Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/RD-81/083		PB83-158733

4. Title and Subtitle	5. Report Date
Rail Highway Crossing Accident Causation Study Volume II. Technical Report	August 1982
	6. Performing Organization Code
7. Author(s) Karl Knoblauch, Wayne Hucke, and William Berg	8. Performing Organization Report No.
9. Performing Organization Name and Address IOCS 4733 Bethesda Avenue Washington, D.C. 20014	10. Work Unit No. (TRAIS) 3101-128
	11. Contract or Grant No. DOT-FH-11-9682
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Research Traffic Systems Division Washington, D.C. 20590	13. Type of Report and Period Covered Final Report October 1979 to October 1981
	14. Sponsoring Agency Code T-0477

15. Supplementary Notes

Volume I is the Executive Summary
FHWA Contract Manager: Janet Coleman, HRS - 32

16. Abstract

This study examines the contributing factors of rail highway crossing accidents at crossings with flashing light and crossbuck warning devices. Included are a literature review, review of data sources, study plan, methodology for the accident analyses and the results of the indepth accident investigation.

After a review of available data an accident sample was choosen for an indepth investigation. The detailed accident investigation involved accident reconstruction utilizing data from North Carolina and Wisconsin State accident reports, the Federal Railroad Administration Rail-Highway Grade Crossing Accident/Incident Report, the United States Department of Transportation-Association of American Railroads Crossing Inventory Information report and accident site investigations.

The accident analysis methodology involved a two step approach. For each accident the accident type was determined based on the event sequence which led to the accident. Then an evaluation was made regarding those contributing factors which, based on the event sequence, were judged to have contributed to the accident.

17. Key Words	18. Distribution Statement
Accident Analysis Rail Highway Grade Crossing Human Factors Accident Causation Flashing Light Warning Devices Crossbuck Warning Devices	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified		148	

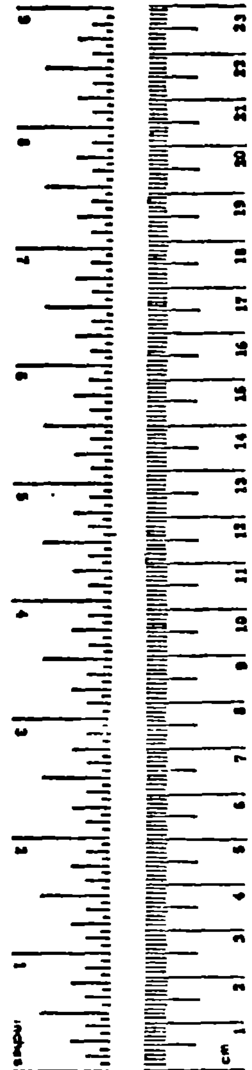
Form DOT F 1700.7 (8-72)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

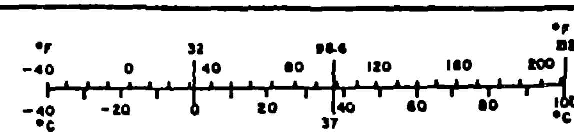
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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	35	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



PREFACE

We would like to acknowledge the assistance of the North Carolina and Wisconsin Departments of Transportation for supplying State accident reports for rail highway crossing accidents.

Throughout this report the pronouns "he", "him", and "his" were utilized to refer to all drivers. The authors felt that a single pronoun as opposed to "she/he", "her/him" and "hers/his", would allow for smoother word flow and be easier on the reader.

Table of Contents

Chapter		Page
1.	INTRODUCTION	1
	Rail Highway Crossings	1
	Purpose of Study	3
	Study Approach	3
	Scope of Study	4
2.	LITERATURE REVIEW	6
	Driver Familiarity with the Accident Crossing	6
	Laws Relating to Rail Highway Crossings	8
	Enforcement Practices	13
	Driver Attitudes and Understanding	13
	Driver Judgment	14
3.	DATA SOURCES	17
	Data Base Evaluation	17
	Data Sources Utilized	20
4.	STUDY PLAN	24
5.	ACCIDENT SITE RECONSTRUCTION	27
	Definition of Terms	27
	Data Collection	33
6.	METHODOLOGY FOR THE ACCIDENT ANALYSIS	39
	Conceptual Model of Driver Behavior	39
	Discussion of Contributing Factors	44

Table of Contents (Continued)

Chapter		Page
	Contributing Factors - Flashing Light Warning Devices	49
	Contributing Factors - Crossbuck Warning Devices	56
7.	ACCIDENT CAUSATION - FLASHING LIGHT WARNING DEVICES	61
	Accident Types and Contributing Factors	61
	Summary of Accident Analysis and Countermeasures	86
8.	ACCIDENT CAUSATION - CROSSBUCK WARNING DEVICES	95
	Accident Types and Contributing Factors	95
	Summary of Accident Analysis and Countermeasures	114
9.	CONCLUSION AND RECOMMENDATIONS	121
	Limitations of the Findings	121
	Conclusions and Recommendations	122
	Further Research	124
APPENDIX A - FIELD SURVEY PROCEDURES FOR RAIL HIGHWAY FLASHING LIGHT CROSSINGS		126
APPENDIX B - FIELD SURVEY PROCEDURES FOR RAIL HIGHWAY CROSSBUCK CROSSINGS		128
REFERENCES		130
BIBLIOGRAPHY		135

List of Figures

Figure		Page
1	Comparison of Rail Highway Fatalities and Federal Crossing Expenditures	2
2	Graphic Representation of Information Handling Zone	28
3	Track Zones and Sight Distances	32
4	Adequate and Inadequate Quadrant Sight Distance	34
5	Operational Steps in Driver Guidance and Control	42
6	Logic Flow Chart for Driver Error - Flashing Light Warning Devices	45
7	Logic Flow Chart for Driver Error - Crossbuck Warning Devices	46
8	Contributing Factors to Driver Recognition Error - Flashing Light Warning Devices	50
9	Contributing Factors to Driver Decision Error - Flashing Light Warning Devices	51
10	Contributing Factors to Driver Recognition Error - Crossbuck Warning Devices	57
11	Contributing Factors to Driver Decision Error - Crossbuck Warning Devices	58
12	Contributing Factors to Driver Recognition Error - R1A - Flashing Light Warning Devices	65
13	Contributing Factors to Driver Recognition Error - R1B - Flashing Light Warning Devices	67
14	Contributing Factors to Driver Recognition Error - R2 - Flashing Light Warning Devices	69
15	Contributing Factors to Driver Recognition Error - R3 - Flashing Light Warning Devices	71
16	Contributing Factors to Driver Recognition Error - R4 - Flashing Light Warning Devices	73
17	Contributing Factors to Driver Decision Error - D1A - Flashing Light Warning Devices	75

List of Figures (Continued)

Figure		Page
18	Contributing Factors to Driver Decision Error - D1B - Flashing Light Warning Devices	77
19	Contributing Factors to Driver Decision Error - D2 - Flashing Light Warning Devices	79
20	Contributing Factors to Driver Decision Error - D3A - Flashing Light Warning Devices	81
21	Contributing Factors to Driver Decision Error - D3B - Flashing Light Warning Devices	83
22	Contributing Factors to Driver Decision Error - D4 - Flashing Light Warning Devices	85
23	Contributing Factors to Driver Recognition Error - R1A - Crossbuck Warning Devices	97
24	Contributing Factors to Driver Recognition Error - R1B - Crossbuck Warning Devices	99
25	Contributing Factors to Driver Recognition Error - R2A - Crossbuck Warning Devices	101
26	Contributing Factors to Driver Recognition Error - R2B - Crossbuck Warning Devices	103
27	Contributing Factors to Driver Recognition Error - R3 - Crossbuck Warning Devices	105
28	Contributing Factors to Driver Recognition Error - R4 - Crossbuck Warning Devices	107
29	Contributing Factors to Driver Decision Error - D1 - Crossbuck Warning Devices	109
30	Contributing Factors to Driver Decision Error - D2 - Crossbuck Warning Devices	111
31	Contributing Factors to Driver Decision Error - D3 - Crossbuck Warning Devices	113

List of Tables

Table		Page
1	Comparative Distribution of Residence of Drivers in Motor Vehicle-Train Accidents	7
2	National Transportation Safety Board Railroad Highway Accident Reports	9
3	Rail Highway Crossing Laws Matrix	12
4	Accidents/Incidents and Casualities at Grade Crossings Involving Motor Vehicles by Train Speed and Type of Train, 1978	16
5	Information Available from Data Sources	22
6	Nonrecovery Zone Boundries	29
7	Approach Zone Boundries	30
8	Accident Types and Contributing Factors Patterns - Education and Enforcement Countermeasures - Crossings with Flashing Light Warning Devices	88
9	Accident Types and Contributing Factors Patterns - Engineering Countermeasures - Crossings With Flashing Light Warning Devices	90
10	Accident Types and Contributing Factors Patterns - Education and Enforcement Countermeasures - Crossings with Crossbuck Warning Devices	116
11	Accident Types and Contributing Factors Patterns - Engineering Countermeasures - Crossings with Crossbuck Warning Devices	117

CHAPTER 1. INTRODUCTION

In general, highway studies have identified human errors as a major factor in automobile accidents. Little research to date, however, has investigated the role of human errors and associated contributing factors in rail highway crossing accidents. This study will thus focus on human errors and related contributing factors.

