cloudy	17	27.9	5	25.0	7	20.6
Rain	4	6.6	3	15.0	1	2.9
Fog	0	0	0	0	0	0
Snow	2	3.3	0	0	2	5.9

*Numbers in parentheses represent persons killed or injured.

Table 15. Summary of total verified accidents where the train struck the vehicle with a vehicle speed greater than or equal to 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
Crossing Angle						
0 - 29	3	4.9	1	5.0	0	0
30 - 59	9	14.8	2	10.0	3	8.8
60 - 90	47	77.0	17	85.0	31	91.2
Unknown	2	3.3	0	0	0	0
Driver Action						
Did not Stop	47	77.0	14	70.0	30	88.2
Stopped then Proceeded	5	8.2	4	20.0	2	5.9
View of Track Obstructed	3	4.9	1	5.0	0	0
Drove Around Gates	3	4.9	0	0	2	5.9
Other, Stopped, Stalled	0	0	0	0	0	0
Unknown	3	4.9	1	5.0	0	0
Trains per Day						
<1	4	6.6	0	0	3	8.8
1 - 5	15	24.6	4	20.0	6	17.6
6 - 10	16	26.2	6	30.0	9	26.5
11 - 15	9	14.8	5	25.0	2	5.9
16 - 20	5	8.2	1	5.0	2	5.9
>20	12	19.7	4	20.0	12	35.3
Type of Development						
Open Space	20	32.8	3	15.0	6	17.6
Residential	7	11.5	5	25.0	4	11.8
Commercial	21	34.4	8	40.0	11	32.4
Industrial	11	18.0	3	15.0	12	35.3
Institutional	0	0	1	5.0	1	2.9
Unknown	2	3.3	0	0	0	0
Percent Trucks						
0 - 5	24	39.3	10	50.0	12	35.3
6 - 10	24	39.3	9	45.0	13	38.2
11 - 15	7	11.6	0	0	6	17.6
>15	6	9.8	1	5.0	3	8.8

Table 15. Summary of total verified accidents where the train struck the vehicle with a vehicle speed greater than or equal to 10 mi/h (16 km/h) at public crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Number of Tracks						
1	35	57.4	12	60.0	16	47.1
2	11	18.0	3	15.0	7	20.6
3	6	9.8	4	20.0	5	14.7
4 - 6	6	9.8	0	0	5	14.7
7 - 9	1	1.6	0	0	1	2.9
Unknown	2	3.3	1	5.0	0	0

Table 16. Accidents at public crossings with active warning devices where the vehicle struck the train.

Year	General Truck Population	Verified Hazardous Material Transporters	Verified School Buses	Verified Passenger Buses
1975	255	1	0	0
1976	284	1	0	2
1977	327	2	0	0
1978	355	3	1	0
1979	384	4	1	2
1980	342	1	1	1
1981	325	0	2	3
1982	269	0	1	3
1983	Not Available	0	0	0

A summary of the accident characteristics for this analysis category is presented in table 19. Comparing this table with a summary of the total accidents presented in table 7 reveals major deviations with regard to severity, roadway classification, and type of development. The occurrence of fatal (27.6 percent) and personal injury (44.8 percent) accidents are higher when the vehicle strikes the train. In addition, a majority of the accidents occur on rural roadways with 34.8 percent occurring in open space developments.

Summary of Conclusions from Train-Involved Accident Analysis

The verification process used to ascertain that vehicles involved in train accidents were either hazardous material transporters, school buses, or passenger buses was stringent. The result was that only 161 hazardous material, 84 school bus and 119 passenger bus accidents were sufficiently verified to remain in the analysis. The verification process resulted in a representative sample of the true regulated vehicle population with a 99 percent level of confidence that the accident characteristics of the sample were a good representation of the total population. The sample can be used, therefore, to describe the total population of regulated vehicle accidents. Determinations, therefore, on prevalent accident characteristics and the proportions of total accidents being struck by, or striking the train, represent those of the total possible population. Estimates of accident magnitude, however, based on the verified sample will provide lower limit estimates.

Table 17. Percentage of total train-involved accidents where the vehicle struck the train.

Year	General Truck Population		Verified Hazardous Material Transporter		Verified School Bus		Verified Passenger Bus	
	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent	Percent of Total	Cumulative Percent
1975	1.3	1.3	0.6	0.6	0	0	0	0
1976	1.4	2.6	0.6	1.2	0	0	1.7	1.7
1977	1.6	4.2	1.2	2.5	0	0	0	1.7
1978	1.7	6.0	1.9	4.3	1.2	1.2	0	1.7
1979	1.9	7.9	2.5	6.8	1.2	2.4	1.7	3.4
1980	1.7	9.5	0.6	7.5	1.2	3.6	0.8	4.2
1981	1.6	11.1	0	7.5	2.4	6.0	2.5	6.7
1982	1.3	12.5	0	7.5	1.2	7.1	2.5	9.2
1983	-	-	0	7.5	0	7.1	0	9.2

Table 18. Z-test of proportions on accidents where the vehicle struck the train.

Vehicle Type	Possible Occurrences	Vehicle Struck Train	Proportion
Verified Regulated Vehicles	364	29	0.0797
General Truck Population	20,397	2,541	0.1246

Z = 2.58 99% Critical Value = 2.58

Table 19. Summary of total verified accidents where the vehicle struck the train at public crossings.

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
<u>Warning Device Type</u>						
Active	12	41.4	6	66.7	11	42.3
Traffic Signal	2	6.9	0	0	2	7.7
Stop Sign	1	3.4	1	11.1	1	3.8
Passive (excluding stop sign)	14	48.3	2	22.2	12	46.2
<u>Month of Year</u>						
January	4	13.8	2	22.2	5	19.3
February	3	10.4	0	0	2	7.7
March	3	10.4	1	11.1	0	0
April	3	10.4	0	0	2	7.7
May	1	3.4	0	0	1	3.8
June	2	6.9	0	0	4	15.4
July	0	0	0	0	2	7.7
August	5	17.2	0	0	1	3.8
September	2	6.9	1	11.1	0	0
October	3	10.3	1	11.1	4	15.4
November	2	6.9	2	22.2	3	11.5
December	1	3.4	2	22.2	2	7.7
<u>Day of Week</u>						
Monday	8	27.7	3	33.4	2	7.7
Tuesday	4	13.8	1	11.1	5	19.3
Wednesday	2	6.9	1	11.1	5	19.3
Thursday	7	24.1	2	22.2	7	26.9
Friday	5	17.2	2	22.2	6	23.0
Saturday	3	10.3	0	0	1	3.8
Sunday	0	0	0	0	0	0

Table 19. Summary of total verified accidents where the vehicle struck the train at public crossings (continued).

Characteristic	Hazardous Material Transporters		School Buses		Passenger Buses	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
<u>Hour of Day</u>						
0100 - 0300	2	6.9	0	0	4	15.4
0400 - 0600	3	10.3	0	0	3	11.5
0700 - 0900	9	31.0	4	44.4	6	23.0
1000 - 1200	8	27.6	0	0	0	0
1300 - 1500	5	17.3	2	22.2	5	19.3
1600 - 1800	2	6.9	2	22.2	2	7.8
1900 - 2100	0	0	1	11.2	3	11.5
2200 - 2400	0	0	0	0	3	11.5
<u>Functional Classification</u>						
Urban Roadway	5	17.2	2	22.2	14	53.8
Rural Roadway	22	75.9	7	77.8	12	46.2
Unknown	2	6.9	0	0	0	0
<u>Severity (Persons)*</u>						
Fatal	8(10)	27.6	0	0	0	0
Personal Injury	13(14)	44.8	2(2)	22.2	8(25)	30.0
Property Damage Only	8	27.6	7	77.8	18	69.2
<u>Visibility</u>						
Dawn	1	3.4	1	11.1	3	11.5
Day	22	75.9	6	66.7	14	53.8
Dusk	1	3.4	1	11.1	0	0
Dark	5	17.3	1	11.1	9	34.7
<u>Weather</u>						
Clear	26	89.8	5	55.6	14	53.8
Cloudy	1	3.4	2	22.2	10	38.5
Rain	0	0	2	22.2	2	7.7
Fog	1	3.4	0	0	0	0
Snow	1	3.4	0	0	0	0

*Numbers in parentheses represent persons killed or injured.

Table 19. Summary of total verified accidents where the vehicle struck the train at public crossings (continued).

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Crossing Angle						
0 - 29	0	0	1	11.1	1	3.8
30 - 59	3	10.4	0	0	6	23.2
60 - 90	24	82.8	8	88.9	19	73.0
Unknown	2	6.8	0	0	0	0
Driver Action						
Did not Stop	24	82.8	5	55.6	20	76.9
Stopped then Proceeded	0	0	2	22.2	2	7.8
View of Track Obstructed	1	3.4	0	0	2	7.8
Drove Around Gates	0	0	1	11.1	0	0
Other, Stopped, Stalled	2	6.9	1	11.1	1	3.8
Unknown	2	6.9	0	0	1	3.8
Trains per Day						
<1	2	6.9	0	0	1	3.8
1 - 5	13	44.8	4	44.4	14	53.9
6 - 10	4	13.8	2	22.2	4	15.4
11 - 15	1	3.4	2	22.2	1	3.9
16 - 20	3	10.3	0	0	3	11.5
>20	6	20.8	1	11.1	3	11.5
Type of Development						
Open Space	18	62.0	3	33.4	7	26.9
Residential	5	17.3	2	22.2	1	3.9
Commercial	1	3.4	1	11.1	9	34.6
Industrial	3	10.4	2	22.2	9	34.6
Institutional	0	0	1	11.1	0	0
Unknown	2	6.9	0	0	0	0
Percent Trucks						
0 - 5	12	41.4	2	22.2	7	26.8
6 - 10	12	41.4	5	55.6	12	46.2
11 - 15	4	13.8	0	0	5	19.3
>15	1	3.4	2	22.2	2	7.7

Table 19. Summary of total verified accidents where the vehicle struck the train at public crossings (continued).

Characteristic	Hazardous Material Transporter Freq.	Hazardous Material Transporter Percent	School Bus Freq.	School Bus Percent	Passenger Bus Freq.	Passenger Bus Percent
Number of Tracks						
1	24	82.8	6	66.7	13	50.0
2	1	3.4	1	11.1	6	23.1
3	2	6.9	1	11.1	4	15.4
4 - 6	0	0	1	11.1	2	7.7
7 - 9	0	0	0	0	0	0
Unknown	2	6.9	0	0	1	3.8

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 1) regulated vehicles have a significantly higher proportion of their accidents occurring with the vehicle being struck by the train and 2) a significantly higher proportion of vehicles striking the train accidents occur with the general truck population. These differences are summarized in table 20.

Table 20. Summary of train-involved accident analysis.

Accident Type	General Truck Population	Verified Hazardous Material Transporter		Verified School Bus		Verified Passenger Bus	
	Percent (1)	Pct. (2)	Diff. (3)	Pct. (2)	Diff. (3)	Pct. (2)	Diff. (3)
Struck by the Train with Vehicle Speed < 10 mi/h	14.0	17.4	-3.4	33.3	-19.3	31.3	-17.3
Struck by the Train with Vehicle Speed ≥ 10 mi/h	11.9	16.8	-4.9	9.5	2.4	16.0	-4.1
Striking the Train	12.5	7.5	5.0	7.1	5.4	9.2	3.3
Total Differences			-3.3		-11.5		-18.1

(1) - Percent of total.
(2) - Percent of total verified accidents.
(3) - Difference between regulated vehicle and general truck accidents.

Inspecting the results of table 20 indicates that if the mandatory stop regulations were changed to not require stops at locations with active warning devices, the result would be a net decrease in train-involved accidents for hazardous material transporters, school and passenger buses of 3.3, 11.5, and 18.1 percent, respectively. Accidents involving the vehicle being struck by the train would decrease in all categories except that involving school buses with vehicle speeds above 9 mi/h. Similarly, an increase in accidents would occur in those instances where the train was struck by the vehicle.

Analysis of Nontrain-Involved Accidents

The accident records of four States, California, Illinois, North Carolina and Washington, were searched to identify accidents that 1) did not involve a train and 2) 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 12. All of the states selected for analysis had computerized accident record systems. The procedure used to identify the appropriate accidents varied from State to State. Some States did not have the roadway milepoint of the crossing readily available. This necessitated the location of the milepoints from straight line maps and then individually requesting computer summaries based on the identified milepoint. Two of the States had the ability to search their computerized files by whether the accidents were railroad-related. This flag was incorporated into the computerized data base whenever the original accident report made reference to a railroad crossing. The use of the railroad-related flag had the effect of increasing the accuracy of the search process and drastically reducing the amount of time and effort required. All of the States used in the study were very cooperative in providing the requisite assistance.

In those States that identified accidents based on roadway milepoint, a computerized summary was obtained of every accident that occurred within ±500 feet (152.4 m) of the crossing. These summaries, plus those coded as railroad-related, were scrutinized to identify accident types that were not related to the study needs. This included accidents that were coded as right angle, parking, driveway, and intersection accidents. Copies of the original accident report, often on microfilm, for the remaining accidents were then inspected. Accidents that made specific mention of a truck, school bus, or passenger bus stopping for a railroad crossing, with

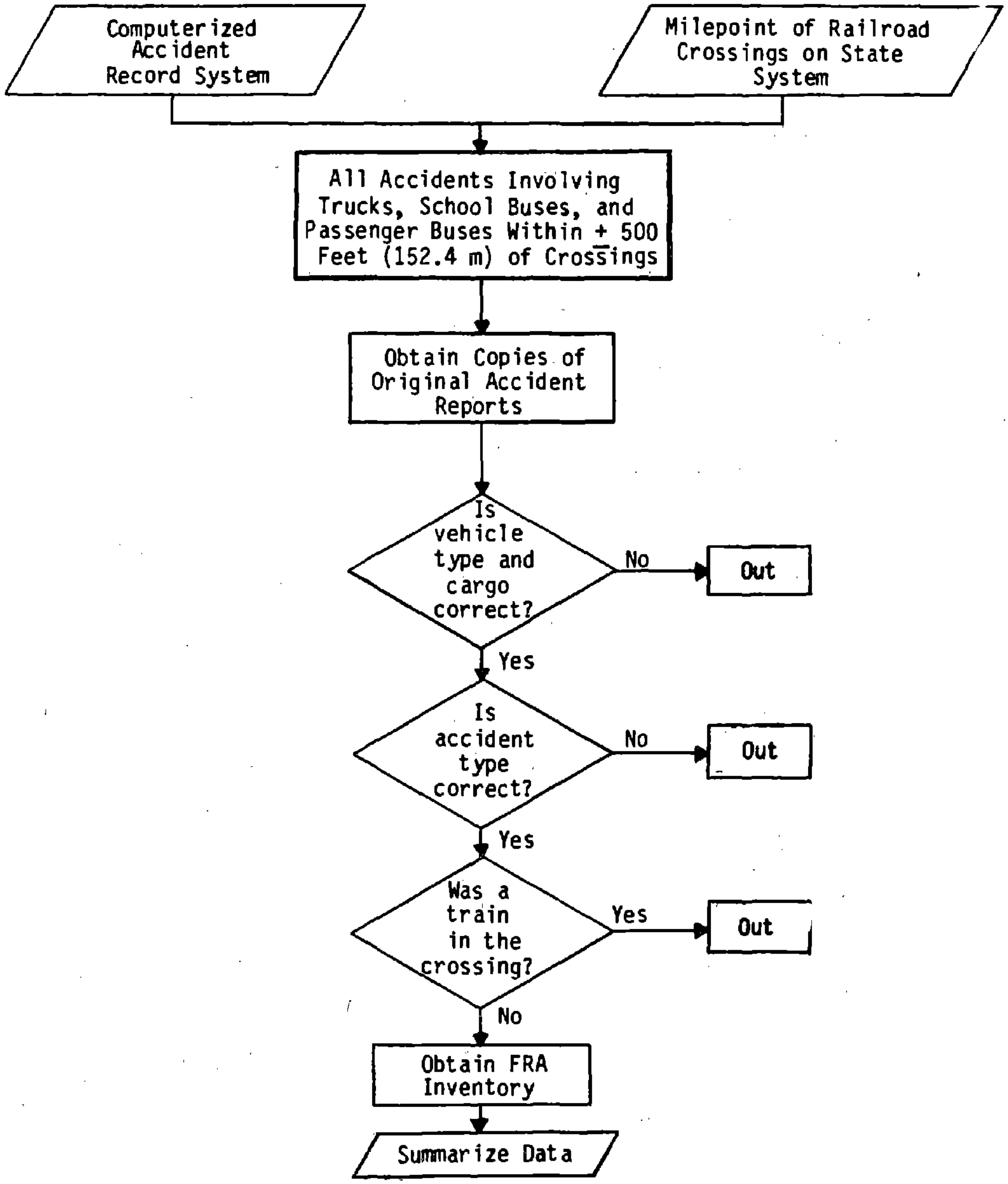


Figure 12. Flowchart of the nontrain-involved accident analysis procedure.

no train present or active devices not activated, were extracted for further analysis. This analysis consisted of obtaining the FRA inventory report and summarizing the accident characteristics.

The selection criteria were very stringent. The accident reports did not need to directly involve a regulated vehicle but they needed to be mentioned in the accident description as stopping at a railroad crossing with no train present or approaching. A rear end accident, therefore, 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 flashers activated. Due to the liberal initial, and restrictive final selection process, 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 of which 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 nontrain-involved accidents resulting from the actions of mandatory stop vehicles. Many instances can be expected where an accident resulting from vehicles queued behind a regulated vehicle will not mention the vehicle, the railroad crossing, and the presence or absence of a train. In addition, the accident type typically resulting from the actions of a mandatory stop vehicle are often low speed, minimal damage accidents. These accidents are often not reported. Another factor influencing the number of accidents selected were the record keeping capabilities and policies of each State. Only one State maintained records back to 1975, one to 1976, and the remaining two States did not maintain records prior to 1978.

A summary of the accidents that were determined as satisfying the selection criteria are presented in table 21. Approximately three-quarters of all the accidents that were identified occurred at crossings with active warning devices. The dominant accident type was rear end, which accounted for 89.8 percent of the total. The much higher involvement rate of school buses (61.7 percent) may be due more to strict accident reporting requirements than an actual higher involvement rate.

Table 21. Summary of nontrain-involved accidents.