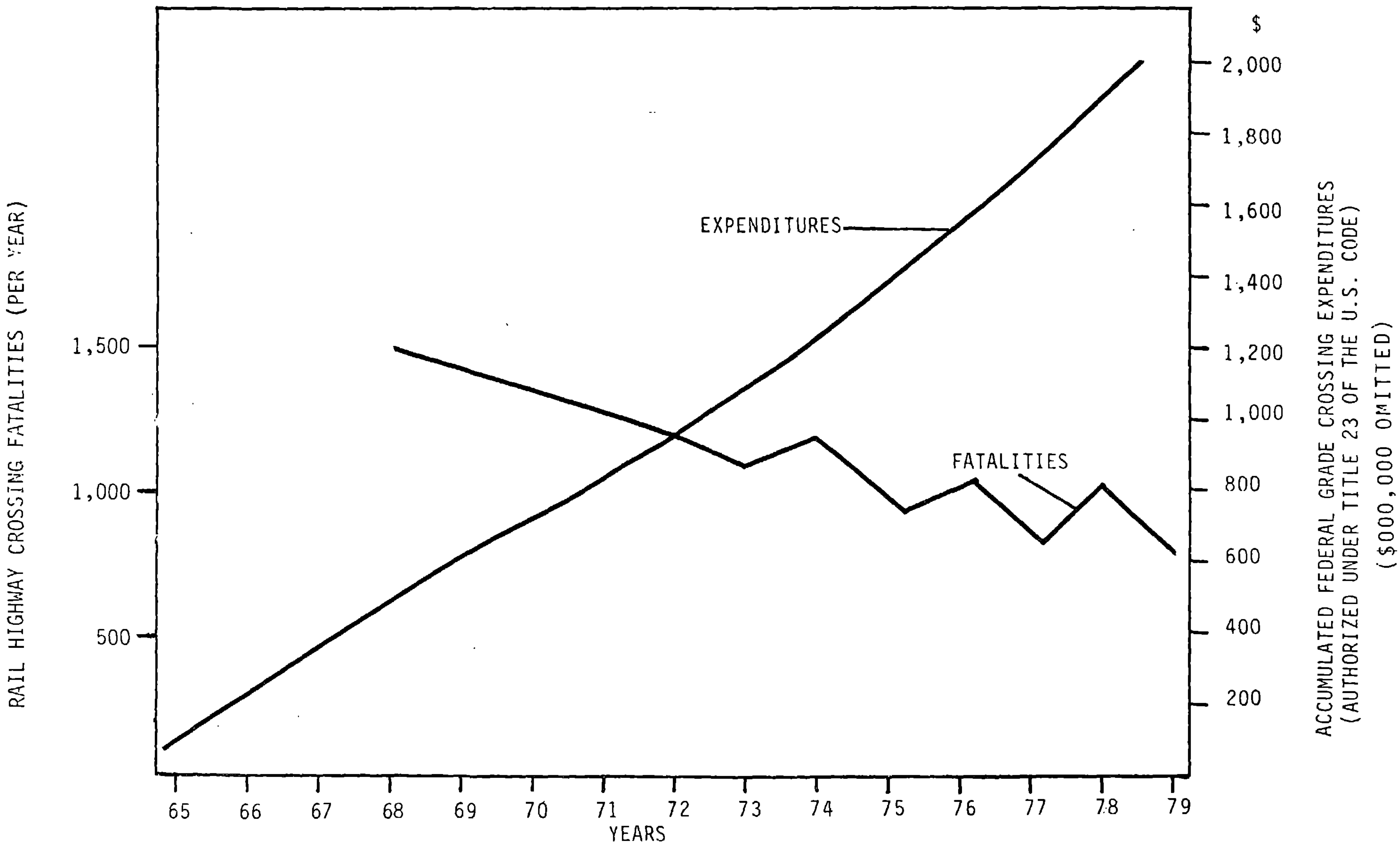
Rail Highway Crossings

Since 1965, Federal expenditures to improve the safety features of rail highway crossings, have approached $2 billion (1). Annual accident fatalities have decreased from 1,546 fatalities in 1968 to 834 fatalities in 1979 (2)*. (See Figure 1.) In recent years, many research studies have been undertaken in an attempt to improve crossing safety. Recent research efforts have explored traffic control devices, and the development of new concepts for use in constant warning time devices.

Despite the high level of research in this area, differences of opinion still remain regarding the major causes of vehicular accidents at rail highway crossings. Some causes frequently considered as major contributors to rail highway crossing accidents are improper signing and signals, lack of warning device credibility and conspicuity, driver inattention, risk taking, and alcohol.

---

*The data from sources 1 and 2 were updated by extrapolation using data supplied by the Federal Highway Administration.



SOURCES (1 and 2) - EXTRAPOLATED WITH FEDERAL HIGHWAY ADMINISTRATION SUPPLIED DATA

Figure 1. Comparison of Rail Highway Fatalities and Federal Crossing Expenditures.

Purpose of Study

The purpose of this study is to identify probable causes and contributing factors of train-vehicle crossing accidents, using a human factors approach. The results of this study may provide input into subsequent research, and give direction to rail highway crossing improvement programs.

Findings are grouped to identify countermeasures which will lessen the effects of the contributing factors to rail highway crossing accidents. The countermeasures are categorized into engineering, education, and enforcement countermeasures.

Study Approach

Two approaches to accident causation analysis prevail in the literature on rail highway crossing safety - the statistical approach and the case study approach. In the statistical approach, large samples of data are analyzed for any prevailing trends. In the case study approach, a smaller sample of crossings is chosen and an indepth analysis of each accident is conducted.

The initial study approach was to use a large data base to test hypotheses to be developed by the study team, using statistical techniques. However, a large data base containing sufficiently comprehensive and reliable information to identify accident causal factors did not exist.

For this reason, the study team chose the case study approach, specifically accident reconstruction, to identify contributing factors involved in rail highway accidents. Accident reconstruction concentrates on identifying patterns of contributing factors associated with specific types of driver failures.

Scope of Study

The scope of the study is limited to crossings with crossbuck and flashing light warning devices. These crossings were chosen for two reasons. First, crossbuck crossings and flashing light crossings together account for 79.7 percent of the total crossings in the United States and for 78.1 percent of the rail highway crossing accidents in 1978. Second, the level of resources available and logistical considerations demanded a focus on particular types of crossings.

In addition, the study was limited to accident involved crossings rather than to all crossings in recognition of the limited resources and time available to conduct field surveys. It was felt that studying only crossings that were accident sites would uncover contributing factors more directly than by studying both accident and non-accident sites, especially given the limited size of the study sample. It should be recognized, however, that non-accident crossings may exhibit the same mix of characteristics that contributed to an accident at another crossing.

Accidents involving alcohol also were excluded from the field work phase of the study for a number of reasons. The study team felt that the lack of sufficiently detailed information in state accident reports would prevent a meaningful study of the alcohol-involved driver. Indepth accident investigation, including actual interviews with the driver and accident witnesses, would be needed to draw any conclusions on this subject. In the study approach used, assumptions were made on how drivers react to a variety of situations. As alcohol affects people differently, any assumptions made about the reactions of drivers under the influence of alcohol would be lacking in validity. Given the level of resources and the time constraints, the alcohol involved accident was eliminated to concentrate greater time and study resources on the "normal" or the alert driver.

In addition, stalled vehicle accidents or accidents involving standing vehicles were eliminated. The focus of our study was to determine what factors cause an approaching driver to be involved in a vehicle-train accident. Since standing vehicles are not involved in approaching a crossing, they were not considered.

CHAPTER 2. LITERATURE REVIEW

This chapter discusses five topic areas found in the literature which the study team found useful. These areas are:

- Driver familiarity with the accident crossing
- Laws relating to rail highway crossings
- Enforcement practices
- Driver attitudes and understanding
- Driver judgment

Each section concludes with a summary of key literature findings that were considered pertinent to a study of human factors involved in rail highway crossing accidents. The impact of these findings in the study design are described.

Driver Familiarity with the Accident Crossing

A review of rail highway crossing accident literature, suggests that drivers involved in rail highway crossing accidents are likely to be familiar with the crossing. In 1968, D.W. Schoppet and D.W. Hoyt (3) found that 80 percent of the drivers involved in rail highway crossing accidents live within 25 miles of that crossing. See Table 1.

This finding was substantiated by a 1973 report by Sanders, Kolsrud, and Berger (4) that found that drivers involved in crossing accidents were likely to live near the crossing and to use the crossing frequently. According to the Sanders' survey, seven out of eight accidents at rail highway crossings involve drivers familiar with that particular crossing. Further, 65 of the 78 surveyed drivers could be considered local residents of the crossing. The Sanders report also stated that 61 percent of the surveyed drivers indicated that they slowed down in approaching this particular crossing primarily because they knew the crossing existed; only 9

Table 1. Comparative Distribution of Residence of Drivers in Motor Vehicle-Train Accidents.

Driver Residence	Motor Vehicle Accidents	Vehicle-Train Accidents
Local resident	79.5	78.3
Residing elsewhere in State	15.7	17.3
Nonresident of State	4.8	4.4
All	100.0	100.0

Source (3)

percent were not familiar with the existence of the rail highway crossing. The Sanders' report (4) concluded that the more familiar drivers were with the crossing, the greater the probability that they would exhibit unsafe driving behavior. Frequent use of the crossing was found to be inversely related to "looking" behavior and percentage of speed reduction.

In 1975, D.D. Peterson and D.S. Boyer (5) conducted a study on the feasibility of in-vehicle warning systems for emergency vehicles and rail highway crossings. Arriving at conclusions similar to earlier studies, Peterson and Boyer cite that many drivers at rail highway crossings are nonreceptive to the warning to varying degrees. To some extent, this phenomenon is offset by the fact that 80-90 percent of drivers negotiating crossings are familiar with the crossing and the train patterns at that crossing by virtue of living in the area or frequently commuting across them. These drivers are susceptible to danger, however, when irregularities in the train patterns occur or crossing conditions change.

In 1978, a study (6) was conducted on rail highway crossing safety of high speed trains. This study found that collisions between trains and road vehicles are not attributed to the driver's lack of familiarity of the existence of the crossing.

In a recent study by E.C. Wigglesworth (7) of rail highway crossing accidents in Victoria, Australia, researchers found that 73 out of 85 fatal accidents involved drivers who were aware of the crossing. Causes of these accidents were attributed to distractions, inattention, forgetfulness, and overfamiliarity with the crossing.

These studies are supported by an analysis of 17 accident investigations conducted by the National Transportation Safety Board (NTSB) (8) between 1966 and 1977. All but one of the involved drivers were familiar with the crossing. NTSB accident findings are summarized in Table 2.

Laws Relating to Rail Highway Crossings

This section describes standards in the Manual on Uniform Traffic Control Devices and relates them to the legal aspects of rail highway crossing accidents. In addition, this section reviews pertinent laws and codes relating to rail highway crossings, and compares the Uniform Vehicle Code to the codes of the states involved in the on-site field work phase of this study.

Table 2. National Transportation Safety Board Rail Highway Accident Reports.

Accident	Warning Device	Date	Familiar With Crossing	
Des Moines, IA	Flashing Lights	07/01/76	Yes	
Plant City, FL	Flashing Lights	10/02/77	Yes	
Collinsville, OK	Flashing Lights	05/05/71	Yes	
Loda, IL	Wigwag	01/24/70	Yes	
Statton, NE	Wigwag	08/08/76	Yes	
Sacramento, CA	Flashing Lights	06/05/75	Yes	
Beattyville, NY	Flashing Lights	09/42/77	Yes	
Everett, MA	Gates	12/28/66	Yes	
Tracy, CA	Flagman	03/09/75	Yes	
Beckemeyer, IL	Crossbucks	02/07/76	Yes	
Aragon, GA	Crossbucks	10/23/74	Yes	
Congers, NY	Crossbucks/Stop Sign	03/24/75	Yes	
Elwood, IL	Crossbucks	11/19/75		No
Masland, OK	Crossbucks	11/15/76	Yes	
Waterloo, NE	Crossbucks	10/02/67	Yes	
		TOTAL	16	1

The Manual on Uniform Traffic Control Devices

The Manual on Uniform Traffic Control Devices, Part VIII,(9) contains standards for traffic control at rail highway crossings. This manual states the purpose of and specifications for these warning devices. (It does not deal with driver responsibility at crossings; the Uniform Vehicle Code provides the laws governing driver actions.) An understanding of the stated purpose of the warning devices emphasized in this study will provide a context in which laws and vehicle codes can be reviewed.

The Manual on Uniform Traffic Control Devices states the purpose of passive traffic control systems, such as signs, pavement markings, and rail highway crossing illumination, is to identify and direct attention to the location of a rail highway crossing to permit vehicle operators and pedestrians to take appropriate actions. The Manual states the purpose of active traffic control systems is to inform motorists and pedestrians of the approach or presence of trains, locomotives, or railroad cars on the rail highway crossing.

Uniform Vehicle Code

Driver requirements at flashing light and crossbuck crossings are described in the Uniform Vehicle Code (10). The Code defines the "appropriate actions" that vehicle operators are to take.

Driver actions described in the code can be classified into three areas of driver behavior: vehicle speed approaching the crossing, vehicle speed passing (i.e. traversing) the crossing, and stopping requirements at the crossing. Listed below are quoted regulations in the Uniform Vehicle Code for these areas.

> Approach Speed (S. 11-801)
>
> No person shall drive a vehicle at a speed greater than is reasonable and prudent under the conditions and having regard to the actual and potential hazards then existing. Consistent with the foregoing, every person shall drive at a safe and appropriate speed when approaching and crossing an intersection or railroad grade crossing . . . . .
>
> Passing (S. 11-306)
>
> No vehicle shall be driven on the left side of the roadway under the following conditions:

When approaching within 100 feet (30.5 meters) of or traversing any . . . rail highway crossing unless otherwise indicated by official traffic control devices. . .

Stopping (S. 11-701)

Obedience to signal indicating approach of train. Whenever any person driving a vehicle approaches a rail highway crossing under any of the circumstances stated in this section, the driver of such vehicle shall stop within 50 feet (15.2 meters) , but not less than 15 feet (1.6 meters) from the nearest rail of such railroad, and shall not proceed until he can do so safely. The foregoing requirements shall apply when:

1. A clearly visible electric or mechanical signal device give warning of the immediate approach of a railroad train;

2. A railroad train approaching within approximately 1,500 feet (457.2 meters) of the highway crossing emits a signal audible from such distance and such railroad train, by reason of its speed or nearness to such crossing, is an immediate hazard;

3. An approaching railroad train is plainly visible and is in hazardous proximity to such crossing.

These codes are the only regulations specifically related to driver behavior at crossings with crossbuck or flashing lights.

State Vehicle Codes

The Uniform Code is the basic guideline from which many states patterned their traffic laws. Vehicle codes in North Carolina and Wisconsin, the states selected for on-site field work, will be examined in this section.

The following matrix compares North Carolina and Wisconsin laws to the Uniform Vehicle Code:

Table 3. Rail Highway Crossing Laws Matrix.

Uniform Vehicle Law	Device Covered By Laws	North Carolina Laws	Wisconsin Laws
Speed Approaching Crossing (S11-801)	Crossbucks & Flashing Lights	Rail highway crossing not mentioned	Same as UVC
Passing Before & at Crossing (S11306)	Crossbucks & Flashing Lights	Bans passing within 100 feet (30.5 meters) of crossing	Bans passing within 100 feet (30.5 meters) of crossing
Stopping at Crossing (S11-701--A)	Crossbucks & Flashing Lights	Requires stop for train same as UVC	Bans crossing when train is coming; Proceed when no train is coming
Stopping for Mechanical or Electrical Device (S11-701--A1)	Flashing Lights	Approximately same as UVC	Driver cannot proceed until devices stop working
Stopping for Audible Signal (S701--A3)	Crossbucks	No related laws	No related laws
Stopping for Train in Sight (S11-704-A4)	Crossbucks	No related laws	No related laws

Enforcement Practices

A 1973 survey by Sanders, Kolsrud, and Berger (4) highlighted the problem of variable enforcement practices. The survey team asked approximately 650 drivers in 4 states (Michigan, Maryland, Texas, and California) who had just traversed a rail crossing the following questions: "Have your ever known anyone who received a traffic ticket for crossing a railroad track when the signal was on or the gate was down?" Approximately 90 percent answered negatively; six percent answered affirmatively; and four percent did not answer. Using unstructured interviews, staff members also surveyed 15 police officers responsible for traffic enforcement in the same four states. All 15 indicated that they had never written a ticket for violations of the law at rail highway crossings and that they were unaware of any tickets being issued for this type of violation.

Driver Attitudes and Understanding

Relatively little research has been done on driver attitudes; however, the research that has explored this field suggests that the average driver harbors misconceptions on the nature of rail highway crossings.

The 1973 study conducted by Sanders, Kolsrud and Berger (4) included an extensive survey on driver attitudes relating to rail highway crossing safety which indicated that drivers do not fully understand the nature of rail highway crossings.

The authors interviewed 1,566 drivers at nine different crossings. This survey showed that 65 percent of these drivers believed that crossbuck warning devices indicated that the crossing with crossbucks has low train volumes. Moreover, 50 percent of these drivers indicated that only slow trains used passive crossings.

In addition, when the survey was administered at an active warning crossing, 27.8 percent of the drivers indicated that all rail highway crossings were equipped with active warning devices. When survey findings administered at both crossbuck and active warning device crossings were totaled, 15.4 percent of drivers surveyed indicated that all rail highway crossings had active warning devices.