Characteristic	Hazardous Material Transporter		School Bus		Passenger Bus	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Warning Device Type						
Active	36	72.0	133	81.6	42	82.4
Passive	14	28.0	30	18.4	9	17.6
Accident Type						
Rear-End	37	74.0	155	95.1	45	88.2
Sideswipe	2	4.0	6	3.7	5	9.8
Ran-off-Road	4	8.0	1	0.6	0	0
Fixed Object	1	2.0	1	0.6	1	2.0
Other	6	12.0	0	0	0	0
Year						
1975	1	2.0	2	1.2	0	0
1976	13	26.0	6	3.7	5	9.8
1977	8	16.0	17	10.4	2	3.9
1978	8	16.0	28	17.2	9	17.6
1979	9	18.0	27	16.6	13	25.5
1980	6	12.0	27	16.6	4	7.8
1981	1	2.0	20	12.3	8	15.7
1982	3	6.0	22	13.4	5	9.8
1983	1	2.0	14	8.6	5	9.8
Month of Year						
January	4	8.0	19	11.7	6	11.8
February	3	6.0	16	9.8	3	5.9
March	5	10.0	20	12.3	7	13.7
April	1	2.0	14	8.6	7	13.7
May	4	8.0	16	9.8	7	13.7
June	6	12.0	5	3.1	3	5.9
July	1	2.0	5	3.1	3	5.9
August	6	12.0	2	1.2	3	5.9
September	7	14.0	13	8.0	4	7.8
October	5	10.0	19	11.6	3	5.9
November	3	6.0	23	14.1	1	2.0
December	5	10.0	11	6.7	4	7.8

Table 21. Summary of nontrain-involved accidents (continued).

	Hazardous Material Transporter		School Bus		Passenger Bus	
Characteristic	Freq.	Percent	Freq.	Percent	Freq.	Percent
Day of Week						
Monday	7	14.0	28	17.2	11	21.6
Tuesday	8	16.0	36	22.1	10	19.6
Wednesday	11	22.0	37	22.7	8	15.7
Thursday	5	10.0	34	20.8	7	13.7
Friday	10	20.0	21	12.9	9	17.6
Saturday	5	10.0	5	3.1	4	7.8
Sunday	4	8.0	2	1.2	2	3.9
Hour of Day						
0100 - 0300	6	12.0	3	1.8	1	2.0
0400 - 0600	2	4.0	2	1.2	1	2.0
0700 - 0900	8	16.0	63	38.7	14	27.5
1000 - 1200	7	14.0	17	10.4	6	11.8
1300 - 1500	13	26.0	57	35.0	15	29.4
1600 - 1800	6	12.0	15	9.2	8	15.7
1900 - 2100	4	8.0	4	2.5	3	5.9
2200 - 2400	4	8.0	1	0.6	2	3.9
Unknown	0	0	1	0.6	1	2.0
Functional Classification						
Urban Roadway	32	64.0	125	76.7	43	84.3
Rural Roadway	18	36.0	38	23.3	8	15.7
Severity (Persons)*						
Fatal	0	0	0	0	0	0
Personal Injury	18(23)	36.0	38(89)	23.3	14(46)	27.5
Property Damage Only	31	62.0	125	76.7	37	72.5
Unknown	1	2.0	0	0	0	0
Visibility						
Dawn	0	0	4	2.5	1	2.0
Day	32	64.0	144	88.2	43	84.3
Dusk	0	0	4	2.5	0	0
Dark	15	30.0	5	3.1	6	11.8
Unknown	3	6.0	6	3.7	1	2.0

*Numbers in parentheses represent persons killed or injured.

Table 21. Summary of nontrain-involved accidents (continued).

	Hazardous Material Transporter		School Bus		Passenger Bus	
Characteristic	Freq.	Percent	Freq.	Percent	Freq.	Percent
Weather						
Clear	33	66.0	106	65.0	31	60.8
Cloudy	1	2.0	9	5.5	3	5.9
Rain	8	16.0	17	10.4	6	11.8
Fog	1	2.0	3	1.8	0	0
Sleet/Snow	2	4.0	17	10.4	10	19.6
Unknown	5	10.0	11	6.7	1	2.0
Crossing Angle						
10 - 29	5	10.0	15	9.2	2	3.9
30 - 59	14	28.0	25	15.3	6	11.8
60 - 90	30	60.0	123	75.5	43	84.3
Unknown	1	2.0	0	0	0	0
Type of Development						
Open Space	13	26.0	29	17.8	11	21.6
Residential	5	10.0	32	19.6	4	7.8
Commercial	16	32.0	79	48.5	26	51.0
Industrial	10	20.0	19	11.7	10	19.6
Institutional	5	10.0	4	7.2	0	0
Unknown	1	2.0	0	0	0	0
Number of Roadway Lanes						
2	34	68.0	110	67.5	22	43.1
3	1	2.0	8	4.9	2	3.9
4	13	26.0	42	25.8	25	49.0
5	1	2.0	1	0.6	1	2.0
6	1	2.0	2	0.4	1	2.0

The specific accident types were also summarized by relevant accident characteristics. Inspection of this summary, presented in table 22, indicates that the majority of the accidents occurred on two-lane roadways, during the day, and with clear weather conditions.

The accident rates, presented in table 23, were determined by the number of vehicles registered, in the appropriate year, for the specific States from which the accident data was obtained. The number of registered vehicles for 1975 was based on the registration of one State, for 1976 and 1977 on two States, and for 1978 through 1983 on four States. The number of hazardous material transporters were obtained by assuming a 1.1 percent mix of the total truck registration. The accident rates exhibit a large variation and are highly skewed, resulting as much from how the data was obtained as from the actual variation in accident rates. For example, the States that had the capability of identifying accidents by the code of railroad-related had a much higher accident frequency than those without this capability.

One of the primary purposes in performing the nontrain-involved accident analysis was to obtain an estimate of the number of these accidents that occur on a nationwide basis. This required a measure of the central tendency of the accident rates obtained from the four-State study. Table 24 represents the mean, median, and their respective 95 percent confidence range for the accident rate of each vehicle type. Inspection of table 24 resulted in using the median as the measure of central tendency. The median was chosen because 1) it provides a lower and thus more conservative estimate of the accident rate, and 2) the 95 percent confidence range is smaller than that of the mean, thus providing a better estimate of the true value.

Conclusions of Nontrain-involved Accident Analysis

The estimates of the nationwide nontrain-involved accident frequencies, table 25, were obtained by using the median value in conjunction with the total number of registered vehicles (excluding Hawaii). It is realized that total vehicle registration is not the optimal measure of

Table 22. Summary of nontrain-involved accident characteristics by accident type.

Accident Characteristic	Rear End		Sideswipe		Run-off-Road		Fixed Object		Other	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Warning Device										
Active	189	79.1	11	84.6	3	60.0	2	66.7	6	100.0
Passive	48	20.3	2	15.4	2	40.0	1	33.3	0	0
Visibility										
Dawn	5	2.1	0	0	0	0	0	0	0	0
Day	195	82.3	11	84.6	5	100.0	3	100.0	5	83.3
Dusk	4	1.7	0	0	0	0	0	0	0	0
Dark	24	10.1	2	15.4	0	0	0	0	0	0
Unknown	9	3.8	0	0	0	0	0	0	1	16.7
Weather										
Clear	152	64.1	8	61.5	4	80.0	0	0	4	66.7
Cloudy	12	5.1	1	7.7	0	0	2	66.7	0	0
Rain	29	12.2	2	15.4	0	0	0	0	0	0
Fog	3	1.3	0	0	1	20.0	0	0	0	0
Sleet/Snow	26	11.0	2	15.4	0	0	1	33.3	0	0
Unknown	14	5.9	0	0	0	0	0	0	1	16.7
Number of Roadway Lanes										
2	147	62.0	6	46.2	5	100.0	3	100.0	5	83.3
3	10	4.2	1	7.7	0	0	0	0	0	0
4	73	30.8	6	46.2	0	0	0	0	1	16.7
5	3	1.3	0	0	0	0	0	0	0	0
6	4	1.7	0	0	0	0	0	0	0	0

Table 23. Accident rates for nontrain-involved accidents.

Year	Hazardous Material Transporter			School Bus			Passenger Bus		
	Freq.	Exposure(1)	Rate(2)	Freq.	Exposure(1)	Rate(2)	Freq.	Exposure(1)	Rate(2)
1975	1	7.1	140.8	2	10.6	194.2	0	0.6	0
1976	13	20.2	643.6	6	29.3	204.8	5	7.2	694.4
1977	8	20.8	384.6	17	28.1	605.0	2	6.8	294.1
1978	8	71.4	112.0	28	64.7	432.8	9	20.5	439.0
1979	9	76.3	118.0	27	64.8	416.7	13	20.6	631.1
1980	6	75.2	79.8	27	62.7	430.6	4	21.4	186.9
1981	1	75.3	13.3	20	67.5	296.3	8	21.4	373.8
1982	3	78.0	38.5	21	75.5	278.1	5	22.5	222.2
1983	1	82.0	12.2	14	75.2	186.2	5	20.9	239.2

(1) - Thousand vehicles
(2) - Accidents per million registered vehicles

Table 24. Mean, median, and respective 95 percent confidence range for nontrain-involved accident rates.

Vehicle Type	Mean (1) Value	Mean (1) 95% Confidence Interval	Median (1) Value	Median (1) Total Range
Hazardous Material Transporters	171.4	822.4	112.0	371.3
School Bus	338.3	557.4	296.3	238.6
Passenger Bus	342.3	861.6	294.1	444.2

(1) Accident rate per million registered vehicles.

Table 25. Estimated nationwide yearly nontrain-involved accident frequency resulting from the actions of mandatory stop vehicles at railroad crossings.

	Hazardous Material Transporter			School Bus			Passenger Bus		
Year	Veh.(1,2)	Rate(3)	Freq.	Veh.(1,2)	Rate(3)	Freq.	Veh.(1,2)	Rate(3)	Freq.
1975	282.8	112.0	32	365.4	296.3	108	94.5	294.1	28
1976	304.1	112.0	34	378.5	296.3	112	97.3	294.1	29
1977	324.4	112.0	37	390.7	296.3	116	98.4	294.1	29
1978	347.8	112.0	39	395.4	296.3	117	192.0	294.1	30
1979	366.3	112.0	41	410.3	296.3	122	106.9	294.1	31
1980	369.4	112.0	42	417.1	296.3	124	108.4	294.1	32
1981	378.4	112.0	43	431.7	296.3	128	109.0	294.1	32
1982	387.2	112.0	44	440.9	296.3	131	114.9	294.1	34
1983	401.4	112.0	45	469.3	296.3	139	112.4	294.1	33

(1) - Thousand vehicles
(2) - Excludes Hawaii
(3) - Accidents per million registered vehicles

exposure. The probability of a nontrain-involved accident occurring at a crossing, either directly or indirectly due to mandatory stop laws, is a function of numerous variables. Included in these variables are the number of regulated vehicles, number of crossings, number of following vehicles, compliance rate, applicable mandatory stop laws, and type of roadway facility. Since it was not possible to control for all of these variables, total vehicle registrations were assumed to provide an acceptable measure of exposure.

The average number of nontrain-involved accidents for the 9-year analysis period was 40 hazardous material transporters, 122 school buses, and 31 passenger buses. These are the annual nontrain-involved accidents that will be assummed to be reduced if regulated vehicles are no longer required to stop at crossings with active devices when the devices are not activated. Inspection of table 25 indicates that the estimates of nontrain-involved accident frequencies appear inordinately low. It can reasonably be expected, for example, that during 1983 there were more than 45 accidents nationwide resulting from hazardous material transporters stopping at crossings with active devices when not activated.

CHAPTER 3 - COLLECTION AND ANALYSIS OF OPERATIONAL DATA

Traffic conflicts, erratic maneuvers, compliance, and lane usage were collected at 12 sites to obtain information on the operational effects of, and the rate of compliance to, the mandatory stop regulation.

Operational Measures

The number of traffic conflicts and erratic maneuvers were obtained to yield information on accident potential. Traffic conflicts are defined as evasive maneuvers taken by a motorist to avoid a potential accident. Erratic maneuvers are similar to conflicts, with the exception that they do not involve a direct evasive action to avoid a collision, but consist of an unexpected maneuver that has accident potential. An example of an erratic maneuver would be a vehicle using the shoulder of the road to pass a stopped mandatory stop vehicle. The traffic conflicts and erratic maneuvers that were recorded during the operational review were:

- Severe or emergency braking of following vehicles. The rationale behind this measure was that it gave an indication of the potential for rear end accidents.
- Encroachment of shoulder or adjacent lane to avoid a rear end collision. In some instances, the following vehicles may use adjacent lanes as possible escape routes if unable to stop in time to avoid a rear end collision.
- Aborted and/or near-miss passing maneuver. This measure was investigated to give an indication of the potential for run-off-the-road, head-on, or sideswipe accidents.
- Start-up disruption. The dissipating queues formed by vehicles accelerating from a stop behind a mandatory stop vehicle were inspected for acceleration and braking actions. This measure was collected to obtain an estimate of the potential for low cost accidents resulting indirectly from the limited acceleration characteristics of some mandatory stop vehicles.

- Passing on the right-hand side. Instances may occur where queued vehicles and the mandatory stop vehicle are passed by following vehicles on the right-hand side. This erratic maneuver has the potential for resulting in run-off-the-road and sideswipe accidents.

- Opposing lane encroachment. The size of many mandatory stop vehicles obstructs the view of oncoming traffic. This view obstruction can result in following vehicles encroaching on the center line to view oncoming traffic when there is a desire to pass. This measure was observed on two-lane roadways where passing maneuvers necessitated the use of the opposing traffic lane.

- Aborted passing maneuver. This measure was investigated on two-lane roadways. The intent of the measure was to provide an indication of the incidence of unsafe passing maneuvers.

- Slowing or stopping by opposing direction vehicles. The presence of a queue may cause disruptions to the opposing direction of traffic on two-lane roadways. These disruptions could indicate the potential for rear end accidents.

In addition to measures of traffic conflicts and erratic maneuvers, observations on the actions of the mandatory stop drivers were obtained. These observations consisted of:

- Violation rate. Data were obtained on whether the regulated vehicles came to a full, rolling, or no stop. Vehicles not coming to a full stop were recorded as being in violation of the mandatory stop provision, provided they were regulated under State regulations.

- Vehicle position on the roadway. This measure was obtained to indicate the utility of pullout lanes. In addition, it was anticipated that it would provide an indication of the mandatory stop driver's perception of hazard and disruption to traffic flow resulting from stopping in the roadway.

All of these traffic conflicts, erratic maneuvers, and observations were identified prior to any data collection procedures. The observers were instructed to not only record these nonaccident measures but to record any other abnormalities that occurred. The data was obtained in conjunction with observations on the number of following vehicles and volume counts broken into 15-minute time periods. The observations on the number of following vehicles was obtained to give an indication of the potential for conflicts and erratic maneuvers. For example, a mandatory stop vehicle with no following vehicles would only yield information on compliance and lateral position of the mandatory stop vehicle. No conflicts or erratic maneuvers could occur since no other vehicles are present.

Test Site Selection Process

The initial data collection plan was to collect data from 12 sites, 6 with and 6 without pullout lanes, in Michigan, Ohio, and Illinois. In addition to the consideration of pullout lanes, appropriate study sites had to have those characteristics which would tend to maximize observational opportunities. Desirable site characteristics were established as:

- Relatively large number of mandatory stop vehicles.
- Relatively high traffic volumes.
- Two-lane roadways to increase the probability of following vehicle conflicts.
- Crossings with well-maintained crossing surfaces.
- Crossings with automatic flashing lights, standard marking, and signing.
- Approach speeds greater than 35 mi/h (56 km/h).
- Straight approaches without grades, so that observable driver actions would not be confounded by geometrics and sight restrictions.

Requiring sufficient volumes of mandatory stop vehicles and ADT, in conjunction with site-specific physical features, complicated the site selection process. The inherent dangers in materials classified as hazardous result in bulk handling facilities being located in primarily rural, low density areas resulting in low roadway volumes. Similarily, passenger bus, and to a lesser extent school bus, traffic is greatest where the population density is high. It was difficult, therefore, to find sites that had a good representation of hazardous material trucks, passenger and school buses. It was determined to concentrate on those locations that had a high representation of hazardous material haulers and to collect the data during those months in which school was in session. By collecting data early in the morning and later in the afternoon, it was possible to obtain observations on the available bus traffic without specifically searching for sites with high anticipated bus volumes. The following site selection process was used.

- The locations of shipping points for hazardous materials were identified. These points included refining facilities, bulk plants, chemical plants, warehouses, or disposal sites. This was accomplished by contacting the environmental protection agencies, fire marshalls and major petroleum companies in Michigan, Ohio, and Illinois. These contacts provided a variety of information including hazardous material routes, hazardous waste facilities, and the location of bulk petroleum depots. The representatives of the individual refineries provided further information, including the routes to and from the plant that had at-grade railroad crossings and those sites that the truck drivers perceived as meeting the physical requirements of the project.

- The location of the shipping points was identified on a map and the presence of the nearby railroad crossings noted. The same procedure was followed with regard to hazardous material routes.

- Data pertaining to the county, nearest city, State, and railroad were used to obtain the DOT/AAR crossing inventory for each crossing. This inventory was used to determine the number of lanes, crossing warning device, percent truck mix, ADT, and train volumes.

- Those crossings with the highest volumes were stratified by the presence of pullout lanes.

- Each candidate crossing was visited. This visit consisted of performing a physical inventory of the locational features (posted speed, grades, crossing condition, land use, and traffic control devices). If the initial investigation indicated that the site had potential then photographs were obtained and an operational review (approach speeds, 15-minute volume count, and verification of mandatory stop vehicles) was conducted.

- The sites for actual data collection activities where then randomly selected from those candidate sites that meet the selection criteria.

Test Site Selection Results

Location of the shipping points and inspection of the maps resulted in the identification of 48 locations as possible project sites. Subsequent inspection of the national inventory revealed that none of these locations were equipped with truck pullout lanes.

Field visits were made to each of the 48 possible sites that did not have pullout lanes. These field inspections resulted in 22 sites being classified as inappropriate with the remaining 26 sites being graded as good, fair, or poor. These sites were stratified by their ranking, and six were randomly selected from the good category.

The failure to identify any sites with pullout lanes necessitated a different approach for pullout-lane site selection. This approach consisted of obtaining a listing of all sites in Michigan, Ohio, and Illinois that were posted, in the FRA inventory, as having pullout lanes. These locations were used to plan an itinerary that would permit the visitation of the prospective pullout-lane sites during the field trips to the sites without pullout lanes.

A total of 79 sites, identified by the national inventory as having truck pullout lanes, were visited. Only two of these sites were determined as actually having pullout lanes. These two sites, located in Michigan, were determined as not being appropriate for the study due to very low volumes of mandatory stop vehicles. The remaining 77 sites were miscoded and did not consist of lanes constructed for the primary purpose of reducing delay and congestion resulting from regulated vehicles stopping in the traveled way. A common error in urban areas 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 difficulty in locating sites with pullout lanes necessitated searching for sites in a state where the location of pullout lanes were known by state personnel. Assistance in this regard was requested from Washington State. A listing from the national inventory of locations with pullout lanes in Washington was forwarded to the Washington Department of Transportation. This list was checked against photologs to ensure that pullout lanes did exist. Of the original list of 32 possibilities, only 8 were identified as actually having pullout lanes in conjunction with relatively high volumes of mandatory stop vehicles and high ADT volumes.