The Sanders (4) study also identified credibility of active signals as another common misconception. Of the drivers surveyed, 37.6 percent believed that the crossing signal does not always indicate that a train is approaching.

Driver Judgment

One factor involved in rail highway crossing accidents is driver judgment. The task of judging train speed or distance is a difficult one for drivers either in moving vehicles or when stopped at a crossing.

In 1968, Schoppert and Hoyt (3) first documented the difficulty of the task of searching and recognizing targets (vigilance behavior). They referenced research on identifying enemy aricraft during World War II, to support their conclusion that humans do not perform well at the task of searching and identifying targets especially under conditions where the probability of target detection is low. Schoppert and Hoyt compared this situation to the passive crossing situation in which drivers must search for oncoming trains when they are not warned of trains beforehand by active devices.

Russell (11), in a study on rail highway crossings, concludes that new and faster trains will add to the judgment problem. Even with adequate sight distances, the ability to estimate the closing speed of high speed trains and make reliable "stop and go" decisions may be poor.

A 1978 report (6) indicates that drivers stopped at crossings cannot judge the speed of the train. The report states, "for most people, accurate judgment of the speeds and distances are impossible tasks. Even if the speed and the instantaneous distance of the train are judged accurately, the driver will not know with certainty whether it is safe or not to cross. The decision to cross or otherwise will, therefore, be largely an intuitive decision

In the case of a moving vehicle and a moving train,the report (6) states, "Average persons are not capable of accurately estimating speeds and distances without instruments. Moreover, the driver must know the critical distances at various combinations of speeds of the train and their own vehicle and must be able to make accurate comparisons in very short periods of time. These tasks are considered humanly impossible even under the most simple conditions.

Even though high speed trains exacerbate the problem, judging closing distances for slower speed trains as well may also be difficult. The data presented in the FRA 1978 Rail-Highway Crossing Accident/Incident and Inventory Bulletin No. 1 (2), shows that the majority of rail highway accidents happen at very low train speeds. Table 4 presents this data. Even though exposure data is not considered in Table 4, these data may suggest that while humans have difficulties judging closing train distances at any speed, they may, in fact, have a more difficult time at slower speeds.

The problem of human judgment was summed up by a California study on the effectiveness of active warning devices at crossings (12). The study concludes, "Automatic devices will not prevent accidents caused by complete driver inattention, excessive speed, violation of the law or lack of driver judgment. Automatic devices are a tremendous preventative tool, but they will only reach their potential when combined with driver awareness of the hazards involved and the obligation a driver faces when approaching a rail street crossing."

Table 4. Accidents/Incidents and Casualties at Grade Crossings Involving Motor Vehicles by Train Speed and Type of Train, 1978.

Train Speed (MPH)	Total Accident/Incident	Killed	Injured
Standing	274	18	125
1 - 9	3,824	44	696
10 - 19	2,431	79	799
20 - 29	2,097	134	927
30 - 39	1,582	233	746
40 - 49	1,106	240	532
50 - 59	382	120	147
60 - 69	95	24	43
70 - 79	62	30	38
80 - 89	2	3	0
90 and Over	2	1	0
Unknown	142	3	67
TOTAL	11,999	929	4,120

Source (2)

CHAPTER 3. DATA SOURCES

Data Base Evaluations

The data bases which can identify accident causation factors at rail highway crossings are extremely limited. Many data bases include demographic information but few include information sufficient to identify accident causation factors.

The study team explored data bases available from organizations of the Federal Government, railroads, insurance companies and state agencies. Originally, the study team felt that data existed which could identify accident causation, however, these efforts proved unsuccessful. It became necessary to combine data bases from different sources and supplement this data with information gathered in two field surveys.

On a national level, sources of data were explored at three agencies: the National Highway Traffic Safety Administration (NHTSA), the Federal Railroad Administration (FRA), and the National Transportation Safety Board (NTSB). NHTSA had gathered four major data bases, FRA had gathered two and NTSB had gathered two data bases. Each of the eight data bases was investigated and evaluated as to its usefulness in determining accident causation factors.

The National Highway Traffic Safety Administration's four computerized data bases deal with highway accidents in general. These data bases are: The National Crash Severity Study (NCSS), the National Accident Sampling System (NASS), the Multi Disciplinary Accident Investigation (MDAI), and the Fatal Accident Reporting System (FARS).

The National Crash Severity Sample data base considered only passenger automobiles and had been actively maintained for a limited time period. It was rejected for this study, because it could not be sorted by auto/train accidents.

The National Accident Sampling System data base was primarily designed to study automobile damage caused by traffic accidents. Started in 1979, it includes demographic information, alcohol involvement and some environmental information. It contains no accident narratives, and little information on rail highway crossing accidents. The study team analyzed the NASS accident forms and determined that they would be of limited use as they do not provide the causation information needed.

The Multi Disciplinary Accident Investigation data base has been maintained by the National Highway Traffic Safety Administration from 1968 to 1978. Data was gathered for this data base by teams of experts in the field of traffic safety. These teams would survey accidents sites and investigate accidents. A narrative is included along with the other data provided. This data base was ultimately rejected, due to the small sample size of 63 rail highway accidents covering the years of 1968 through 1978. In addition, the accident reports varied greatly as to their causation information. Certain teams provided excellent narratives with good detail while others provided only sketchy information which was not suitable for use in an accident causation study.

The final data base in the NHTSA computers is the Fatal Accident Reporting System data base. FARS includes all fatal accidents which occur in the highway accidents each year. The FARS data base contains approximately 1000 rail highway crossing accidents for each year that data was collected. This system includes data categories in environmental areas, demographics, signal and warning type and alcohol involvement.

This data base does not include either a narrative on the accidents involved or sight distances at the crossings. Both narrative and sight distance information are crucial to a study of accident causation.

The Federal Railroad Administration maintains two data bases of interest to our study. The first data base which we investigated was the United States Department of Transportation - Association of American Railroads (U.S. DOT-ARR) Crossing Inventory Information data base and the second was the Federal Railroad Administration (FRA) Rail-Highway Grade Crossing Accident/Incident data base.

The U.S. DOT-AAR Crossing Inventory Information data base includes information on the physical characteristics of the crossings, railroad operational information at the crossings and some geometric information. A major drawback with this data base is the lack of sight distance information.

The FRA Rail Highway Grade Crossing Accident/Incident Report data base includes all rail highway accidents reported to the FRA. This data base is fairly extensive as to demographics, crossing type and estimated damages and injuries. However, it also lacks both a narrative and sight distance information.

The National Transportation Safety Board data base is not a computerized data base but is a structured collection of accident investigations. NTSB also uses the team of experts approach similar to the approach used for the MDAI data base system. The data base is divided into two distinct categories: major accidents and minor accidents. Major accidents are described in lengthy written narratives while minor accidents are described in brief reports which include no narrative. Information on minor reports resembles information provided by data bases such as FARS and NASS.

The NTSB source covered 17 major accidents. Though the information is presented in a format which would have been extremely useful to our study, the sample size was not random in nature and was extremely small.

The study team investigated the possibility that insurance companies may have good data bases. As part of our data base search, we contacted four insurance companies: Liberty Mutual, Geico, State Farm and Allstate Insurance Companies. Insurance company data bases are generally designed to provide statistics on the rate structure of individual accounts. They include little if any information on accident causation of rail highway accidents.

The railroads contacted for information indicated that the rail highway accident files kept in various claims offices would not be released to our study team for legal reasons. After identical replies from a number of railroads, the team decided to discontinue the data search in this area.*

State data bases are varied in the amount and type of information provided. Some states have narratives and diagrams along with standard demographic information, while others have basic forms that provide little information.

Data Sources Utilized

The study team chose North Carolina and Wisconsin as field survey sites. There were a number of reasons for their selection. First and most important, these state accident

*Certain railroads did provide us with track circuit data for our on-site survey crossings.

reports provided good information and the accident reports were fairly complete. In addition, the reports were accessible; these states agreed to provide photocopies of each individual accident report for 1978 and 1979.

While the accident reports from North Carolina and Wisconsin were relatively complete, they lacked good sight distance information, information on train speed, average daily traffic and train volume information.

The study team decided that a combination of the U.S. DOT-AAR Crossing Inventory Information data base, the FRA Rail-Highway Grade Crossing Accident/Incident data base, the Wisconsin and North Carolina Accident reports and the data gathered on the field survey would provide a usable data base.

Table 5 was constructed to enable the study team to better evaluate the data bases and to decide which information elements would be needed in determining accident causation factors.

The matrix illustrates how data bases were combined to provide the necessary data elements. The U.S. DOT-AAR Crossing Inventory Information data base provides elements missing from state reports, specifically traffic volume, train volume, train speed ranges and maximum timetable speed. The FRA Rail-Highway Grade Crossing Accident/Incident data base provides information on the actual train speed involved in the accidents investigated and the speed of the vehicle at impact (this data was missing in the Wisconsin Accident reports). In addition the FRA Accident data base would serve as a check against the state accident reports. Finally, the site visits would allow the study team to measure quadrant, approach and stop line

Table 5. Information Available From Data Sources.

Accident Causation Elements	DOT/AAR Inventory Report	FRA Accident Report	FARS DATA BASE	North Carolina Accident Reports	Wisconsin Accident Reports	On-Site Survey Data
Age			X	X	X	
Sex			X	X	X	
Time of Day		X	X	X	X	
Sight Distance Case #1						X
Sight Distance Case #2		X*		X*	X*	X
Sight Distance Case #3						X
Track Circuit						X
Warning Device	X	X	X*	X	X	X
Weather		X	X	X	X	
Vehicle Approach Speed			X	X		
Train Speed		X		X		
Vehicle Speed at Impact		X		X		
Steep Approach Grade			X	X	X	X
Heavy Traffic	X					X
Adjacent Intersection	X			X	X	X
Rough Crossing						X
Train Volume	X					
Train Speed Range	X					
Type of Vehicle		X	X	X	X	
Crossing Angle	X*					X
Clutter						X
Narrative				X	X	
Alcohol Use			X	X	X	

*Incomplete Data Element

sight distances necessary to determine the type of driver failure involved in the accidents being reconstructed. In addition, the site survey would provide information on geometric conditions such as sharp curves, adjacent intersections, and steep approach grades.

CHAPTER 4. STUDY PLAN

Given the constraints of the study described in Chapter 1, to limit the field surveys to crossbuck and flashing lights crossings and to eliminate alcohol-involved and stalled vehicle accidents, a study plan was developed. In addition to these constraints, selection of field sites was limited to those crossings where all of the data items were available, specifically the U.S. DOT-AAR Crossing Inventory Information print-outs, the FRA Rail-Highway Grade Crossing Accident/Incident reports, and the state accident reports. With these considerations in mind, the following study plan was developed:

Preliminary analysis of state accident reports

On receiving 1978 and 1979 accident reports from Wisconsin and North Carolina, crossings were sorted first by type of warning device (i.e., flashing light, crossbuck) and then by county within the state.

Geographical selection for accident site investigation

In Wisconsin, the geographical survey area was limited to six contiguous southeastern counties of Milwaukee, Waukesha, Dane, Jefferson, Rock, and Dodge. This selection was made to limit travel time between crossing locations.

The entire state of North Carolina was considered for the sample area. This decision was influenced by the fact that North Carolina statewide provided only 54 flashing light accident reports.

Compiling information packets

After the geographical survey areas were chosen, the Federal Railroad Administration was contacted to procure the U.S. DOT-AAR Crossing Inventory Information printouts and the FRA Rail-Highway Grade Crossing

Accident/Incident Reports for each of the crossings within these areas. These reports were combined with the state accident reports and data packets were assembled for each crossing.

Sample Selection

Not all accident crossings in the survey areas were used for sample selection purposes. The study team reviewed each data package and eliminated crossings with the following characteristics:

- Data packet was incomplete (i.e., the U.S. DOT-AAR Crossing Inventory Information Printout, the FRA Rail-Highway Grade Crossing Accident/Incident Report or the State Accident Report was missing).

- Accident involved alcohol
- Accident involved a stopped, stalled or standing vehicle

Given the time and resource constraints, the study team decided that the survey should consist of approximately 40 total crossings in each state.

Samples were selected individually for each state. In Wisconsin, a random sample was selected. The sample that was chosen consisted of 24 flashing light crossings, and 16 crossbuck crossings for a total of 40 crossings. The 24 flashing light crossings had 20 accidents in 1979 and 4 accidents in 1978. The 16 crossbuck crossings experienced 10 accidents in 1979 and 6 accidents in 1978.

In North Carolina, 19 flashing light crossings were chosen on a random basis. Next the crossbuck sample of 20 was chosen so that these crossings would cluster around the flashing light crossings in the sample to minimize travel time.

Accident Site Investigation

The study team analyzed the accident using the three data sources previously obtained as well as data collected on-site. All of this information was combined into field information packets for each accident in the sample. The actual site survey procedures used by the study team are further described in the next chapter.

Accident Analysis

The study teams analyzed the field information packets for each crossing using a two step approach. First, for each accident, the accident type was determined based on the event sequence which led to the accident. Second, an evaluation was made regarding those contributing factors which, based on the event sequence, were judged to have contributed to the accident. Details of this process are described in Chapter 6.

CHAPTER 5. ACCIDENT SITE RECONSTRUCTION

One major aspect of the accident site investigation is determining, after the fact, what accident-involved drivers saw as they approached the crossing where the accident occurred.

As a driver approaches a crossing, his perspective changes and the amount of sight distance also changes. Therefore, specific points along the roadway from which to measure sight distance must be defined and important site characteristics as seen from these points identified. To accomplish this, the study team adapted the information handling zones defined in the <u>Users Guide to Positive Guidance</u> (13) to meet the specific needs of the study.

Since the zones and sight distance are important to the accident site investigation this chapter will begin by defining these zones and the associated sight distance terminology used in the analysis. The accident site investigation procedures followed on the site surveys also will be described.

Definition of Terms

<u>Information handling zones</u> are particular areas of road which correspond to sections of roadway on which drivers should ideally make certain decisions concerning the upcoming rail highway crossing. Decisions differ from zone to zone. Three information handling zones are significant for this study: hazard zones, nonrecovery zones and approach zones. (See Figure 2.)

<u>Hazard Zone</u> -- The hazard zone is the rectangle formed by the width of the roadway and a distance measured along the roadway on either side of the tracks. This zone is the area where

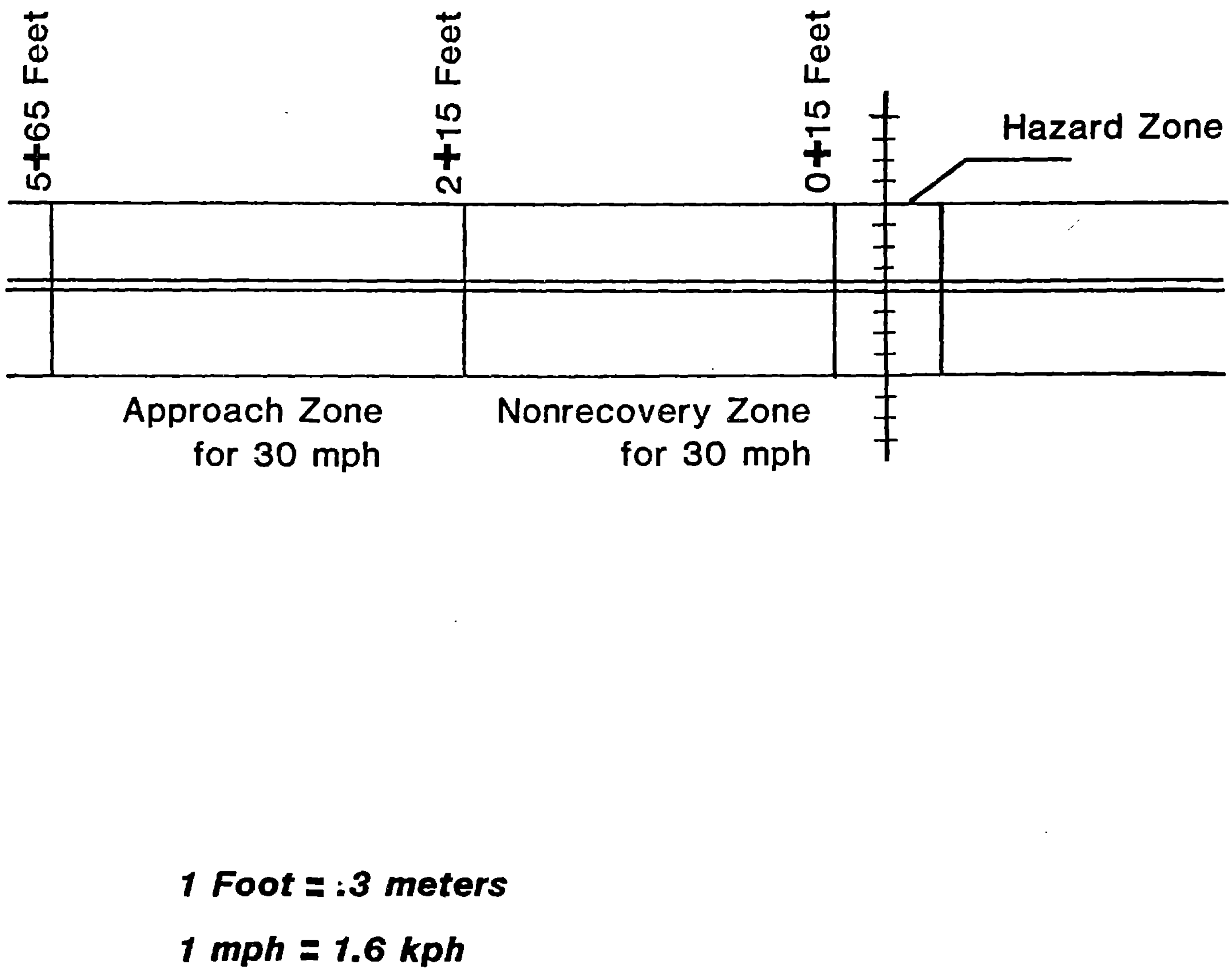


Figure 2. Graphic Representation of Information Handling Zones.

stopped or approaching motor vehicles can collide with the approaching or stopped trains. For the purpose of our study, this zone begins 15 feet (4.6 meters) from the closest rail and ends 15 feet (4.6 meters) from the farthest rail. (See Figure 2).