The final sites selected for data collection activities, and the alternate locations, are shown in table 26. A complete listing of all the sites that were inspected and the reason for their elimination, are presented in appendix B of volume II.

Data Collection Activities

The plan called for data to be collected for 9 hours at each approach of the 12 crossings (6 with pullout and 6 without pullout lanes), for a total of 216 hours of data collection. The only exception made to this plan was at the site in Alabaster, Michigan. Inclement weather resulted in data being collected for only 8 hours on each approach. This data short-

Table 26. Summary of candidate sites for operational analysis.

Site No.	Roadway	State	County	City	US DOT-AAR X-ing Number	Initial Ranking	Comments
*1	M 46	MI	Tuscola	-	-	Good	This site is located on the main truck route between I-75 and the Michigan thumb area. There is sufficient room for the placement of the data collection equipment and observer refuge. The site consists of 2-lane, 2-way approaches, standardized flashers with no gates.
11	Ill. Rt. 10	IL	Champaign	Champaign	291050E	Good	This site is located within 2 miles of a gasoline storage facility. It has sufficient room for data collection equipment and observer refuge, and has high volumes of hazardous material haulers.
12	Co. Rd. 25	IL	Champaign	-	543267R	Good	This site is located within 2 miles of a gasoline storage facility and on the main truck route connecting this storage facility and US-150. There is sufficient room for data collection equipment and nothing to cause any traffic conflicts.
16	US 23	MI	Iosco	Alabaster	250947A	Good	This site is located on the main truck route running along the northeast coast of Michigan. It has high volumes of mandatory stop vehicles and sufficient room for the data collection activities.
17	US 23	MI	Arenac	Omer	250918P	Good	This site is located on the main truck route running along the northeast coast of Michigan. It has high volumes of mandatory stop vehicles and sufficient room for the data collection activities.
*18	Seaman Rd.	OH	Lucas	Oregon	473859G	Good	This site is located on the main truck route from the gasoline storage facility in Oregon, OH to the adjoining highways. One storage facility is within 1/4 mile of this crossing. This site has high volumes of gasoline tankers and sufficient room for the data collection activities.
19	Wynn Rd.	OH	Lucas	Oregon	473858A	Good	This site is located on the main truck route connecting the gasoline storage facility in Oregon, OH to the main highways of the area. This site has high volumes of gasoline tankers and sufficient room for the data collection activities.
20	SR 2	OH	Lucas	Oregon	473856L	Good	This site is located on the main eastbound truck route serving the northern shoreline of Ohio. It has a high vehicle volume as well as large numbers of gasoline tankers. There is also room for data collection equipment and personnel.

* Alternate Site

Table 26. Summary of candidate sites for operational analysis (continued).

Site No.	Roadway	State	County	City	US DOT-AAR X-ing Number	Initial Ranking	Comments
1W	SR 12	WA	Walla Walla	Walla Walla	097090V	Good	This site has pullout lanes on both approaches and is located in an urban industrial area. It has a moderate ADT with a high percentage of truck traffic. There is also room for data collection activities.
2W	SR 12	WA	Yakima	Yakima	104439L	Good	This site has pullout lanes on both approaches and is located in an industrial, urban area. It has high traffic volumes with a high truck mix. There is also sufficient room for data collection activities.
3W	SR 516	WA	King	Kent	396581U	Good	This site has pullout lanes on both approaches and is located in an urban residential area. As a result, it has high vehicular volumes but a moderate percentage of trucks. There is also sufficient room for data collection activities.
4W	SR 12	WA	King	Renton	400106A	Good	This site has pullout lanes on each approach and it is located in an urban industrial area. It has high volumes and a high percentage of trucks. There is also sufficient room for the data collection activities.
5W	SR 12	WA	Walla Walla	Walla Walla	808516F	Good	This site has pullout lanes on each approach and it is located in an urban area. It has moderate vehicular volumes and a high percentage of trucks. There is also sufficient room for data collection activities.
6W	SR 395	WA	Franklin	Connell	813957N	Good	This site has pullout lanes on each approach and it is located in a rural area. It has moderate vehicular but very high percentage of trucks.
*7W	SR 6	WA	Lewis	Chehalis	848565F	Good	This site has pullout lanes on both approaches. It is located in a rural area with moderate vehicular volumes but a high percentage of trucks.
*8W	SR 97	WA	Yakima	Toppenish	099199T	Good	This site has a pullout lane on the northbound approach only. It is located in a rural commercial area with a high vehicular volume and truck percentages.

* Alternate Site

fall was compensated by 3 hours of additional data being obtained at the Omer, Michigan site.

All of the sites in Michigan, Ohio, and Illinois that were visited by the project team were used in the study. The proposed site in Franklin County, Washington, however, could not be located by the data collection team. Contact was made with a representative of the Union Pacific Railroad who mentioned that the crossing was removed and the roadway paved in 1981. The reserve site in Lewis County was used in its place. A summary of the physical characteristics of the final sites that were used in the study is presented in table 27.

The difficulty in identifying sites with pullout lanes resulted in changes to both data magnitude and interpretation. The difference in data 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 result 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 in that Illinois requires stops by school buses and Washington requires stops by hazardous material transporters. To help ensure compatability between the hazardous material transporters, data collected in different study areas were only obtained on trucks that were placarded. A summary of the applicable FMCSR and State laws is presented in figure 13.

Data was collected simultaneously on each approach by two data collectors. Each data collector observed one approach and manually collected the following data:

- Driver action of mandatory stop vehicle. The driver action was classified as full stop, rolling stop, or no stop. Vehicles were classified as rolling stop when they slowed appreciably, to

Table 27 - Summary of the physical characteristics of the data collection sites.

Site No.	State	County	Roadway	RR Crossing Device	Pullout Lanes Yes	Pullout Lanes No	Number of Roadway Lanes	Land Use
16	Michigan	Iosco	SR 23	Std. Flash. Lights		X	2	Open Space
17	Michigan	Arenac	SR 23	Std. Flash. Lights		X	2	Residential
20	Ohio	Lucas	SR 02	Gates		X	2	Commercial
29	Ohio	Lucas	Wynn Rd.	Gates		X	2	Open Space
11	Illinois	Champaign	SR 10	Std. Flash. Lights		X	2	Open Space
12	Illinois	Champaign	CR 25	Std. Flash. Lights		X	2	Open Space
W1	Washington	Walla Walla	SR 12	Cant. Flash. Lights	X		4	Industrial
W2	Washington	Yakima	SR 12	Cant. Flash. Lights	X		4	Industrial
W3	Washington	King	SR 516	Gates	X		4	Residential
W4	Washington	King	SR 181	Cant. Flash. Lights	X		4	Industrial
W5	Washington	Walla Walla	SR 12	Cant. Flash. Lights	X		4	Open Space
W7	Washington	Lewis	SR 6	Cant. Flash. Lights	X		2	Open Space

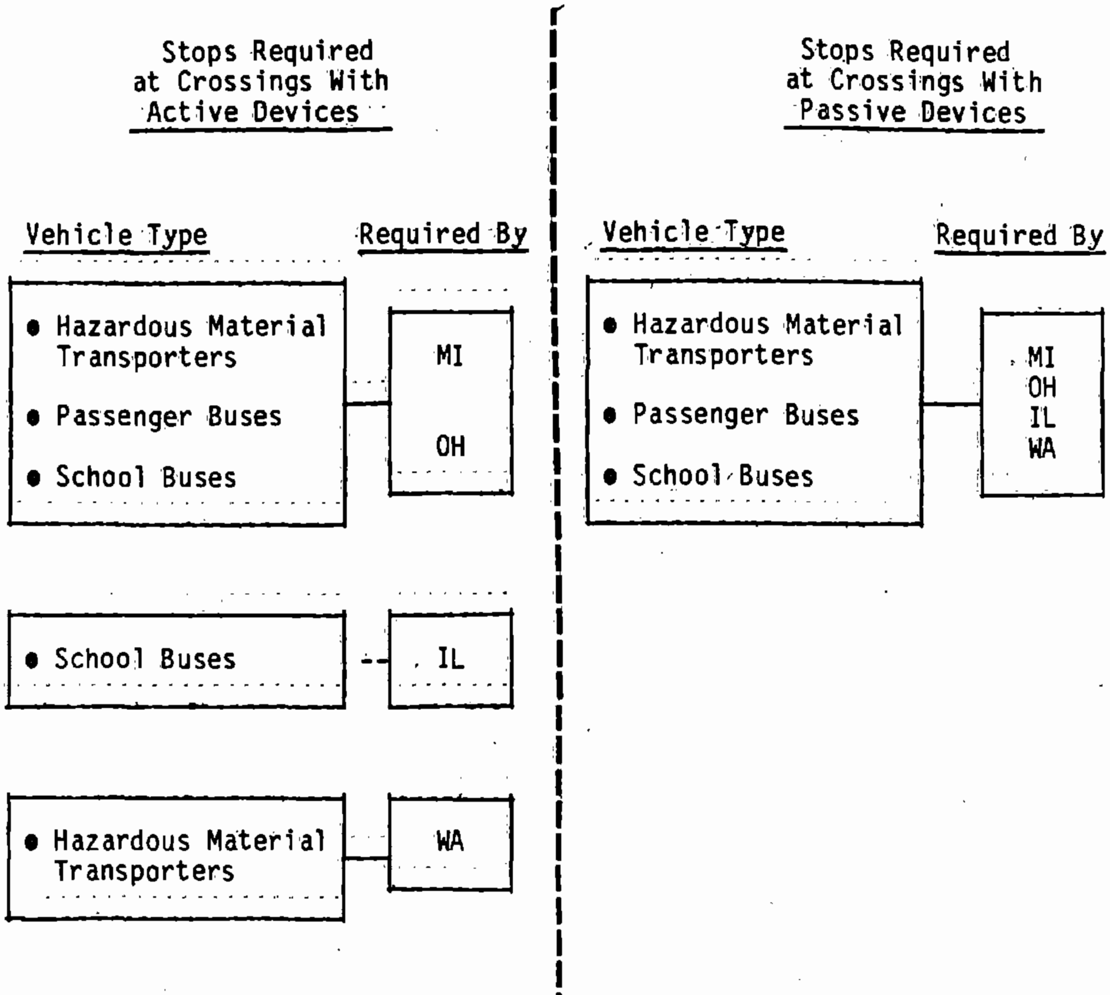


Figure 13. Summary of State mandatory stop laws for vehicle types observed in the study areas.

approximately less than 15 mi/h (24 km/h), from their initial speed but did not come to a stop. "No stop" were those instances where the observed vehicle slowed very little or not at all.

- Placard type. The color of the placard was recorded for all observed vehicles.
- Directional volumes and total number of trucks including those not classified as hazardous material transporters.
- The number of following vehicles that were impacted by the regulated vehicle stopping at the crossing.
- Position on the roadway. The lateral positioning (lane) of the mandatory stop vehicle was recorded for those vehicles which came to a full or rolling stop.
- Traffic conflicts and erratic maneuvers. Instances of normal brake light application were not recorded as traffic conflicts.
- The presence or absence of the Interstate Commerce Commission (ICC) registry numbers were noted. Difficulty was encountered in differentiating between the ICC numbers denoting interstate carriers and the MPSC numbers denoting carriers only involved in intrastate commerce. The location of the observers and the presence of dirt on the trucks resulted in the accuracy of these observations being questionable.

Data Collection Results

The data collected has been grouped together by similarities in physical features (i.e., pullout versus no pullout lanes) and, State law.

Michigan and Ohio Data

Data from Michigan and Ohio (with State laws similar to the regulations of FMCSR), collected at sites with no pullout lanes, were grouped together. A summary of the observations is presented in table 28.

Table 28. Summary of vehicle type and driver action for operational data collected at sites without pullout lanes in Michigan and Ohio.

Vehicle Type	Total Observations	Placard Type Red	Green	Black	Orange	Yellow	Driver Action Full Stop	Rolling Stop	No Stop	Violation Rate of State Law (Percent)
Truck	8	6	0	1	1	0	1	2	5	87.5
Tank Truck	192	181	7	3	0	1	78	57	57	59.4
Passenger Bus	5						4	1	0	20.0
School Bus	28						19	9	0	32.1

Generalized Placard Codes:

Red - Flammable
Green - Non-Flamable Gas
Black - Corrosives
Orange - Explosives
Yellow - Oxidizers/Radioactive

A total of 233 mandatory stop vehicles were observed at four sites, two in Michigan and two in Ohio. The largest number of observations were tank trucks with 192 incidents. This is largely the result of the site selection process and is not representative of the overall roadway vehicle mix. Since the sites were selected with consideration to the proximity of petroleum refineries, they can be expected to have a large proportion of tank trucks.

The only sample size which is large enough to form a conclusion on the violation rate are tank trucks. The overall violation rate was 59.4 percent with 29.7 percent of the vehicles not even slowing down to a rolling stop. It is also interesting to note, that while the number of observations on school buses is small, all of them came, at least, to a rolling stop.

Table 29 contains the results of the conflicts and lateral position observations. These observations are broken down into categories of following vehicles to facilitate calculation of conflict and erratic maneuver rates. Conflict and erratic maneuver rates were determined by considering the number of opportunities that were available. For example, there were nine occurrences when a tanker was followed by two vehicles. In only five of these occurrences, however, did the tanker come to a rolling or a full stop. There were, therefore, ten following vehicles that had to react to the tanker slowing down or stopping in the roadway. Two of these instances resulted in severe braking for a conflict rate of two conflicts in ten opportunities or, alternatively, one in five.

The only conflict and erratic maneuver types observed were those pertaining to braking and centerline encroachment. The largest erratic maneuver rate was that pertaining to centerline encroachment when school buses had one vehicle following. The encroachment indicates that the driver of the following vehicle was considering passing the school bus at the crossing. No actual passing maneuvers were observed, however, until both vehicles were past the crossing.

Table 29. Summary of observational data at sites without pullout lanes in Michigan and Ohio.

Vehicle Type	Number of Following Vehicles	Occurrences of Following Veh. Per Observation		Following Vehicle Conflicts and Erratic Maneuvers*			Position of Mandatory Stop Vehicles	
		Total Observation	Full or Rolling Stop	Centerline Encroachment	Severe Braking	Locked Tires	Fully on Roadway	Partially on Shoulder
Truck	0	7	2	-	-	-	1	1
	1	0		0	0	0	0	0
	2	1	1	0	1 (1/2)	0	1	0
	3	0		0	0	0	0	0
	≥4	0		0	0	0	0	0
Tanker	0	139	103	-	-	-	87	16
	1	33	20	3 (3/20)	3 (3/20)	1 (1/20)	17	3
	2	9	5	0	2 (2/5)	0	5	0
	3	5	3	1 (1/9)	0	0	2	1
	≥4	6	4	1 (1/21)	0	0	4	0
Passenger Bus	0	3	3	-	-	-	3	0
	1	2	2	0	0	0	2	0
	2	0		0	0	0	0	0
	3	0		0	0	0	0	0
	≥4	0		0	0	0	0	0
School Bus	0	11	11	-	-	-	9	2
	1	9	9	4 (4/9)	0	0	8	1
	2	3	3	1 (1/6)	0	0	3	0
	3	2	2	0	0	0	2	0
	≥4	3	3	0	0	0	3	0

* Number in parenthesis represent the number of conflicts per following vehicles i.e. (number of conflicts/number of observed following vehicles).

There were no following vehicles, and therefore, no opportunity for conflicts or erratic maneuvers, in 68.7 percent of the observations. This is one possible explanation of why there was such a small number of observed conflicts and erratic maneuvers.

Of those vehicles that came to a full or rolling stop, 86 percent remained fully on the roadway. In only five instances where there were following vehicles did the mandatory stop vehicle partially use the roadway shoulder. This sample was too small to make any determinations on whether use of the shoulder affects the rate of conflicts or erratic maneuvers.

Illinois Data

Data from Illinois (with State laws similar to the recommendations of the UVC, with the exception of school buses), collected at two sites with no pullout lanes, are presented in table 30. A total of 64 observations were obtained, with tank trucks accounting for 42 of the 64. Table 30 contains the calculation of violation rates, based on the applicable State law. There were no observable instances where school buses failed to, at least, come to a rolling stop. Approximately 44 percent of the school buses came to a rolling stop instead of a full stop. This is in violation of the State regulations.

Table 31 contains the results of the conflicts and lateral position observations. There were no following vehicles, and therefore, no opportunity for conflicts in 54.7 percent of the observations. There were no incidences of locked tires or skidding in Illinois. The conflict and erratic maneuver rates were not substantial in any vehicle type or volume of following vehicle group. Over 76 percent of the vehicles that came to a full or rolling stop remained fully on the traveled way.

Washington Data

Data from Washington (with State laws similar to the recommendations of the UVC), with the exception of hazardous material transporters collected at sites with pullout lanes, are presented in table 32. A total

Table 30. Summary of vehicle type and driver action for observational data collected at sites without pullout lanes in Illinois.

Vehicle Type	Total Observations	Placard Type					Driver Action			Violation Rate of State Law (Percent)
		Red	Green	Black	Orange	Yellow	Full Stop	Rolling Stop	No Stop	
Truck	2	2	0	0	0	0	0	1	1	00.0
Tank Truck	42	40	2	0	0	0	7	15	20	00.0
Passenger Bus	4						0	3	1	00.0
School Bus	16						9	7	0	43.8

Generalized Placard Codes:

Red - Flammable
Green - Non-flammable Gas
Black - Corrosives
Orange - Exposives
Yellow - Oxidizers/Radioactive

Table 31. Summary of observational data at sites without pullout lanes in Illinois.

Vehicle Type	Number of Following Vehicles	Occurrences of Following Veh. Per Observation		Following Vehicle Conflicts*		Position of Mandatory Stop Vehicles	
		Total Observation	Full or Rolling Stop	Severe Braking	Centerline Encroachment	Fully on Roadway	Partially on Shoulder
Truck	0	1	0	0	0	0	0
	1	1	1	1 (1/1)	0	1	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	≥4	0	0	0	0	0	0
Tanker	0	27	16	-	0	12	4
	1	5	3	1 (1/3)	0	1	2
	2	4	1	0	1 (1/2)	1	0
	3	3	0	0	0	0	0
	≥4	3	2	1 (1/11)	1 (1/11)	1	1
Passenger Bus	0	3	3	-	-	3	0
	1	1	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	≥4	0	0	0	0	0	0
School Bus	0	6	6	-	-	6	0
	1	6	6	0	1 (1/6)	4	2
	2	2	2	0	0	2	0
	3	0	0	0	0	0	0
	≥4	2	2	0	1 (1/9)	1	1

* Number in parenthesis represent the number of conflicts per following vehicles (i.e., number of conflicts/number of observed following vehicles).