Nonrecovery Zone -- The nonrecovery zone is the area preceding the hazard zone that begins at the point along the roadway where drivers must make stop/go decisions. Theoretically, if the stop/go decision is delayed beyond the beginning of the nonrecovery zone, the amount of roadway remaining will be insufficient to avoid a collision. The nonrecovery zone ends at the beginning of the hazard zone. This zone is illustrated for a speed limit of 30 MPH (48.3 KPH) in Figure 2.

Nonrecovery zone distances are based on the design speed of the roadway and on the assumption that worst case driving conditions exist. Table 6 shows nonrecovery zone boundaries for various assumed speeds. Boundary distances were approximated by interpolating data found in the Transportation and Traffic Engineering Handbook (14).

Table 6. Nonrecovery Zone Boundaries.

Assumed Speed	Beginning of Zone	End of Zone
25 mph	165 feet	15 feet
30	215	15
35	250	15
40	290	15
45	325	15
50	415	15
55	465	15

1 MPH = 1.6 KPH
1 FOOT = .3 METERS

Source (14)

Approach Zone -- This zone is the area in which drivers begin to formulate actions needed to avoid colliding with trains. Drivers use this zone to search for a train or signal, to recognize any hazards, and to decide on the proper course of action. The approach zone precedes the nonrecovery zone. Its beginning point is based on the design speed of the roadway and it ends at the nonrecovery zone. Worst case driving conditions are assumed. Figure 2 also illustrates the approach zone for a vehicle speed of 30 MPH (48.3 KPH): Table 7 shows approach zone boundaries for various assumed speeds. Boundary distances were approximated by interpolating data found in the Users Guide to Positive Guidance (13).

Table 7. Approach Zone Boundaries.

Assumed Speed	Beginning of Zone	End of Zone
25 mph	465 feet	165 feet
30	565	215
35	665	250
40	765	290
45	840	325
50	915	415
55	1,040 feet	465 feet

1 MPH = 1.6 KPH
1 FOOT = .3 METERS

Source (13)

Sight Distance and Associated Track Zones are closely related to each other. The importance of a particular sight distance or the critical track zone depends on the circumstances existing at the time the driver approaches a crossing or is stopped at a crossing. Such factors as vehicle speed, train speed, and weather conditions combine to influence the importance of a sight distance or critical track zone. Three sight distances and two critical track zones are significant for this study. A graphical representation of these sight distances and critical track zones are shown in Figure 3.

The three sight distances are:

- Approach Sight Distance
  (See Figure 3 - from point B to point D)

- Quadrant Sight Distance
  (See Figure 3 - from point B to point E)

- Stop Line Sight Distance
  (See Figure 3 - from point C to point F)

The two track zones are:

- Critical Track Zone for Stopped Vehicles
  (See Figure 3 - from point D to point F)

- Critical Track Zone for Moving Vehicles
  (See Figure 3 - from point D to point E)

Approach Sight Distance -- The approach sight distance is measured from the crossing to the point along the roadway where the crossing and warning device first become visible to approaching drivers. Inadequate approach sight distance exists when the approach distance is either less than the minimum stopping distance or less than the distance from the beginning of the nonrecovery zone to the crossing (See Figure 3).

Critical Track Zone (for a moving vehicle) -- The critical track zone is the distance measured from the roadway to the point on the tracks at which a train would be hazardous to vehicles entering the nonrecovery zone. At this point, time to stop for the train or to safely cross the railroad tracks in advance of the train would be inadequate. (See Figure 3)

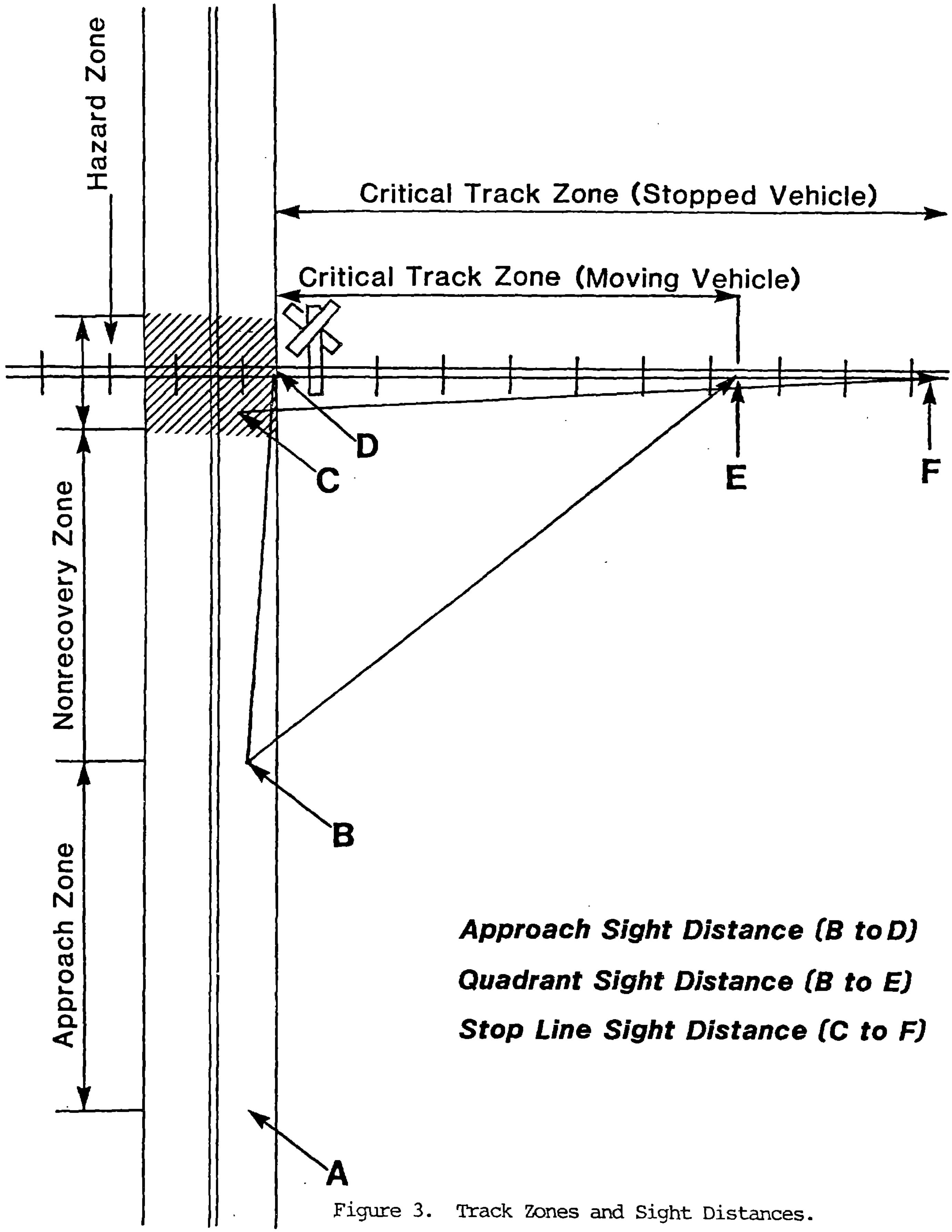


Figure 3. Track Zones and Sight Distances.

Quadrant Sight Distance -- The quadrant sight distance is measured from the roadway to the point on the tracks at which an approaching train would be visible to an approaching driver. This sight distance is typically measured by using the beginning of the nonrecovery zone as the driver reference point. When actual speeds traveled by approaching vehicles are known, the minimum stopping point is used as the driver reference point instead. Trees, buildings or hills may be the objects that limit the track view. Where the quadrant sight distance is less than the critical track zone for moving vehicles, the site is said to have limited or inadequate sight distance. Where this distance is greater than the critical track zone for moving vehicles, adequate quadrant sight distance exists. Figure 4 graphically illustrates this point.

Critical Track Zone (for stopped vehicles) -- The critical track zone for stopped vehicles is the distance measured from the roadway to a point along the tracks at which an approaching train would present a hazard to any vehicle entering the hazard zone. A vehicle would not have sufficient time to accelerate from a stop or near stop and cross the tracks safely.(See Figure 3.)

Stop Line Sight Distance -- This distance, sometimes called stop bar sight distance, is measured from the roadway to the farthest point on the tracks visible to the driver of a stopped vehicle. Where this distance is less than the critical track zone for stopped vehicles, a condition of indequate stop line sight distance exists.(See Figure 3)

Data Collection

Data collection was based on a combination of existing state and federal reports. Information gathered during on accident site investigation supplemented these reports. Finally, data items judged to be crucial to accident reconstruction were then compiled on a preliminary accident analysis work sheet.

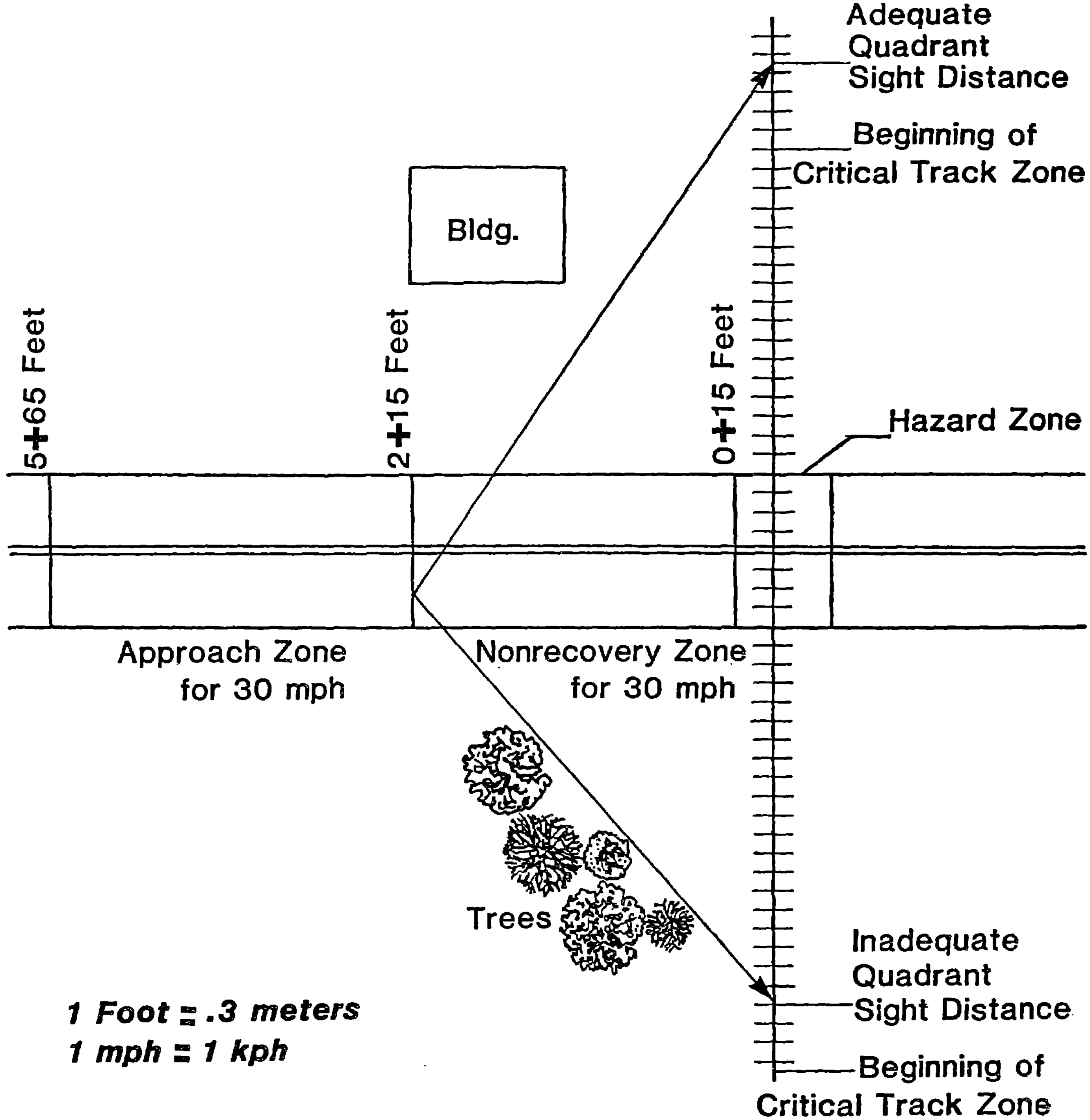


Figure 4. Adequate and Inadequate
Quadrant Sight Distance.

The data sources used for accident site investigation were:

- State accident reports
- FRA Rail-Highway Grade Crossing Accident/Incident Reports
- U.S. DOT-AAR Crossing Inventory Information printout

State Accident Reports -- The state accident report served as the basis for accident reconstruction. These reports contained speed information, the type of warning device and whether or not it was functional at the time of the accident, environmental conditions and general site information. Narratives with supplemental information were included in these reports; however, the amount of information provided was highly variable. The most useful information in the report was the speed limits of the road, the approach speed of the vehicle and, in some cases, the final vehicle speed at impact. Skid mark information from these reports also proved useful in the study analysis.

Wisconsin accident reports proved to have one serious omission: they did not include information on vehicle approach speed or vehicle speed at impact. This information was collected from the FRA Rail-Highway Grade Crossing Accident/Incident reports or was calculated from the impact speed reported in the FRA report.

FRA Rail-Highway Grade Crossing Accident/Incident Reports -- Information in the FRA accident reports proved especially valuable in two respects; first, the reports provided a second source of information used to validate data in the state accident reports, and secondly, they provided additional information not available from state accident reports. The additional information in the FRA reports included train speed, the position of the train car which was hit by the motor vehicle, and the vehicle speed at impact (not available in Wisconsin state reports).

When information from state reports and FRA reports differed, the study team judged which data best fit into the overall circumstance. When this judgment could not be made, the information in the state accident reports was accepted.

U.S. DOT-AAR National Railroad-Highway Crossing Inventory

The inventory provided data on train volumes and average daily traffic for the roadway which was important in determining accident causation. In addition, the inventory provided information on maximum timetable train speed and the range of typical train speeds. Warning device information is also included in the inventory.

The supplemental information that was used in the preliminary accident analysis was:

- Crossing Site Drawing
- Crossing Site Photographs
- Accident Analysis Work Sheet

Crossing Site Drawing -- The site drawing details the characteristics of the crossing. The field survey team first measured the approaching zones -- approach, nonrecovery, and hazard -- using the speed limit of the approach road.

The location of any signs, commercial drives, intersecting roads and buildings were noted. Any vertical or horizontal curves in the roadway were noted, and the crossing angle was measured.

From the beginning of the nonrecovery zone, approach sight distance was measured and a determination made as to its adequacy. For the approach sight distance to be adequate, the driver must clearly be able to see the crossing signal or sign from the beginning of the nonrecovery zone. Also, the actual quadrant sight distance was measured from the beginning of the nonrecovery zone and a determination made as to its adequacy based on train speed and road vehicle speed limits.

The next factor noted on the site drawing was the minimum stopping point based on the actual vehicle speed and on the prevailing weather and illumination conditions at the time of the accident. The team determined if the minimum stopping point would have allowed adequate sight distance in the following manner. A photograph was taken of a team member standing along the railroad tracks with a target pole at the point the train was calculated to have been when the vehicle was at the minimum stopping point. If the pole was not in sight, the site was judged to have inadequate sight distance for this accident.

Finally, for accidents involving vehicle skid marks, a decision point was calculated. A photograph was taken of the target pole at the approximate location of the train. This last measurement indicated the point at which the driver reacted.

The final measurement noted on the site drawing was the track circuit at flashing light crossings.

Crossing Site Photographs -- The photographs of the crossings were for the purpose of documenting the crossings and their immediate surroundings. The photographs helped to recall clutter or other characteristics that may have impacted on driver behavior at the time of the accident. Each photograph was numbered to correspond to a point on the site drawing.

A set of crossing photographs included a pan* of two photographs from the beginning of the approach zone, a pan of four photographs from the beginning of the nonrecovery zone and one photograph each from the minimum stopping point and decision point where applicable.

Preliminary Accident Analysis Work Sheet -- This work sheet highlighted important facts in state and FRA accident and inventory reports such as initial speed of the vehicle, train speed, impressions of the survey team members, weather conditions at the time of the accident and the time of day. In addition, notes on clutter, unusual geometric designs, reasons for the initial assignment of cause and any other information deemed helpful for the final accident analysis were included.

*To take overlapping photographs in such a manner as to create a panoramic effect.

CHAPTER 6. METHODOLOGY FOR THE ACCIDENT ANALYSIS

The data collected for each accident in the indepth accident sample was analyzed using a two step approach. For each accident the accident type was determined based on the event sequence which led to the accident. Then an evaluation was made regarding those contributing factors which, based on the event sequence, were judged to have contributed to the accident.

The event sequence accident types denote a number of recognition, decision and action errors and are discussed in the section on the Conceptual Model of Driver Behavior. The succeeding sections discuss the criteria for selection of the contributing factors and define the contributing factors for accidents at crossings with flashing light and crossbuck warning devices.

Conceptual Model of Driver Behavior

This section describes the framework which was used to evaluate the event sequence accident types and the contributing factors for the indepth accident sample. A conceptual model of driver behavior was adapted to the rail highway crossing situation so that each accident could be characterized in terms of the event sequence which led to the collision, and the prevailing conditions which were believed to have significantly contributed to the occurrence of the accident.