Table 32. Summary of vehicle type and driver action for observational data collected at sites with pullout lanes in Washington.

Vehicle Type	Total Observations	Placard Type					Driver Action			Violation Rate of State Rule (Percent)
		Red	Green	Black	Orange	Yellow	Full Stop	Rolling Stop	No Stop	
Truck	32	20	6	4	2	0	0	1	31	100.0
Tank Truck	86	78	3	2	0	3	5	2	79	94.2
Passenger Bus	25						20	0	5	00.0
School Bus	32						28	0	4	00.0

Generalized Placard Codes:

Red - Flammable
Green - Non-flammable Gas
Black - Corrosives
Orange - Exposives
Yellow - Oxidizers/Radioactive

of 175 observations were obtained with a more uniform proportion of mandatory stop vehicle types than the other study area. Tank trucks were still predominant with 86 occurrences, with placarded trucks, passenger buses, and school buses representing 32, 25, and 32 observations, respectively. Violation rates were high with placarded trucks at 100 percent and tank trucks at 94.2 percent. Approximately 97 percent of the trucks and 92 percent of the tank trucks did not even come to a rolling stop. Table 33 contains the results of the conflicts and lateral position observations.

The high violation rate in conjunction with 59.4 percent of the observations occurring with no following vehicles contributed to low conflict rates. In addition, the Washington sites consisted of four-lane facilities with pullout lanes. The presence of four lanes reduces the potential for conflicts when compared to two-lane facilities. The existence of four lanes also resulted in modifying the type of data being collected. There were not, for example, any observations made on centerline encroachments or passing maneuvers.

The pullout lane was only used by 14.3 percent of those vehicles which came to a full or rolling stop. In those instances where the mandatory stop vehicles was being followed by one or more vehicles, the pullout lane was used approximately 19 percent of the time. It does not appear, therefore, that the use of the pullout lane is related to the presence of following vehicles. The use of pullout lanes for this study is based on driver characteristics on a four-lane roadway. The rate of pullout lane usage may be much higher on two-lane roads where the mandatory stop driver knows that the only alternative to delay is for following drivers to perform a passing maneuver in the opposing traffic lane.

Analysis of Combined Observational Data

Although the States chosen for study had variations in their manadatory stop laws, there are sufficient similarities to permit comparative analysis. This analysis is concerned with providing insight to two issues:

Table 33. Summary of observational data at sites with pullout lanes in Washington.

Vehicle Type	Number of Following Vehicles	Occurrences of Following Veh. Per Observation		Following Vehicle Conflicts*		Position of Mandatory Stop Vehicles	
		Total Observation	Full or Rolling Stop	Locked Tires (Skidding)	Severe Braking	Fully on Roadway	Partially on Shoulder
Truck	0	22	0	-	-	0	0
	1	5	0	0	0	0	0
	2	3	1	0	2 (2/3)	0	1
	3	0	0	0	0	0	0
	≥4	2	0	0	0	0	0
Tanker	0	46	4	-	-	3	1
	1	21	2	0	0	0	2
	2	6	1	0	1 (1/2)	1	0
	3	4	0	0	0	0	0
	≥4	9	0	0	0	0	0
Passenger Bus	0	14	11	-	-	11	0
	1	7	6	0	1 (1/6)	6	0
	2	2	1	0	0	1	0
	3	0	0	0	0	0	0
	≥4	2	2	0	0	2	0
School Bus	0	22	20	-	-	17	3
	1	4	4	0	1 (1/4)	3	1
	2	2	1	1 (1/2)	0	1	0
	3	2	1	0	0	1	0
	≥4	2	2	0	1 (1/9)	2	0

* Number in parenthesis represent the number of conflicts per following vehicles i.e. (number of conflicts/number of observed following vehicles).

1. What is the overall compliance or violation rate?
2. Do the differences in State laws result in different driver reaction?

The first issue was addressed by combining action for each vehicle type based on similarities in the State laws. Inspection of table 34 indicates that trucks and tank trucks have a violation rate of 97.5 and 70.1 percent, respectively. The violation rate for school buses, presented in table 35, was 36.4 percent. Consideration must be given to sample size even when the observations from the different study areas are combined. The number of observations on passenger buses from Michigan and Ohio was too small to analyze. Tank truck is the only category with a significant number of observations.

Table 34. Summary of placarded truck driver compliance data from Michigan, Ohio, and Washington.

Vehicle Type	Total Observations	Driver Action Full Stop	Rolling Stop	No Stop	Violation Rate
Trucks	40	1	3	36	97.5
Tank Trucks	278	83	59	136	70.1

Table 35. Summary of school bus compliance data from Michigan, Ohio, and Illinois.

Vehicle Type	Total Observations	Full Stop	Rolling Stop	No Stop	Violation Rate
School Buses	44	28	16	0	36.4

The second issue regarding driver action in the different States was analyzed using the chi-square test. The observations on trucks and tank trucks were combined for Michigan, Ohio, and Washington and compared with those from Illinois. The difference is that Michigan, Ohio, and Washington are in basic agreement with the FMCSR, requiring stops by placarded vehicles at crossings with active devices, while Illinois is not. The null hypothesis being tested in table 36 is that the frequency of truck and tank truck driver action (i.e., full, rolling, and no stop) is the same for Michigan, Ohio, and Washington as it is for Illinois.

Table 36. Chi-square analysis for trucks and tank trucks.

	Full Stop	Rolling Stop	No Stop	Total
MI, OH, and WA	84	62	172	319
IL	7	16	21	44

Chi-square = 6.03
df = 2
95% Critical Value = 5.99

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

Summary of Conclusions from Observational Data

The frequency of conflict and erratic maneuvers was not sufficiently large to permit any conclusions or to justify extrapolation to a nationwide basis. To obtain a sufficiently large data set, a much larger data collection effort would need to be undertaken.

The violation rate, where drivers do not come to a full stop, was high with regard to trucks (97.5 percent) and tank trucks (70.1 percent). The violation rate of school buses was lower (36.4 percent) than trucks and tank trucks. While these observations are interesting, only tank trucks had a sufficiently large sample to provide credibility to the conclusions. The high violation rate provides one explanation of why difficulty was encountered in establishing the threshold speed based on the analysis of accident speed relationships. If vehicles required to stop do not stop, their accident speed characteristics would be the same as trucks not required to stop. Therefore, the high violation rate and the high degree of accident-speed association between vehicles required and not required to stop support the conclusion that vehicles governed under the mandatory stop provisions are not complying with the appropriate regulations.

If the compliance rate was higher, there would be a good possibility that observed differences between the train-involved accident characteristics of the general truck population and the regulated vehicles would be even more pronounced. This would be especially true in those accidents where vehicles traveling less than 10 mi/h (16 km/h) were struck by the train. Similarly, an increase in nontrain-involved accidents could also be expected with an increase in the compliance rate.

CHAPTER 4 - DETERMINATION OF DELAY, FUEL CONSUMPTION, AND POLLUTION CONSEQUENCES

Analysis Methodology

Estimates of delay, fuel consumption, and air pollution resulting from the mandatory stop requirement at all active crossings were obtained by using the NETSIM model. This model was developed by the FHWA as a generalized tool to analyze the impact of different traffic control strategies for roadway networks. Since 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 was concerned with estimating the impact of regulated vehicles when the active devices were not activated. The presence of trains was not, therefore, 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 strategy permitted the main street traffic to flow unimpeded unless intentionally stopped at the crossing. While this strategy provided a dependable simulation of a railroad crossing, it is inherently assumed that vehicles slow down at a crossing only for the arrival of a train. The actual speed of vehicles over a crossing are, however, dependent upon the defensive driving behavior of the motorists and the condition of the crossing surface. Assuming that the vehicles slow down only for a train, however, does not affect the accuracy of the results since comparisons are being performed between conditions with and without the mandatory stop regulations. The same basic assumptions are, therefore, being applied to both situations.

The vehicles making a stop at the crossings are creating short-term blockages. This blockage event is analogous to a bus stopping to load or discharge passengers. This analogy was used to model bus stops prior to the railroad node. The vehicle, acting as a bus, is required to stop and dwell for an amount of time which is assumed to reflect the time required for a vehicle to stop and check the tracks for oncoming trains. The resultant traffic blockage and associated operational and environmental impacts were assessed from the effects of the stop on the simulated traffic.

The railroad-highway crossing situation was modeled in a small network. Within this network were three railroad crossing situations and two intersections. Each of the railroad crossing situations represented a different geometric condition. These conditions included:

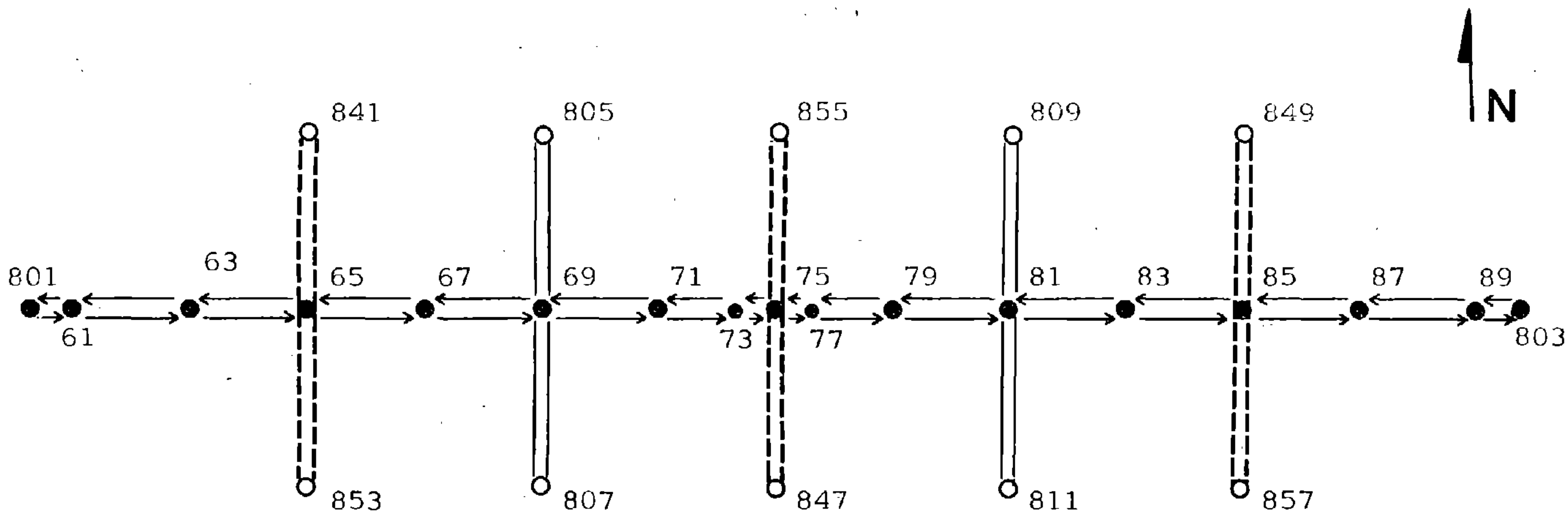
- Two-lane roadway (one lane in each direction)
- Two-lane roadway (with pullout lanes)
- Four-lane roadway (two lanes in each direction).

These sitations were represented by varying the number of lanes on the associated link description. No left turns were permitted throughout the network so that traffic on any link was not influenced by the opposing traffic flow. The links were sufficiently long to enable traffic to reach free flow conditions before encountering the next railroad crossing. table 37 describes the directional link configurations and node descriptions that are depicted in figure 14.

Table 37. Node descriptions and directional link configurations.

Nodes		
Railroad Crossing	Intersection	Link Description
65	69	61-81, one lane, eastbound
75	81	73-77, bus stop lane, eastbound
85		81-89, two-lanes, eastbound
		89-69, one lane, westbound
		77-73, bus stop lane, westbound
		69-61, two-lanes, westbound

Traffic was input to the network at the nodes numbered with 800's. The distances between the nodes served as the links of traffic. Varying volumes of traffic were input in order to represent a full range of ADT



All distances between east and west bound nodes = 1,200 feet except:

71-73 and 79-77 = 925 feet
73-75 and 77-75 = 275 feet

Figure 14. Test section for mandatory stop NETSIM model (1 ft = 30 cm).

classifications. Varying percentages of trucks were also input in order to reflect the impacts of the stopping and starting of heavy vehicles. The percent mix of hazardous material transporters applicable for the NETSIM analysis was different than that which was required for the accident analysis. The estimate required for the accident analysis was based on total truck registration, including pickups, panels, and walk-ins. This was required because the yearly data on truck registrations, available from the highway statistics publications, are inclusive of all truck types. [31] For the NETSIM analysis, however, an estimate of hazardous material transporter mix, based only on the medium to heavy truck population, was required. This need was present because the NETSIM analysis was being performed on, and expanded by, categories of truck mix obtained by truck classification counts. Truck classification counts typically include only medium to heavy weight trucks.

The percentage of vehicles transporting hazardous materials was estimated from the 1977 Truck Use and Inventory Survey.[32] This survey estimated that there were 309.8 thousand vehicles transporting hazardous materials in sufficient quantitites to require a placard under the Code of Federal Regulations, title 49, Transportation. The same reference estimated that there were 4,062.3 thousand trucks, excluding pickups, panels, and walk-ins. These estimates yield a 7.6 percent mix of medium to heavy trucks transporting hazardous materials.

Simulated hazardous material transporters (buses) were input to the network in proportion to the 7.6 percent mix of medium to heavy trucks with bus stops established only in the westbound direction. The eastbound direction was, therefore, simulating a condition of no stops with the westbound direction, with the established bus stops, simulating the mandatory stop condition. The result of the differences exhibited between the eastbound and westbound traffic permits a comparison of the impact of the mandatory stop requirement versus the no stop situation, under similar geometrics. The configuration of the model is forcing every vehicle designated as a hazardous material transporter to stop at the railroad crossings when traveling westbound. This is essentially simulating a 100 percent compliance rate which is not what actually takes place. The NETSIM model is, therefore, idealized in that full compliance is assumed.

The impacts of the mandatory stop requirement were determined by simulating the impacts associated with the movement of traffic over the links, both upstream and downstream from the crossing. Since the comparisons of impact were made between simulated differences, there was no need to consider the specific fuel and emission features of the vehicle fleet. The consumption and emission characteristics were relative with the calculated difference being the measure of interest.

Model Verification and Calibration

The assumptions made in configuring the NETSIM were tested to ascertain that the simulation model was capable of replicating mandatory stop operations. This was accomplished by performing repetitive simulation runs and comparing the output of these runs with actual field data. Comparisons between the simulated and actual data consisted of 1) input-output checks to verify that the data was properly entered and returned, and 2) vehicle traces to verify that vehicles were properly advanced in simulated time. Each simulated run was made with a different random number seed to alter the stochastic processes within the model. Variables such as volume, speed, percent trucks, and number of hazardous material transporters were varied as necessary to get a representative cross section of traffic situations.

Field data were collected, in 10-minute increments, for a total of 12 man-hours at 2 locations in Michigan. Measured distances were established, inclusive of the railroad crossing, at each site consisting of 350 feet (106.7m) at one site and 950 feet (289.6m) at the other. Total vehicle counts, classification counts, and travel time by vehicle type were obtained. Two NETSIM networks were constructed, one representing a 350-foot (106.7m) section and the other a 950-foot (289.6m) section of two-lane roadway. Simulation runs were made with the eastbound direction simulating a no mandatory stop condition and the westbound simulating mandatory stops.

The results of the final calibration runs are presented in figures 15 and 16 for the 350- and 950-foot (106.7m and 289.6m) traps, respectively. The simulated points on the plots are the averages of 30 points for each of the five-volume increments. The 30 points were obtained by running the model five times on each of the five-volume increments for six 10-minute intervals (1-hour). Inspection of the graphs indicates that the simulated speeds are approximately 1 to 2 mi/h (1.6 to 3.2 km/h) higher than the field measurements. A difference this small can be due to field measurement error. Since relative differences between the no stop and mandatory stop conditions are being analyzed, this error will not influence the results.

Inspection of the graphs also reveals that field measurements should have been obtained at additional sites with a wider range of volumes. The data that was obtained consisted of observations in the lower volume ranges. Comparison of the lower volume trend line with that of the westbound direction, for both the 350- and 950-foot (106.7 and 289.6m) traps, implies that the simulation is replicating the general behavior.

Simulation Results

The NETSIM model was run to simulate four categories of truck volume (1 to 4, 5 to 6, 7 to 10, and greater than 10 percent) and four categories of average daily traffic (ADT) (0 to 1000, 1001 to 5000, 5001 to 10,000, and greater than 10,000). On the truck mix this was accomplished by performing the simulation on 3, 5, 8, and 12 percent mixes of truck volumes. The values obtained for these runs were assumed to be representative of their entire respective range. A similar strategy was performed with regard to the ADT ranges. The actual volumes used in the model varied, according to the NETSIM algorithm, but were initially set by assuming that 50 percent of the highest volume within that range would occur during an 8-hour period. A simulation speed of 45 mi/h (72 km/h) was chosen as being the speed best representative of both urban and rural conditions.

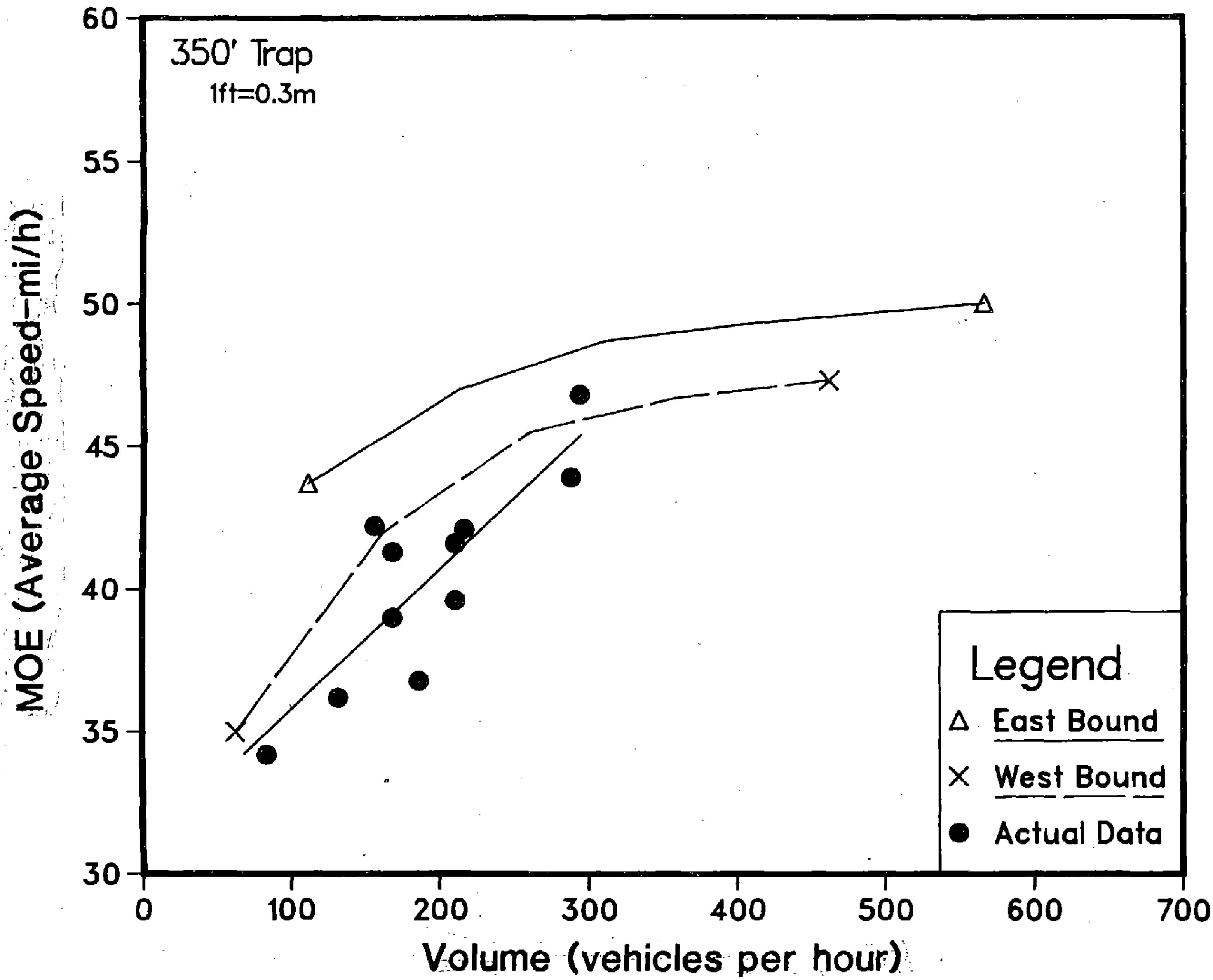


Figure 15. NETSIM calibration results for a 350 foot (106.7m) trap.

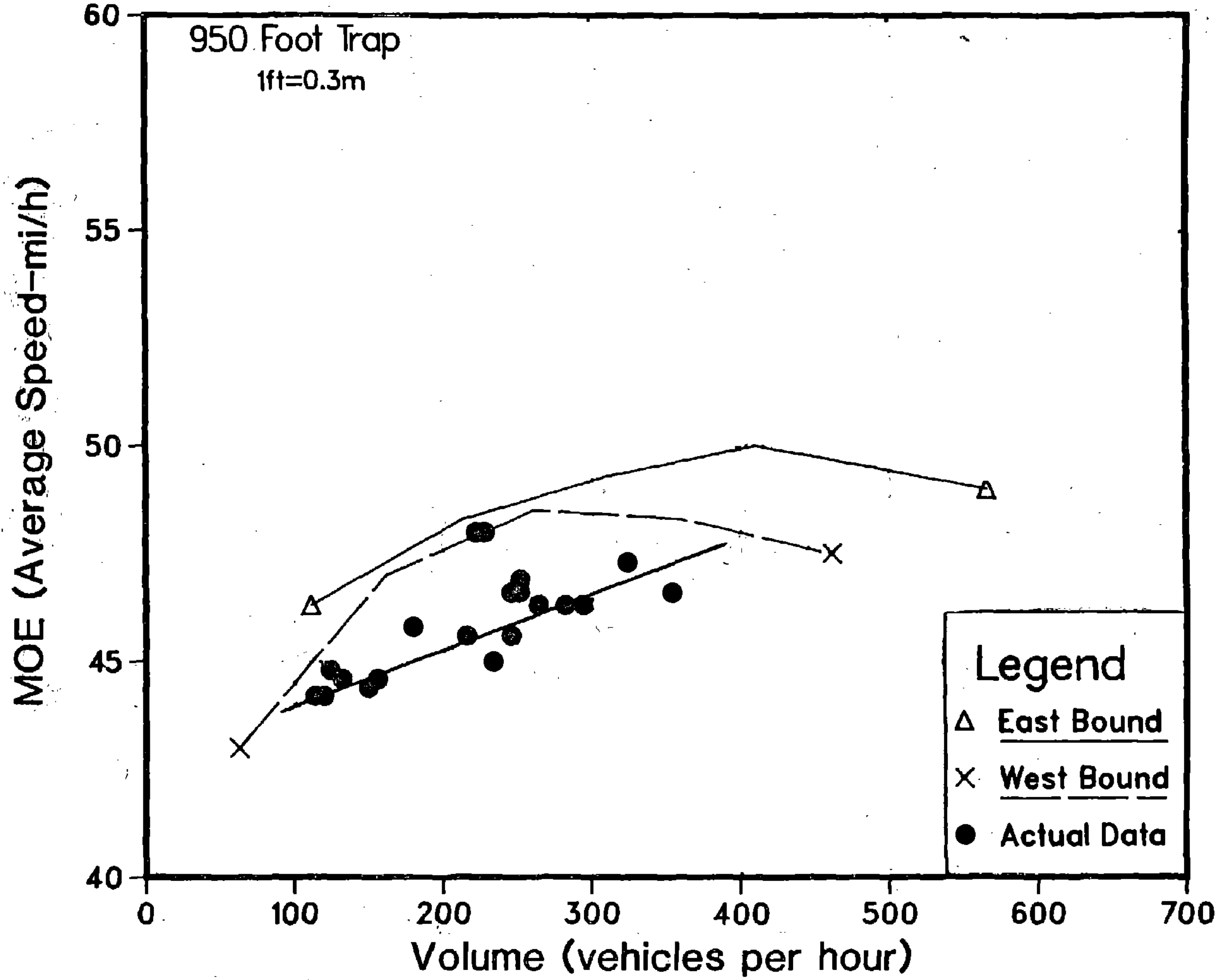


Figure 16. NETSIM calibration results for a 950-foot (298.6 m) trap.

In those instances where the simulation was performed on low roadway volumes in conjunction with a small percent truck mix, a default value of one hazardous material transporter per simulation hour was used. This was performed to permit a simulation of their effect without over emphasizing their impact.

The results of the simulation for delay and fuel consumption, for different categories of truck mix and volume, are contained in appendix D of volume II. As expected, multilane facilities are the most efficient in reducing delay and conserving fuel with two-lane facilities without pull-out lanes being the least efficient.

The primary purpose of performing the NETSIM analysis was to obtain an estimate of the savings, or differences, in delay, fuel consumption, and noxious emissions between vehicles governed and not governed under 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, ADT, and percent truck mix. The expansion was performed by using the number of working days (260) in a year. The number of working days 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 number of roadway lanes, ADT, and percent truck mix. The estimate of the number of crossings in each category were obtained by performing a stratification of 2,974 randomly selected crossings, of the total 53,207 crossings with active devices (excluding highway signals). Table 38 presents the nationwide estimates of the annual delay, fuel consumption, and noxious emissions conserved by not requiring stops at crossings with active devices when unactivated. Tables depicting the intermediate steps, in addition to the simulation results, are contained in appendix D of volume II.

Table 38. Estimates of annual, nationwide, excess consumption resulting from mandatory stops at active crossings when unactivated.

Excess Delay hours/year	Excess Fuel Consumption[1] (gallons per year)	Excess Noxious Emissions (tons/year)[2] HC	CO	NO_x
1,483,000	12,267,000	9,000	144,000	19,000

1 - 1 gallon = 3.8 liters
2 - 1 short ton = 0.9 tonne

Conclusions of NETSIM Analysis

The NETSIM simulation was performed by placing bus stops prior to each railroad crossing in only one direction. Buses in the same proportion as the mix of hazardous material transporters (7.6 percent) were used to simulate trucks in both directions. One direction was, therefore, representative of the current FMCSR and the other that of the recommendations of the UVC. Differences between the two directions provided an estimate of the excess consumption of delay, fuel, and noxious emissions.

There were a number of inherent assumptions (used in performing the NETSIM model) that must be considered when interpreting the results:

- The model simulated the impact on the traffic stream of hazardous material transporters stopping at railroad crossings. The impacts of school and passenger buses were not included in the nationwide estimates.

- The model was run on single truck volume estimates which were assumed to be representative of their respective volume range. This was necessary to keep the number of simulation runs within reasonable limits and to facilitate expanding to nationwide totals.

- Train arrivals were not simulated. The obtained estimates are not, therefore, accounting for the instances when vehicles would need to stop for trains occupying the crossing.

The NETSIM simulation indicates that if vehicles are not required to stop at crossings with active devices when unactivated, there would be an annual nationwide savings of 1,483,000 hours of delay, 12,267,000 gallons (46,614,600 liters) 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 based on the number of working days (260) in a year. Since there is considerable truck movement on weekends and, since school and passenger bus movements were not simulated, the NETSIM results are conservative.

CHAPTER 5 - ACCIDENTS ATTRIBUTABLE TO SIGNAL NONOPERATION

Changing the mandatory stop regulation to exclude stops at crossings with active warning devices when the devices are not activated places the primary responsibility of recognizing the presence of a train on the detection system. If changes to the regulation occur, and if the active warning system fails for any reason, there will be an increase in the possibility of train-involved accidents. This is especially true in those accidents where the vehicle strikes the side of the train. The magnitude of this increase will be dependent upon how often the signal system does not operate in the actual presence of a train.

Crawford performed a study of those accidents which, during 1975 and 1976, were reported as being caused by signal nonoperation.[8] Only 50 of the alleged 261 accidents reported as attributable to signal nonoperation actually involved signal malfunction. Twenty-four of these accidents were determined to be the result of actual equipment malfunction, 19 to human error, and 7 to vandalism. In addition, another 57 accidents were determined to be caused by the operation of insulated railroad equipment, which is not designed to activate the signals. There were several reasons for the erroneous reports, such as, reporting nonoperational devices when the crossings were equipped with passive devices, or reporting them as not operating when, in fact, they were.

Johnston carried the work of Crawford one step further by making an estimate of the accidents caused by equipment malfunction and applying this estimate to nationwide data.[9] Johnston conservatively estimated that 20 percent of the reported nonoperational device accidents were actually due to equipment malfunction. When this was applied to the number of yearly accidents, it was determined that only 0.3 percent of all yearly accidents occurring at crossings with active devices were the result of equipment malfunction, as presented in table 39.

Johnston's calculations were performed to estimate the number of accidents which could be attributed only to equipment malfunction. These estimates were adjusted to include all reasons for signal nonoperation.

This was done because it makes no difference to the driver involved in an accident if the signal did not operate due to vandalism, human error, or the fact that the insulated railroad unit was not designed to activate the warning system. The reasons behind the signal nonoperation were of no concern in this study, only the fact that they did not operate. Interpreting Crawford's work from a different perspective reveals that 107 of a possible 261 accidents were either directly or indirectly the result of the warning system not being in the active state when railroad equipment was present. Forty-one percent, therefore, of all the accidents studied by Crawford actually involved signal nonoperation. The remaining 154 alledged signal nonoperation accidents were erroneously reported.

Table 39. Estimate of yearly accidents resulting from equipment malfunction occurring at crossings with active warning devices. (all vehicle types)

Year	Equipment Failure Accidents	Percentage
1979	15	0.3
1980	16	0.3
1981	10	0.2
1982	10	0.3
1983	9	0.3

(Source: [9], p. 3)

Johnston based his yearly estimates of accidents involving equipment malfunction on a 20 percent reporting accuracy rate. If the estimate of 41 percent for all accidents involving signal nonoperation is used in lieu of 20 percent, it represents approximately two times the percentage used by Johnston. An estimate of the total yearly train-involved accidents resulting from signal nonoperation, regardless of the cause of nonoperation, is, therefore, approximately two times greater than the 0.3 estimated by Johnston as being caused by equipment malfunction alone. The result is that less than 0.70 percent of yearly train accidents can be expected to involve signal nonoperation.

It should be noted that this estimate is very high when compared with the results of the analysis performed for this study. Of all of the 680 accidents investigated, both verified and unverified, there were 13 accidents reported as involving nonoperating signals. Ten of these incidents occurred at crossings with passive warning devices, and one of the three accidents at active crossings occurred while a flagman was directing traffic. This study, therefore, identified only 2 of the possible 13 reported accidents (or 15 percent for the total 9-year analysis period), as actually being caused by signal nonoperation. The reasons for the lower incidence of signal nonoperation accidents with regulated vehicles could be due to 1) the driving expertise and characteristics of professional truck and bus divers, and 2) the effect of the mandatory stop regulations. To address the first consideration it would be necessary to perform an analyses similar to Crawford's only on those accidents involving trucks and buses. This would yield a better estimate of any expected increase in accidents than an estimate based on the total accident population. Since this estimate was outside the context of this study, and since the second factor was a possibility, 0.70 was used as the estimate of possible accident increase due to signal nonoperation.

Conclusion of Accidents Attributable to Signal Nonoperation

The total number of train-involved accidents was assumed to increase due to signal nonoperation by 0.70 percent per annum, if currently regulated vehicles are not required to stop at crossings controlled with active devices when not activated. Applying this increase to the previously estimated change in train-involved accidents (table 20) results in the net percent change presented in table 40. This table indicates that train-involved accidents will decrease by changing the current FMSCR regulation.

Table 40. Estimated net percent change in train-involved accidents.

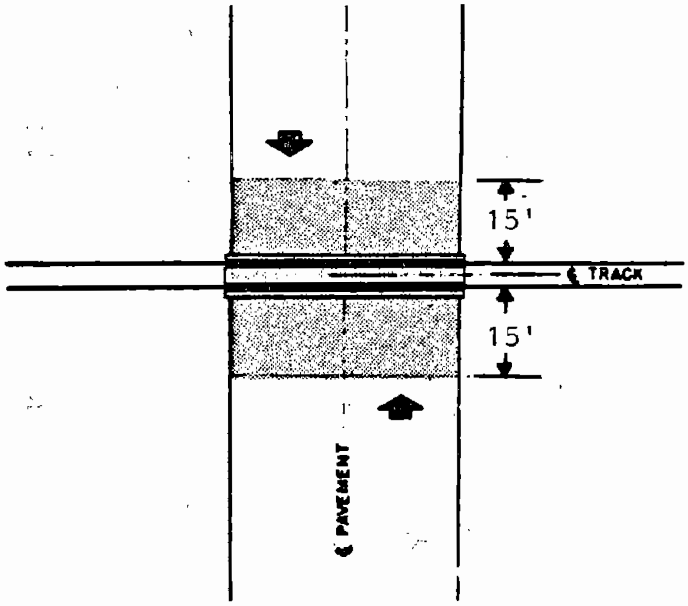
Category	Hazardous Material Transporter	School Bus	Passenger Bus
Estimated Change in Accident Totals from (table 20)	- 3.3	- 11.5	- 18.1
Estimated Increase Due to Signal Nonoperation	0.70	0.70	0.70
Net Change in Accidents	- 2.6	- 10.8	- 17.4

CHAPTER 6 - MINIMUM WARNING TIME NEEDS

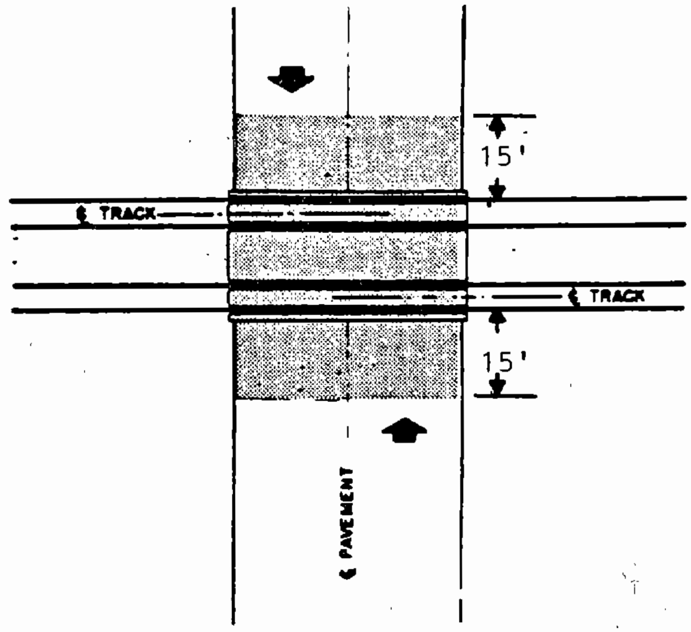
Most State laws and the Federal Motor Carrier Safety Regulation 49CFR Section 392.10 require vehicles transporting bulk hazardous materials to stop at crossings equipped with active warning devices when the devices are not activated. Furthermore, to reduce the potential for stalling on the tracks, the drivers are prohibited from shifting gears while proceeding over the crossing. The drivers are required, therefore, to select a low gear, with maximum speed ranges of approximately 3 to 8 mi/h (4.8 to 12.8 km/h) and maintain that gear past the crossing. It can take as long as 18 seconds for a truck with a 55-foot (16.8 m) trailer stopping 15 feet (4.6 m) before a single track crossing intersects the roadway at 90 degrees to clear the crossing. This estimate of clearance time does not include the perception and reaction time required by the driver, nor does it take into consideration the extra time required for nonoptimal physical conditions, such as roadway grades, multiple tracks, and obtuse crossing angles. These considerations, plus the increasing use of multiple trailers, can increase the amount of time for the trailer to clear the tracks to well over 20 seconds.

The Manual on Uniform Traffic Control Devices (MUTCD) requires that a minimum of 20 seconds be provided to motorists before the arrival of a train.[10] If it takes longer than 20 seconds for a vehicle to cross the tracks, and if the crossing action is initiated just as the signals are activated by a train, the vehicle will be struck by the train, even if the driver complies with all laws.

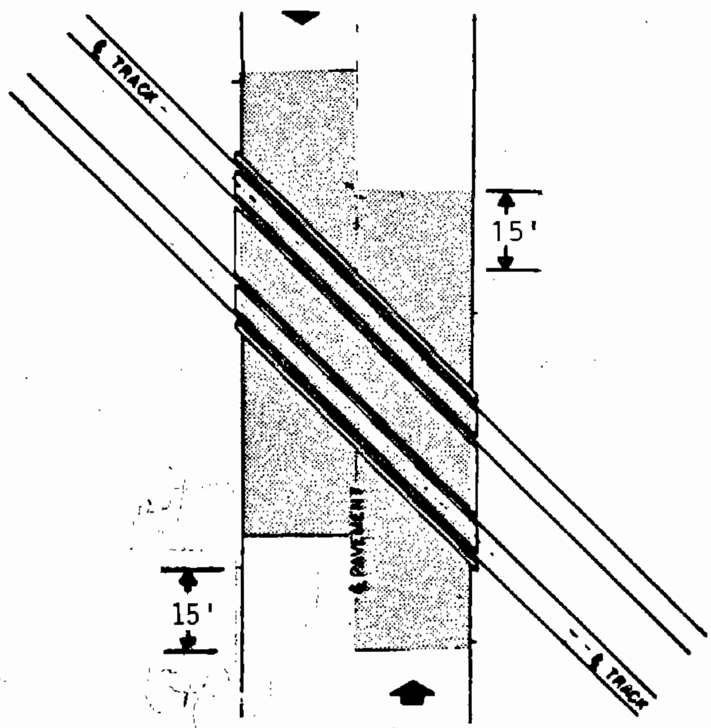
The purpose of this task was to obtain estimates of the minimum warning time required for different combinations of vehicle lengths, roadway grades, and geometric track configurations. This was accomplished by identifying a hazard zone which extended 15 feet (4.6 m) on either side of different track combinations, as presented in figure 17, and performing a computer simulation of the appropriate clearance times. Fifteen feet (4.6 m) was selected as the distance before the crossing due to the FMCSR 392.10 requiring stops to "within 50 feet (15.2 m), and not closer than 15 feet (4.6 m), to the tracks." The addition of 15 feet (4.6 m) after the crossing was done to provide a margin of safety to compensate for differ-



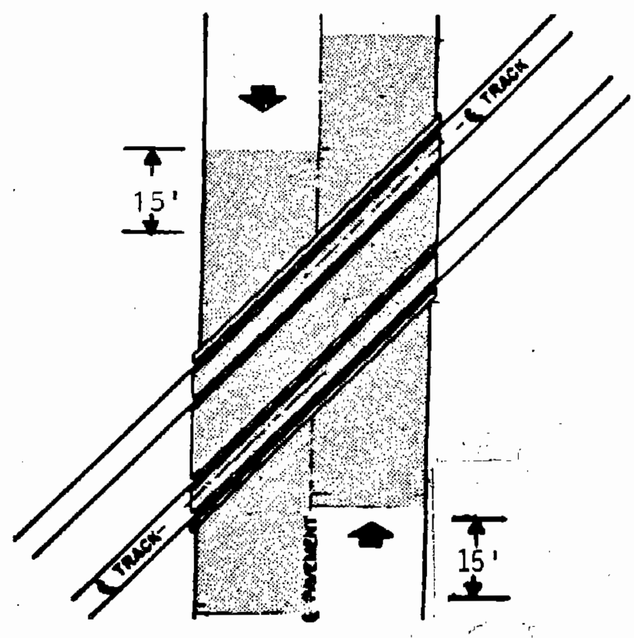
Single Track
(right angle)



Double Track
(right angle)



Double Track
(acute angle)



Double Track
(obtuse angle)

Figure 17. Track and hazard zone configuration.

ent driver characteristics, truck acceleration capabilities, and for those vehicles which stop at a distance greater than 15 feet (4.6 m) from the crossing.

Simulation Procedure

The simulation was performed at the University of Michigan Transportation Research Institute (UMTRI) by using a method for predicting truck acceleration performance, under a variety of conditions. This method was developed by UMTRI during the FHWA project "Truck Tractive Power Criteria" (Project No. DTFH61-83-C-00046). The applications for this project were limited to typical highway tractor-trailer combinations in the fully loaded condition with the following assumptions:

- Single, double, and triple vehicle combinations, with overall lengths of 65, 70, and 115 feet (19.8, 21.3, and 35 m), respectively, were considered. The gross vehicle weight was 80,000 pounds (36,287.4 Kg).
- Vehicles are assumed to stop 15 feet (4.6 m) prior to the tracks and clear the hazard zone when the rear most portion of the trailer is 15 feet (4.6 m) past the far rail.
- The tractor has a manual transmission and is started in a low gear and remains in that gear until it has cleared the crossing.
- Roadway upgrades are assumed to exist in the range of 0 to 13 percent in the vicinity of the crossing.

Simulation Results

Figure 18 demonstrates that the maximum velocity attainable on flat grades can vary over a substantial range, depending on the gear selected. The variation in the maximum velocity is reduced on steeper grades where there are fewer choices for a reasonable gear. For example, depending upon the gear selected, a truck on a flat grade can vary in the maximum attainable velocity from less than 4 to more than 7 mi/h (6.4 to 11.2 km/h). The restrictions in gear selection, however, imposed by a grade of 6 percent, result in a maximum attainable velocity of less than 4.5 mi/h

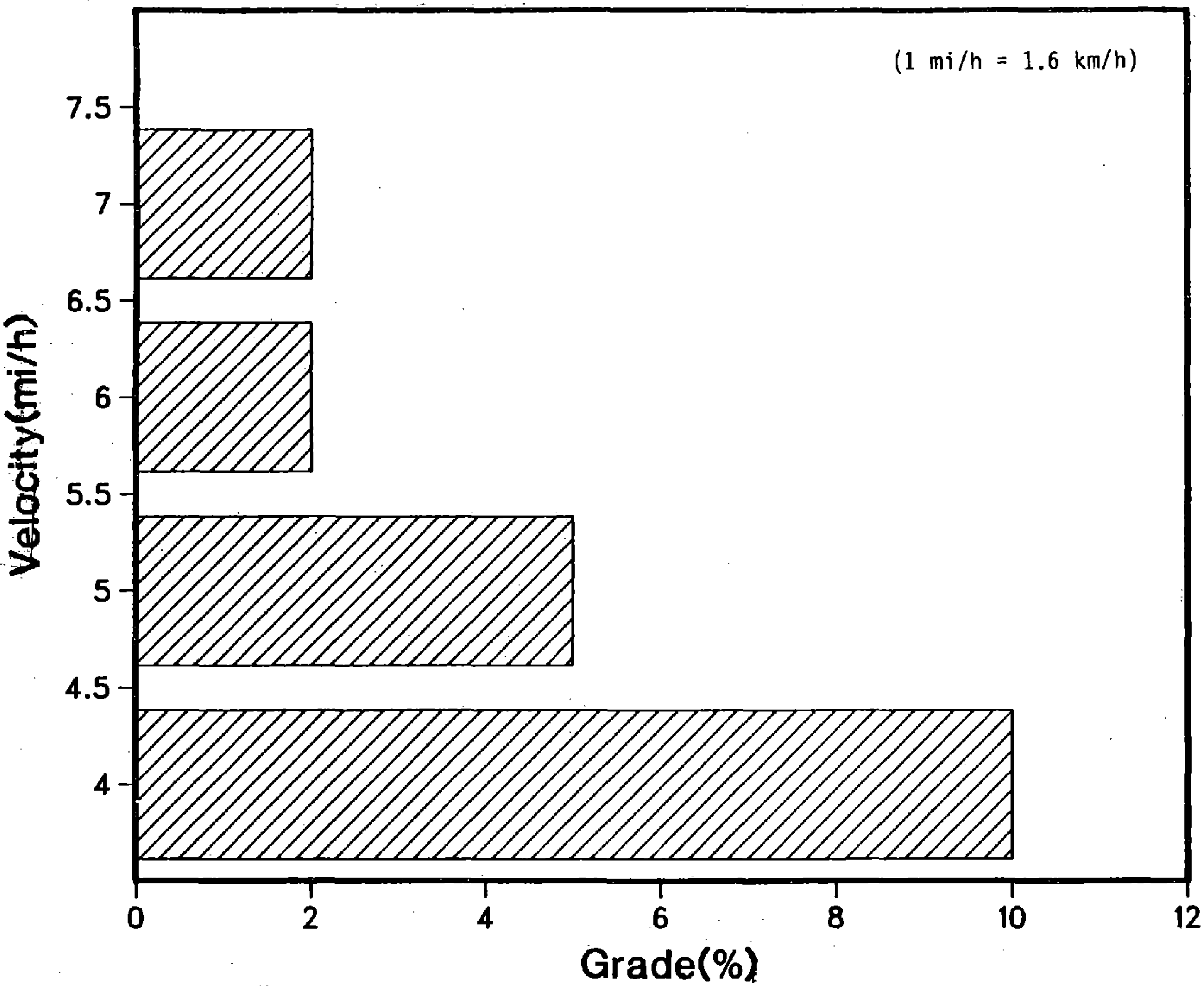


Figure 18. Range of maximum truck speeds as a function of grade.

(7.2 km/h). The maximum attainable velocity directly affects the amount of time required for a vehicle to clear the hazard zone.

The range of clearance times reflects the possible variations in driver gear selection practice. The times required for semitrailers, doubles, and triples, presented in tables 41, 42, and 43, respectively, were determined by selecting the speed assumed to be used by the majority of drivers for the given roadway grade. Speeds on flat grades approximate 6 mi/h (9.6 km/h) while those on steeper grades approximate 4 to 5 mi/h (6.4 to 8.0 km/h). The shortest times for each of the grade ranges in the tables can be interpreted as reasonable estimates of typical vehicles and driver practices on the indicated grade. The longest times, listed for grades of 11 to 13 percent, apply not only to rail-highway crossings with that grade condition, but may also be interpreted as the prevailing clearance times for that portion of the truck population having gear ratios of approximately 15:1 available.

Considering the catastrophic consequences of train accidents, the maximum times shown in the tables (for the 11 to 13 percent grades) may be the best choice for design of warning devices at rail-highway grade crossings, regardless of the grade of the highway. Although this choice is conservative in comparison to the performance of a majority of the tractor-trailers encountering any given rail crossing, it will accommodate the slower vehicles that exist within the overall truck population. It should be noted that the values in the tables do not include any perception and reaction time. A complete description of the simulation procedure and rationale is presented in appendix E of volume II.

Table 41. Clearance times (seconds) for 65 ft. tractor-semitrailer*.

Grade (%)	Length of Hazard Zone (Feet)								
	35'	45'	55'	65'	75'	85'	95'	105'	115'
0-2	11.5	12.4	13.2	14.1	14.9	15.8	16.6	17.5	18.3
3-5	14.4	15.5	16.6	17.7	18.9	20.0	21.2	22.3	23.5
6-10	16.6	18.0	19.4	20.7	22.1	23.5	24.8	26.2	27.5
11-13	20.0	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7

* 1 foot = 0.3048 meters

Table 42. Clearance times (seconds) for 70 ft. doubles*.

Grade (%)	Length of Hazard Zone (Feet) 35'	45'	55'	65'	75'	85'	95'	105'	115'
0-2	11.9	12.8	13.6	14.5	15.4	16.2	17.1	17.9	18.8
3-5	14.9	16.1	17.2	18.3	19.5	20.6	21.8	22.9	24.0
6-10	17.3	18.7	20.0	21.4	22.8	24.1	25.5	26.9	28.2
11-13	20.9	22.6	24.3	26.0	27.7	29.4	31.1	32.8	34.5

Table 43. Clearance times (seconds) for 115 ft. triples*.

Grade (%)	Length of Hazard Zone (Feet) 35'	45'	55'	65'	75'	85'	95'	105'	115'
0-2	15.8	16.6	17.5	18.3	19.2	20.0	20.9	21.8	22.6
3-5	20.0	21.2	22.3	23.5	24.6	25.7	26.9	28.0	29.1
6-10	23.5	24.8	26.2	27.5	28.9	30.3	31.6	33.0	34.4
11-13	28.6	30.3	32.0	33.7	35.4	37.1	38.8	40.5	42.2

*1 foot = 0.3048 meters

Calibration of Simulation Results

Data was collected at three locations in Michigan for use in calibrating the simulation results. All of the locations used for field data collection consisted of zero grades. Attempts were made, while collecting the operational data in Michigan, Ohio, Washington, and Illinois, to locate crossings that were on roadway grades for collection of additional data. Since the presence of roadway grade is not noted on the FRA inventory, the only way of identifying appropriate crossings was by observing them in the field with assistance from State personnel. No crossings on grades with sufficient truck volumes were located. The calibration results are, therefore, restricted to crossings at zero grade.

Observations on time versus distance were made on a total of 77 truck-trailers that came to a complete stop prior to the crossing. It is not known what percent of the vehicles were loaded, or for those that were loaded, the gross vehicle weight. In addition, all of the observations were on single bottom truck-trailer combinations.

The results of the calibration are presented in figure 19. A 95 percent confidence band constructed around the simulated results indicate that no field observations exceeded the upper time limit. This suggests that the model provides a properly conservative estimate of the actual time required for truck-trailers to clear the railroad crossing hazard zone. If a perception and reaction time is added to all of the simulation results then all of the field observations would fall below the simulation values.

Conclusions of Minimum Warning Time Needs

The results of the warning time analysis indicate that further analysis should be performed on the sufficiency of current advance warning time criteria. It is recognized that the minimum warning time of 20 seconds is adjusted at crossings with steep approaches or where extremely long vehicles are apt to cross. The increasing occurrence of double and triple bottom truck trailers could, however, result in many previously adequate advance warning times now being inadequate.

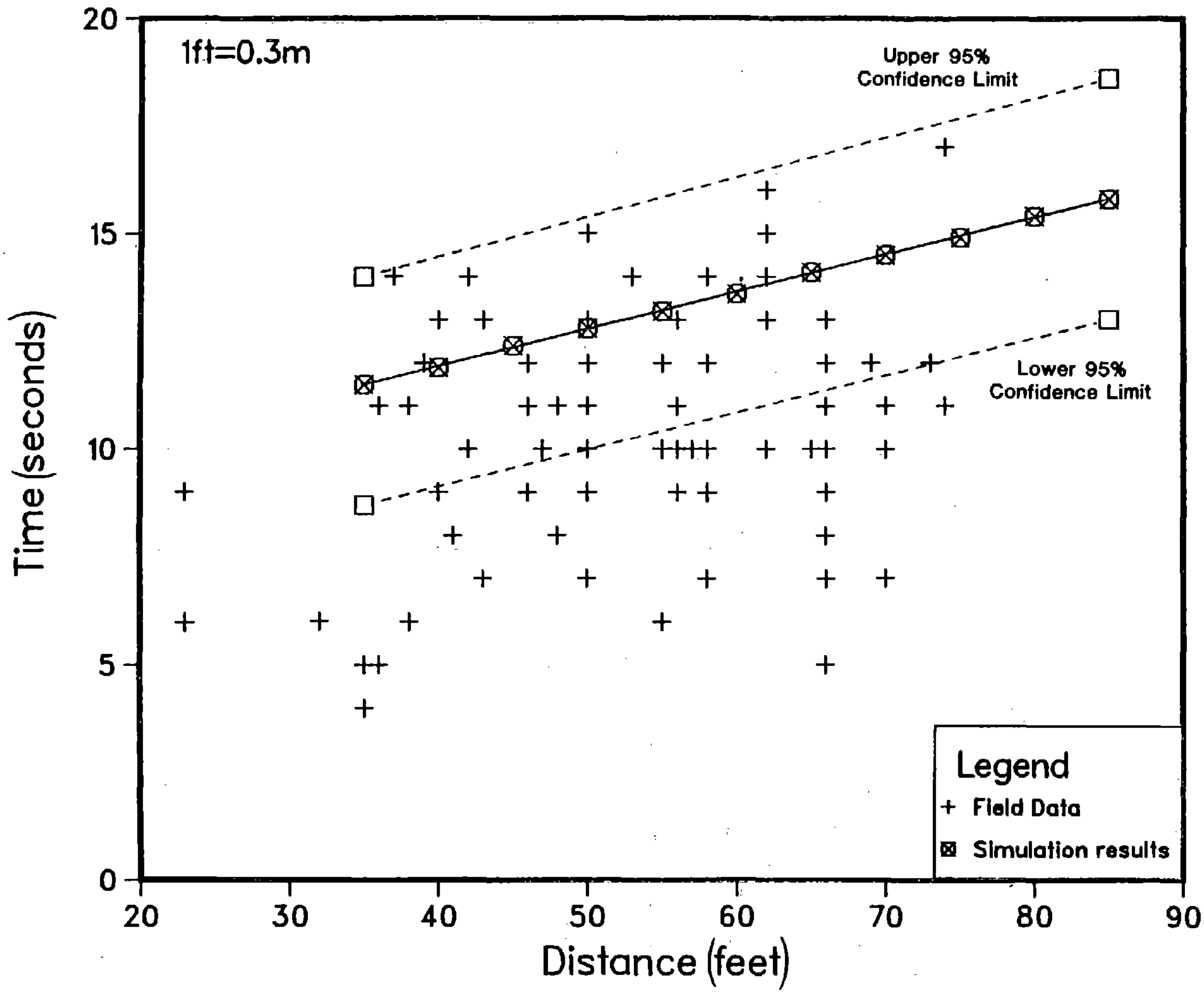


Figure 19. Calibration of minimum warning time analysis.

CHAPTER 7 - ESTIMATES OF PULLOUT-LANE CONSTRUCTION AND MAINTENANCE COSTS

One area of potential savings by eliminating the requirement of mandatory stops at crossings with nonactivated active warning devices are the construction and maintenance costs associated with the installation of pullout-lanes. These lanes (also termed truck and bus stopping lanes), are installed to 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. Typical design standards for the construction of truck pullout lanes are presented in figure 20.

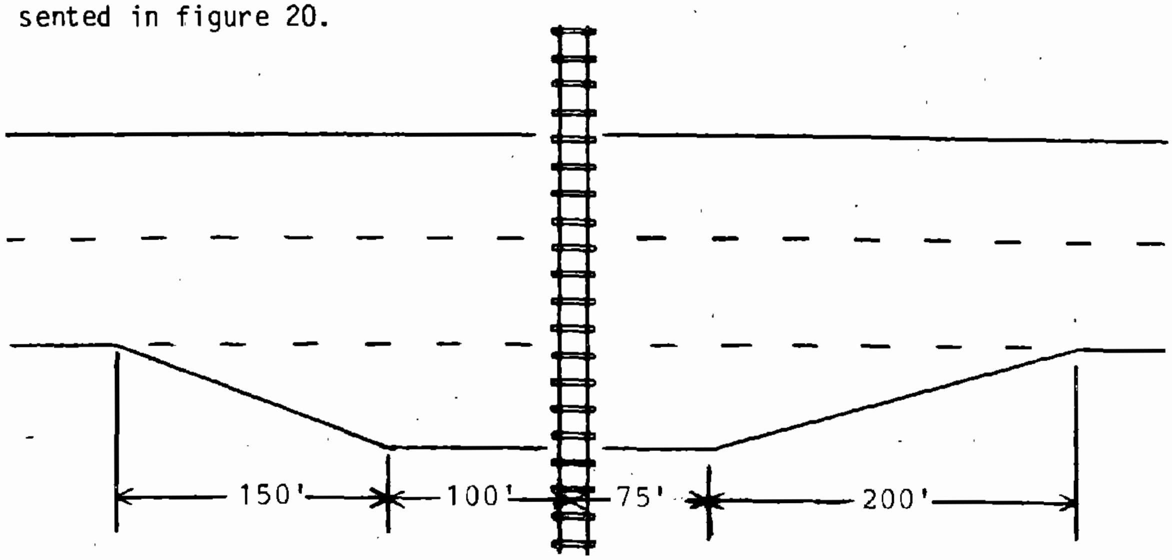


Figure 20. - Typical pullout-lane specifications.

The costs associated with the construction of pullout lanes includes more than just the installation cost of the pullout-lane itself. There are costs associated with extending the crossing surface over the rails, extending the gate arms, when present, and often times, converting the mast-mounted flashing lights to cantilevered lights. The overall costs associated with each of these items is dependent upon the frequency of occurrence and the number of tracks involved. Efforts were extended in three primary directions to determine the costs associated with pullout lanes. These efforts were 1) estimating the total number of pullout lanes, 2) estimating yearly installations and physical features, and 3) obtaining cost estimates.

Estimating the Total Number of Pullout Lanes

The FRA National Inventory was searched to obtain an estimate of the total number of crossings nationwide that were coded as having pullout-lanes. This search of the current records, with no restrictions, revealed that 2,581 crossings are coded as having truck pullout lanes. The difficulties, however, in locating sites with pullout-lanes for the collection of operational data 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 664 crossings being identified as existing on two-lane facilities with truck pullout-lanes. This estimate will probably be lower than what actually exists since there are some multiple-lane roadways with pullout lanes. This was found to be the case in the State of Washington. It is likely, however, that the vast majority of installations will be on two-lane, two-way facilities that pose passing restrictions without a pullout-lane.

Estimating Yearly Installations and Physical Features

Established procedures for updating physical or operational changes at a crossing exist for both the States and operating railroads. Whenever changes take place, such as installation of new warning devices or the installation of pullout-lanes, the States and railroads work cooperatively to inform FRA of the changes. FRA uses the changes to create a new, or current, inventory listing. The condition of the crossing prior to the change is maintained for a number of years to provide a history of the crossing. Due to the large number of crossings, and inventory updates, the history files are not, in all cases, maintained prior to 1980.

The information in tables 44 and 45 presents the analysis of 78 crossings randomly selected for the 664 previously identified crossings. The current and historic files of these 78 crossings on two-lane

Table 44. Summary of the highest priority warning device sample sites with pullout lanes.

Number of Tracks	Flashing Lights Mast Mounted	Flashing Lights Cantilevered	Gates W/Flashing Lights Mast Mounted	Gates W/Flashing Lights Cantilevered	Passive
1	10 (0.13)	5 (0.06)	7 (0.09)	1 (0.01)	27 (0.35)
2	6 (0.08)	1 (0.01)	3 (0.04)	1 (0.01)	8 (0.11)
3	1 (0.01)	0	3 (0.04)	1 (0.01)	1 (0.01)
4	1 (0.01)	0	0	0	2 (0.03)

( ) = proportion of the total sample

Table 45. Summary of the crossing surface type at sample sites with pullout lanes.

Number of Tracks	Asphalt	Full Depth Timber	Sectional Timber	Concrete
1	40 (0.51)	2 (0.03)	8 (0.10)	0
2	15 (0.19)	1 (0.01)	1 (0.01)	2 (0.03)
3	4 (0.05)	0	2 (0.03)	0
4	3 (0.04)	0	0	0

( ) = proportion of the total sample

facilities with pullout lanes were inspected to determine the date of pullout-lane installation, the number of tracks, type of crossing surface, and type of warning device.

Six crossings were identified, from the sample of 78 crossings, that had pullout lanes constructed during the 3-year analysis period of 1980 through 1983. The majority of these crossings had bituminous crossing surfaces and mast-mounted flashing lights.

Estimating Construction and Maintenance Costs

Estimates of construction and maintenance costs were obtained through an investigation of the literature and a survey of the States and railroads. The primary source for the maintenance costs was a 1982 technical paper by Bryant presented to the Communication and Signal Division meeting of the Association of American Railroads.[22] Bryant studied 400 crossings, stratified them by their warning device type and number of tracks, and determined the average yearly maintenance cost. The results of his analysis are presented in table 46.

Table 46. Average annual maintenance cost.

Stratification Category	Total Crossings Sampled	Average Annual Maintenance Cost
Single Track		
Flashers	76	$1,172.15
Flashers & gates	49	1,511.86
Cantilevered flashers	62	1,055.83
Gates and cantilevered flashers	53	2,080.58
Double Track		
Flashers and gates	66	1,879.80
Gates and cantilevered flashers	47	2,311.18
Special Layout		
Multiple tracks, etc.	47	3,032.09

(Source [22] pp. 1-2)

Surveys were forwarded to nine States and railroads to determine costs, design standards, and warranting criteria pertaining to the installation of pullout lanes. The initial recipients of the surveys were those States and railroads that were identified through the national inventory as having the largest number of pullout lanes. Prior to the forwarding of any surveys, telephone calls were made to identify the person within each State that was knowledgeable of pullout-lane installation. Most of the States contacted either stated that they did not have the number of pullout lanes identified or that they were installed so long ago that no one familiar with the lanes was still employed. The result was that completed surveys were only received from two States. The response rate from the railroads was higher with 6 of the 9 surveys being returned. A summary of the responses from the States and railroads are presented in appendix F of volume II.

Estimates of Yearly Expenditures for Pullout-Lanes

The estimates of nationwide pullout-lane installation and maintenance costs are based on the survey results and Bryant's work in conjunction with the installation rates estimated from the pullout-lane sample. Where appropriate, the results of the different combinations of physical features, determined from the sample of pullout-lane crossings, were broken into proportions to provide the total costs. The estimates of pullout-lane construction costs are based on cost estimates for full depth bituminous wearing surface, excavation, 6-foot (1.8 m) class A shoulders, and a 15 percent engineering and inspection fee. For the purpose of estimating costs, pullout-lanes are assumed to be installed in both directions of travel.

A determination of the average number of yearly installations is presented in table 47. This determination was based on the sampled 78 crossings containing 6 installations in a 3-year period. When these installations are expanded from the sample size of 78 to the population size of 664, and normalized to 1 year, the result is 17 crossings per year. This average annual installation rate was assigned costs based on the physical characteristics. (table 48) The assigned unit costs were obtained from information contained in the returned surveys and currrent construction estimates.

Table 47. Determination of average annual pullout-lane installation.

Estimates obtained from Sample			Estimate of Entire Population		
Installations	Sample Size	Analysis Period (Years)	Population Size	Average Installations Per 3 Years	Average Installations Per 1 Year
6	78	3	664	51.1	17.0

Table 48. Determination of average annual installation cost.

Average Installations Per Year	Crossing Type	Cost Components	Average Cost (Dollars)	Total Average Annual Cost
17	A	1. Asphaltic surface with one track.	(24 ft @ 382) 9168	
		2. Mast mounted flashing lights.	5895	
		3. Pullout-lane construction (both approaches).	20,000	
		Subtotal	$35,063	$596,000

The proportions contained in table 44 were applied to the total pull-out population of 664 sites to achieve the stratification presented in tables 49 and 50. These tables provide the information necessary to apportion the costs based on the types of warning devices and crossing surfaces that are present. The costs that need to be apportioned, however, are incremental in lieu of total maintenance costs.

The incremental costs were used since the presence of pullout lanes do not, by themselves, predicate the need for specific types of warning

Table 49. Total number of crossings with pullout lanes and the indicated warning devices.

Number of Tracks	Flashing Lights		Gates W/Flashing Lights		Passive
	Mast Mounted	Cantilevered	Mast Mounted	Cantilevered	
1	86	40	60	7	229
2	53	7	27	7	73
3	7	0	27	7	7
4	7	0	0	0	20

Table 50. Total number of crossings with pullout lanes and the indicated crossing surface type.

Number of Tracks	Asphalt	Full Depth Timber	Sectional Timber	Concrete
1	340	20	66	0
2	126	7	7	20
3	33	0	20	0
4	27	0	0	0

devices. These devices would probably exist at the crossing even without pullout lanes. The presence of the lane does, however, require an extension of the gate arms and cantilevering of the flashing lights when these devices are present. This rationale was used to determine the incremental costs presented in tables 51 and 52. For example, the maintenance cost difference ($569.00) in providing gates with cantilevered flashers ($2,081.00) and gates with mast-mounted flashers ($1,512.00) was assumed to be required by the addition of the 12-foot (3.7m) pullout-lane. The cost of extending the gate arm was assumed to be $100, and no maintenance cost was assigned to maintaining the pullout lane itself. Notice that the cost of maintaining cantilevered flashers is less than the cost of maintaining mast-mounted flashers. This may be due to less vandalism cost.

The incremental maintenance costs, contained in tables 51 and 52, were applied to the number of crossings with each warning device configuration and crossing surface type to yield the average annual maintenance costs presented in tables 53 and 54. The average annual cost of maintaining the warning device is approximately $16,000 and the average cost of maintaining the crossing surface is approximately $629,000 for a combined maintenance cost of $645,000.

<u>Conclusion of Pullout-Lane Cost Analysis</u>

The analysis strategy of only acknowledging pullout lanes as existing on two-lane roadways resulted in only 664 crossings. This is probably smaller than the actual number of pullout lanes which exist but a better estimate than the 2,581 crossings which result from searching the national inventory with no restrictive selection criteria.

It is estimated that there are 17 crossings nationwide that have pullout-lanes constructed each year. The cost of this construction is estimated to be $596,000 per year. The incremental annual maintenance costs incurred by providing pullout lanes was determined to be $645,000. This maintenance cost does not include the cost of maintaining the surface condition of the pullout lanes themselves.

Table 51. Incremental cost of warning device maintenance (dollars) for installing pullout lanes.

Number of Tracks	Flashing Lights Mast Mounted	Flashing Lights Cantilevered	Gates W/Flashing Lights Mast Mounted	Gates W/Flashing Lights Cantilevered	Passive
1	0	-116.00	100	569.00	0
2	0	-116.00	100	431.00	0
3	0	-116.00	100	431.00	0
4	0	-116.00	100	431.00	0

Table 52. Incremental cost of crossing surface maintenance (dollars) incurred by the installation of pullout lanes (1).

Number of Tracks	Asphalt	Full Depth Timber	Sectional Timber	Concrete
1	24	39	39	6
2	24	39	39	6
3	24	39	39	6
4	24	39	39	6

(1) Costs are presented in dollars per track foot.

Table 53. Total incremental cost (dollars) of maintaining warning devices at crossings with pullout-lanes.

Number of Tracks	Flashing Lights		Gates W/Flashing Lights		Passive	Average Annual Cost
	Mast Mounted	Cantilevered	Mast Mounted	Cantilevered		
1	0	-5,000	6,000	4,000	0	5,000
2	0	-1,000	3,000	3,000	0	5,000
3	0	0	3,000	3,000	0	6,000
4	0	0	0	0	0	0
					Total	16,000

Table 54. Total incremental cost (dollars) of maintaining the crossing surface at crossings with pullout-lanes.

Number of Tracks	Asphalt	Full Depth Timber	Sectional Timber	Concrete	Average Annual Cost
1	196,000	19,000	62,000	0	277,000
2	145,000	13,000	13,000	6,000	177,000
3	57,000	0	56,000	0	113,000
4	62,000	0	0	0	62,000
				Total	629,000

CHAPTER 8 - ECONOMIC CONSEQUENCES OF THE MANDATORY STOP RULE

The previous sections of this report have summarized the activities that were undertaken to determine the total consequences of requiring certain vehicles to stop at railroad crossings with active devices, when the devices are not activated. The results of these activities, when appropriate, are converted to current and future economic consequences.

Current Economic Consequences

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 are presented on an average annual basis.

Accident Costs

Costs associated with collisions between trains and hazardous material transporters, school buses, and 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 material transporters. A study performed by NTSB for accidents from 1975 through 1979, determined that the average property damage only costs for trucks carrying hazardous materials colliding with trains was $27,007.[2] This figure is a conservative estimate of the actual costs incurred. The potential damage to units of the train, clean up of environmentally damaging pollutants, emergency response actions, litigation, and, in some cases, evacuation of endangered citizens can dramatically raise the property damage costs. How conservative this estimate can be was emphasized by accidents that occurred after the data was collected for the NTSB study. These accidents involved four separate truck-train accidents occurring during a 10-day period in 1980, resulting in nine fatalities, nine injuries, and $718,000 in property damage. In this 10-day period, the property damage was 43 percent of what might be expected for the entire year. Another truck accident 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 more accurate information on the actual costs incurred from train accidents with trucks transporting hazardous materials, buses, and school buses. These organizations stated that the costs pertaining to environmental cleanup, litigation, and property damage claims were either not available or considered as proprietary information. These responses prompted a determination to base accident costs on appropriate information available from the NTSB study and the NSC. The NSC costs were used in lieu of competing estimates from the National Highway Traffic Safety Administration (NHTSA) because 1) the NSC costs are more widely used by the States, and 2) the NSC costs include an overall average for personal-injury accidents.

The costs and sources presented in table 55 were used in determining the overall cost of the accident consequences. Notice that the 1983 NSC costs were used in all accident and severity categories with the exception of property-damage-only and personal-injury accidents for hazardous material transporters. This was done because, while train accidents with buses and school buses are often catastrophic in terms of fatalities and personal injury, bus accidents typically do not incur property damage losses comparable to those incurred by hazardous-material-transporter accidents.

Estimating the overall accident cost savings for train-involved accidents required the breakdown by accident severity. This breakdown, presented in table 56, was accomplished by only including those accidents which had been previously verified. The information contained in Table 56, for example, reveals that 0.38 of the 161 train-hazardous material transporter accidents involved a personal injury. For every personal-injury accident that occurred there was an average of 1.8 persons injured.

The estimated net reduction in accidents, from table 40, were applied to the total accidents that were verified over the 9-year analysis period. A reduction of 4 hazardous material accidents, 9 school bus and 21 passen-

Table 55. Accident costs estimates[1].

Vehicle Type	Train-Involved PDO	PI	F	Nontrain-Involved PDO	PI	F
Hazardous Material Transporters	27,007*	34,457**	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

1 - Based on 1983 NSC Accident Cost Estimates with noted exceptions.
PDO - Property damage only
PI - Personal injury
F - Fatality
* - Based on NTSB study (Source: 2 p. 2)
** - The sum of NTSB-PDO costs and NSC-PI costs

Table 56. Breakdown of accident severity for verified train-involved accidents occurring from 1975 through 1983.

Accident Severity	Hazardous Material Transporters	School Buses	Passenger Buses
Total	161	84	119
Property Damage Only	70	51	71
Personal Injury (Persons)	61 (111)	30 (126)	40 (210)
Fatal (Persons)	30 (54)	3 (4)	8 (21)
Ratio of Personal Injury	0.38	0.36	0.34
Persons Injured/Personal Accident	1.80	4.20	5.30
Ratio of Fatal	0.19	0.04	0.07
Persons Killed/Fatal Accident	1.80	1.30	2.60

ger bus accidents are the estimated total accident reductions presented in table 57. The estimate of total accident reductions are broken into categories of accident severity in table 58. When accident costs are assigned to the estimated reductions in accident severity, in table 59, the result is a total savings of $2,086,000 for a 9-year period. The annual savings in train-involved accidents, by not requiring vehicles to stop at crossings with unactivated warning devices, is $232,000.

Table 57. Estimated 9-year train-involved accident reduction with no mandatory stop requirements.

Vehicle Type	Total Accidents for 9 Years	Estimated Percent Reduction	Estimated 9-Year Reduction
Hazardous Material Transporters	161	2.6	4
School Buses	84	10.8	9
Passenger Buses	119	17.4	21

Table 58. Estimated 9-year train-involved reduction in accident severity with no mandatory stop requirements.

Vehicle Type	Total	Property Damage	Personal Injury (Persons)	Fatal (Persons)
Hazardous Material Transporters	4	1	2 (4)	1 (2)
School Buses	9	6	3 (13)	0
Passenger Buses	21	12	7 (37)	2 (5)

Table 59. Estimated 9-year train-involved accident savings (dollars) resulting from no mandatory stop requirements.

Vehicle Type	Property Damage	Personal Injury	Fatal	Totals
Hazardous Material Transporters	27,000	138,000	420,000	585,000
School Buses	7,000	112,000	0	119,000
Passenger Buses	14,000	318,000	1,050,000	1,382,000
TOTAL				2,086,000

Estimates of the annual reduction in nontrain-involved accidents was obtained by averaging the annual accidents from table 25. Applying the cost of property-damage-only accidents to these estimates, as presented in table 60, results in an annual nontrain accident cost reduction of $222,000. The property-damage-only cost was applied to the nontrain-involved accidents because they are typically accidents of low severity.

Table 60. Estimated annual accident savings (dollars) for nontrain-involved accidents resulting from no mandatory stop requirements.

Vehicle Type	Estimated Yearly Reduction	Cost Per Accident	Estimated Yearly Cost
Hazardous Material Transporters	40	1,150	46,000
School Bus	122	1,150	140,000
Passenger Bus	31	1,150	36,000
TOTAL			222,000

The estimated total annual train and nontrain accident cost savings resulting from not requiring stops at crossings with active devices when not activated is, therefore, $454,000 ($232,000 + $222,000). It should be realized that this estimate is a conservative, lower bound estimate. It is based only on those accidents which were positively identified as involving hazardous material transporters, school and passenger buses. In both the train and nontrain-involved accident categories there are additional accidents which could not be verified and, in the case of nontrain-involved, were not identified or reported.

Pullout-Lane Construction and Maintenance Costs

The cost of pullout-lane construction and maintenance cost was determined, in chapter 7, as being $596,000 and $645,000, respectively. This is a conservative estimate since only pullout-lanes installed on two-lane roadways were included in the analysis.

Fuel Consumption Costs

Results from the NETSIM analysis indicate that there are 12,267,000 gallons/year (46,614,600 liters/year) consumed at active crossings due to the mandatory stop provision. Applying a conservative estimate of $1 per gallon results in $12,267,000 in excess fuel expenditures 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 that were required to stop. In determining the associated cost of delay, the NETSIM estimates were separated into truck and following vehicle delay. This was accomplished in order to apply cost estimates based on vehicle type.

The value of time estimates were obtained from 1977 estimates provided in a publication published by the American Association of State Highway Officials (AASHTO).[23] All of the following vehicles were assumed to be automobiles that experienced delays of less than 5 minutes in duration. Applying the estimates provided by AASHTO for occupancy rate and value of time, for an average traveler trip, resulted in a delay cost of 33¢ per hour. For trucks, the delay cost was assumed to represent market costs rather than the value of personal user time, as 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 value used for both automobile and truck delay represents 1975 values provided by AASHTO and were not updated by the Consumer Price Index to yield current values.

The NETSIM estimates of delay, contained in tables D-8 and D-9 of volume II, were multiplied by the hourly delay cost to obtain the totals respresented in table 61. The total cost of delay resulting from requiring vehicles to stop at active crossings when the devices are not activated is $1,510,000.

Table 61. Estimated annual delay savings resulting from no mandatory stop requirements.

Vehicle Type	Annual Hours of Delay	Hourly Time Value (Dollars)	Total (Dollars)
Automobile	1,350,000	0.33	446,000
Truck	133,000	8.00	1,064,000
Total			1,510,000

Future Economic Impacts

The future impacts were determined by projecting the truck registrations per year to the year 1995. (table 4) This was accomplished by using the least squares method to establish the best fit lines presented in figures 21 through 23, for trucks, school buses, and passenger buses, respectively. Assuming that growth would remain constant, the equations were

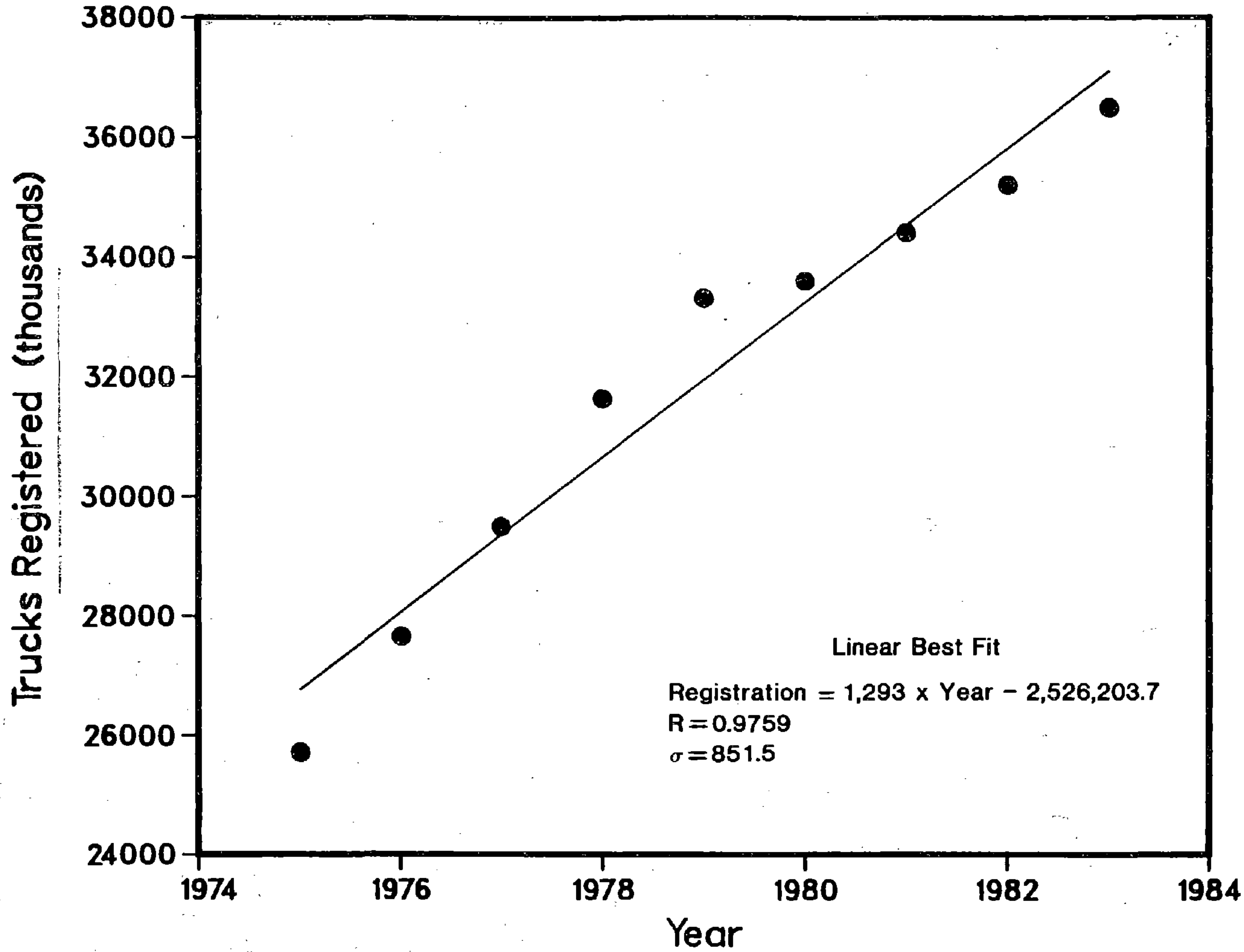


Figure 21. Least squares regression analysis for yearly truck registrations.

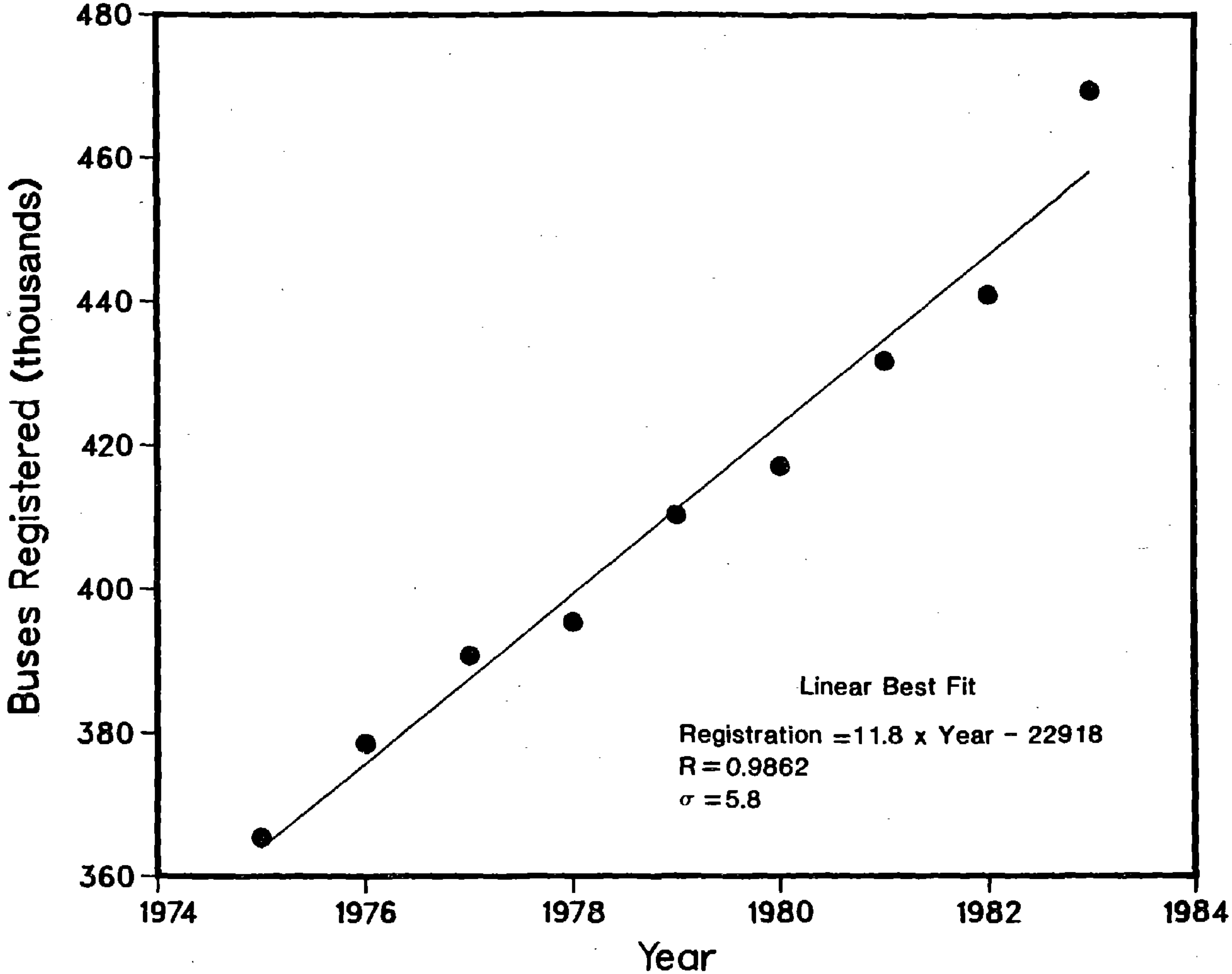


Figure 22. Least squares regression analysis for yearly school bus registrations.

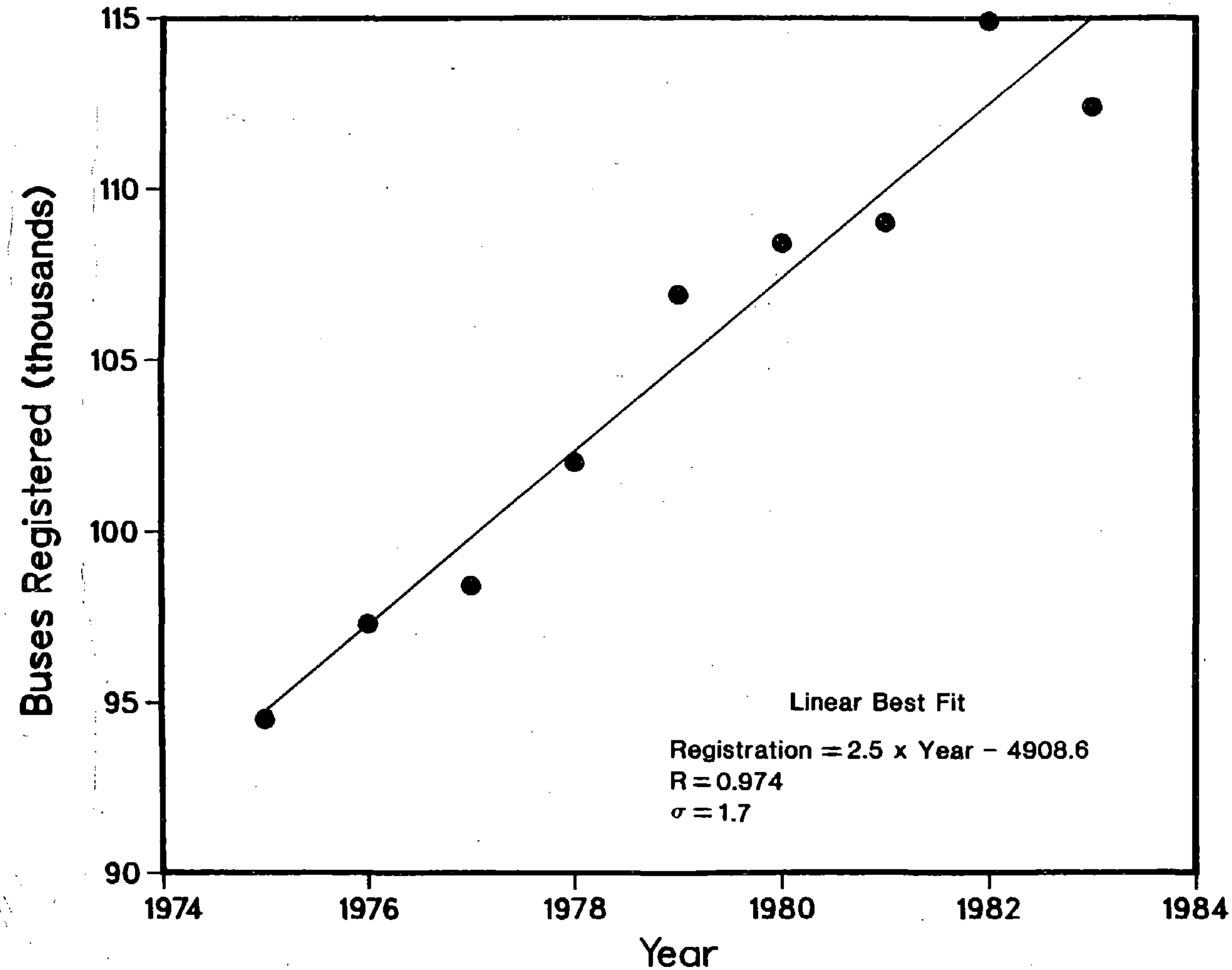


Figure 23. Least squares regression analysis for yearly passenger bus registrations.

used to predict yearly vehicle registrations through 1995. The predicted 1985 registrations were then used as the base to estimate the accident, fuel consumption, and delay costs associated with each year in the prediction period. These predictions, and associated costs presented in table 62 are based on the assumptions that growth, percent mix of hazardous material transporters, delay, fuel consumption, and accident rates remain constant.

Conclusions of Economic Consequences

The average annual economic consequences of the mandatory stop requirement at active grade crossings for both 1983 and 1995 are summarized in table 63. In obtaining the 1995 cost, it was assumed that both the construction and maintenance costs for pullout lanes would remain constant.

Table 63. Summary of 1983 and 1995 annual cost of requiring vehicles to stop at crossings with active warning devices when not activated.

Cost Category	1983 Annual Cost (Dollars)	1995 Annual Cost (Dollars)
Train & Nontrain-Involved Acc.	454,000	567,000
Pullout-Lane Construction	596,000	596,000
Pullout-Lane Maintenance	645,000	645,000
Fuel Consumption	12,267,000	16,193,000
Delay	1,510,000	1,993,000
TOTAL	15,472,000	19,994,000

Table 62. Estimated annual accident and fuel cost savings resulting from no mandatory stop requirement at crossings with active warning devices when not activated.

	Total Vehicle Registration (1)	Train and Nontrain Accident Cost Reduction (2)	Fuel Cost Reduction (2)	Delay Cost Reduction (2)
Hazardous Material Transporters				
1986	458.6	115	12,660	1,558
1987	472.9	118	13,052	1,607
1988	487.1	122	13,445	1,655
1989	501.3	125	13,837	1,703
1990	515.5	129	14,230	1,752
1991	529.8	132	14,623	1,800
1992	544.0	136	15,015	1,848
1993	558.2	139	15,408	1,897
1994	572.4	143	15,800	1,945
1995	586.6	147	16,193	1,993
School Bus				
1986	493.6	157	-	-
1987	505.4	161	-	-
1988	517.2	164	-	-
1989	529.0	168	-	-
1990	540.8	172	-	-
1991	552.5	176	-	-
1992	564.3	179	-	-
1993	576.1	183	-	-
1994	587.9	187	-	-
1995	599.7	191	-	-
Passenger Bus				
1986	122.5	193	-	-
1987	125.1	197	-	-
1988	127.6	201	-	-
1989	130.1	205	-	-
1990	132.7	209	-	-
1991	135.2	213	-	-
1992	137.7	217	-	-
1993	140.3	221	-	-
1994	142.8	225	-	-
1995	145.3	229	-	-

(1) - Thousands
(2) - Thousand Dollars

CHAPTER 9 - CONCLUSIONS

The conclusions presented below are based on the results of the project anlaysis, observations made during the study, and the literature review.

1. The stringent verification process used in this study resulted in a relatively small number of both train and nontrain-involved accidents being selected for analyses. There were 169 accidents that could not be verified as either involving or not involving the specific vehicle types or accident characteristics required for analysis. If more of these accidents could have been verified and included in the analysis, the accident frequencies would have been much higher. The accident frequencies and associated accident costs contained in this report, therefore, represent a lower limit on the actual values.

2. There were higher proportions of hazardous material transporters, school buses, and passenger buses being struck by a train, at crossings with active devices, than that which occurred for trucks not transporting hazardous materials. This difference was found to be significant at the 0.01 significance level.

3. The percentage of accidents involving vehicles impacting trains 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 0.01 level.

4. If the mandatory stop requirement did not require stops at crossings with active warning devices when the devices are not activated the primary responsibility of recognizing the presence of a train would be placed on the train detection system. It was conservatively estimated that this would result in train-involved accidents increasing 0.70 percent, due to nonoperation of the warning system. This estimate for accidents due to nonoperating

warning systems would, however, decrease to 0.33 percent if accidents involving insulated railroad equipment could be eliminated. Train detection systems are not designed to automatically detect the presence of insulated equipment.

5. Requiring vehicles to stop at crossings with active devices when no train is present or approaching results in an increased number of vehicle-to-vehicle accidents. The annual nationwide estimate of such nontrain-involved accidents was determined to be 40, 121, and 31 for hazardous material transporters, school buses, and passenger buses, respectively. These estimates appear to be inordinately low for nationwide totals. It can reasonably be expected, therefore, that these estimates represent a lower limit on the actual values.

6. If the mandatory stop regulation did not require stops at crossings with active devices when not activated there would be a net annual decrease in train-involved accidents for hazardous material transporters, school and passenger buses of 2.6, 10.8, and 17.4 percent, respectively. The net decrease would occur even though there would be an increase in accidents where trains are struck by vehicles and in accidents due to warning device nonoperation.

7. Requiring vehicles to stop at crossings with active devices when not activated results in 1,483,000 hours of excess delay and 12,267,000 gallons of excess fuel being consumed. Truck pullout lanes at railroad crossings, necessitated indirectly by the mandatory stop regulations, results in an estimated annual expenditure of $596,000 for construction and $645,000 for maintenance.

8. Requiring vehicles to stop at crossings with active devices when not activated results in excess annual expenditures of $454,000 in accident costs, $12,267,000 in fuel, and $1,510,000 in the value of time lost due to delay.

9. A higher percentage of school and passenger bus accidents occur at crossings with active control devices. This may be due to exposure. A larger proportion of bus trips can be expected to occur in urban areas with higher population densities and vehicular traffic. Urbanized roadways with high ADT are more likely to have active warning devices than low-volume rural roadways.

10. A higher percentage of hazardous material transporter accidents occurred at crossings with passive warning devices. This may be a function of exposure since the hazardous material depots, warehouses and shipping points are often located in low-density rural areas.

11. The violation rate, where 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 and passenger buses had consistently lower violation rates than trucks and tank trucks.

12. The increased use of double and triple bottom truck trailers results in the minimum MUTCD advance warning of 20 seconds being insufficient at many railroad grade crossings.

13. The accident record systems of most States that were contacted are not conducive to identifying nontrain-involved accidents occurring in the vicinity of a railroad crossing. The task of identifying these accidents was much easier when they were either coded as railroad-related or the milepoints of the railroad crossings were known. It would be advantageous for individual States to incorporate into their accident record systems a method of retrieving accidents occurring in the vicinity of railroad crossings. Such retrieval capabilities will provide the

ability to analyze nontrain-involved accidents resulting from the physical and operational features of the crossing, such as poor crossing surfaces and changes in grade.

14. Research is required to determine the most effective means of informing motorists, sufficiently in advance of the crossing, of the type of warning device present. Supplemental messages placed on the existing advance warning signs (W10-1) could satisfy this need.

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