The assignment of contributing factors for any given accident requires that the operational steps in driving guidance and control be fully specified. Fundamentally, an accident occurs because a driver is not able to select an appropriate speed and path through a roadway segment, and/or is unable to successfully carry out that decision. The fact that a driver has made an error is not the essential consideration. Rather, it is necessary to focus attention on the prevailing conditions which interacted to create the opportunity for driver error. These prevailing conditions would encompass the full spectrum of driver, vehicle, and roadway characteristics.

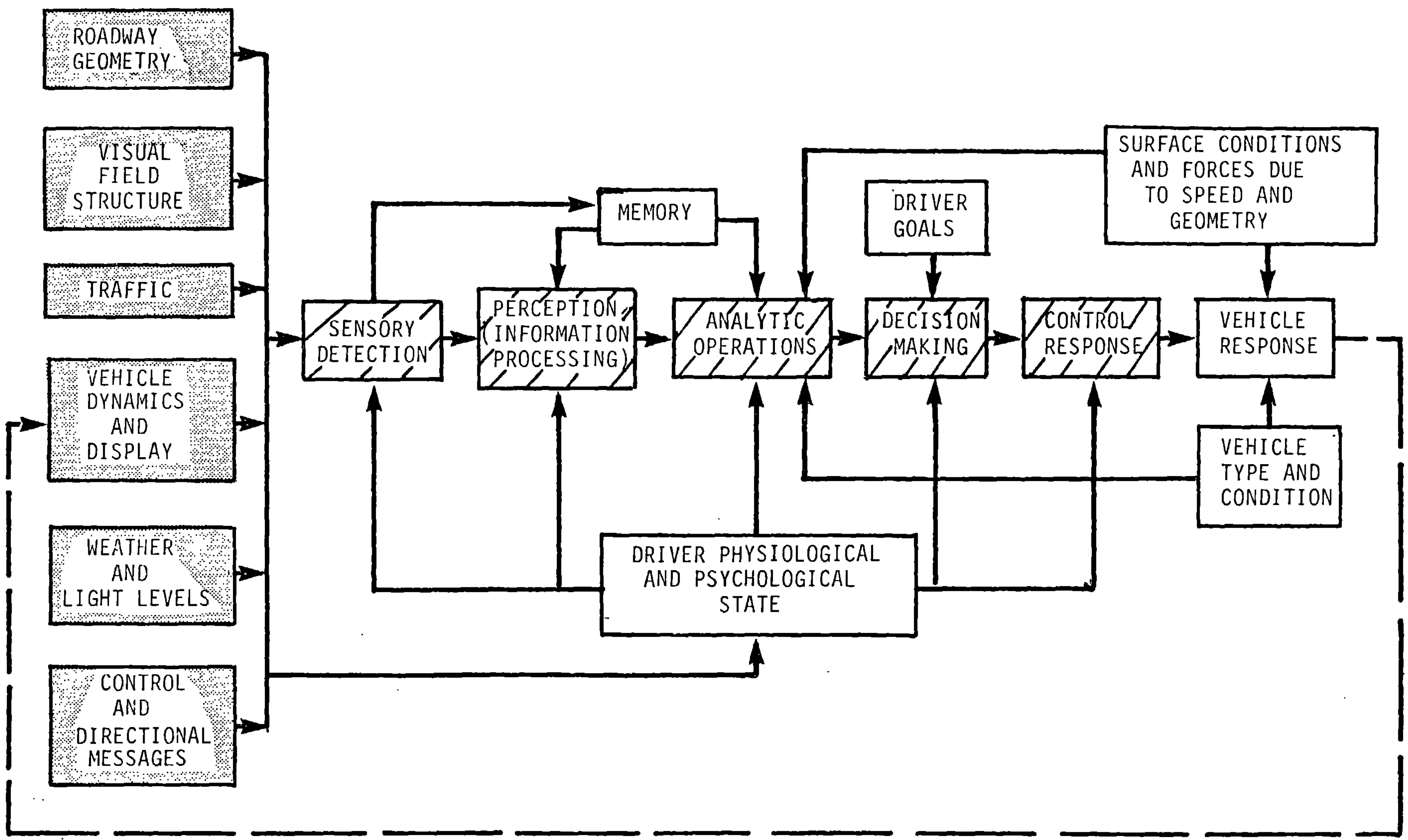
A useful model for conceptualizing these behavioral relationships is one formulated by Michaels (15) and shown in Figure 5. The model depicts the operational steps in driving guidance and control in the context of a driver-vehicle-roadway system. The shaded blocks labled sensory detection, perception, analytic operations, decision-making, and control response constitute the basic chain characterizing the driver guidance and control process. A breakdown at any one of these tasks can lead to an accident.

The performance of these tasks is shown to be a function of a variety of information inputs from the driver-vehicle-roadway system. In the context of the rail highway crossing, roadway geometry includes the various design features of the street or highway as well as the crossing itself. Visual field structure refers to the objects, lines, edges, road textures and contrasts within the driver(s) visual field. Traffic information includes the velocities and positions of other vehicles, including approaching trains. Information about vehicle response to adjustments in speed and path are transmitted to the driver by means of kinesthetic senses or visual reading of dashboard instruments. Weather and light conditions affect the driving process by altering the available tire-roadway friction as well as the amount of information that can be seen and used for vehicle control.

Traffic control devices, including the warning devices at the rail highway crossing, inform or misinform the driver, depending in part on their conspicuity and credibility. The driver's prior knowledge influences his expectancy regarding various rail highway crossing situations, and therefore the way in which he responds to the hazard presented by the crossing. Vehicle type and condition also influence the response of drivers to hazardous situations. Finally, the driver's own physiological and psychological state will modify the entire guidance and control process.

It is clear that the possible driver-vehicle-roadway interactions are numerous and complex. If reasonable countermeasures to rail highway crossing accidents are to be developed, then it follows that the principal interaction patterns which are active in the case of vehicle-train accidents must be identified, categorized, and interpreted in the context of a systematic model of driver behavior. For the purposes of this study, the basic tasks in the driving guidance and control process were aggregated into three elements: recognition, decision, and action.

It was hypothesized that the occurrence of a vehicle-train accident was the result of a recognition, decision, or action error. A recognition error was defined as a breakdown in the detection and/or perception of information necessary to: (a) recognize the presence or approach of a train, and (b) identify the available actions that would avoid a collision. A decision error was defined as a breakdown in either the analysis of that information, or the selection of an appropriate collision avoidance maneuver. For this type of error, it was assumed that the necessary information to perform these tasks had been detected and perceived in sufficient time to make a decision and successfully complete the maneuver. An action error was defined as the failure to successfully execute what would have been an appropriate collision avoidance maneuver.



Source (15)

Shaded Boxes - Information Inputs
Hatched Boxes - Driver Guidance and Control Process

Figure 5. Operational Steps in Driver Guidance and Control.

The evaluation of the possible presence of recognition, decision, or action errors associated with rail highway crossing accidents required that these basic tasks be considered within the context of a specific set of time-space relationships for a vehicle-train encounter. The principles of information handling zones as defined by positive guidance concepts (13) were used for this purpose. They were described in Chapter 5.

The basic recognition, decision, and action steps of the driving guidance and control process were integrated within the information handling zone framework to produce a set of logic flow charts which characterize the critical sequence of events which preceded each of the sample vehicle-train accidents. Each unique event sequence was examined for predominant patterns of contributing driver-vehicle-roadway factors. These joint patterns of event sequences and contributing factors then served as the foundation for characterizing the behavioral causes of various types of vehicle-train accidents, the frequency with which these patterns appeared, and potential countermeasures which might be considered.

Figure 6 illustrates the logic flow chart for event sequences and categories of driver error at crossings with flashing light warning devices. Figure 7 illustrates the logic flow chart for event sequences and categories of driver error at crossings with crossbuck warning devices. The charts are structured with the event sequence proceeding from top to bottom. At each recognition, decision, or action point, the alternative paths are identified. The charts therefore appear as trees whose branches terminate with a collision between the vehicle and train. Because each path or branch is unique, the driver error which resulted in the accident is identified both by type (recognition, decision, action), and by a number which references the specific event sequence. Each event sequence in figures 6 and 7 has a unique identification i.e., R1, R2, . . . D1, D2, . . . A1, A2. These event sequences are referred to in chapters 7 and 8 to identify the event sequence accident type to which the accidents were assigned.

For example, three possible decision errors were defined: D1, D2, and D3. In each case, the driver is believed to have recognized the train from the approach zone. For the D1 and D2 errors, the driver recognizes the train, but decides to maintain his initial speed and enters the nonrecovery zone. Once within the nonrecovery zone, the driver either decides to attempt to traverse the crossing ahead of the approaching train (error D1), or decides to make an emergency stop by placing the vehicle into a skid (error D2). In the case of a D3 error, the driver stops in advance of the hazard zone, but decides to traverse the crossing after the approaching train has entered the critical track zone. In each of the above situations, a decision error has been made. It then remains to examine the prevailing driver, vehicle, and roadway conditions to determine if there is a plausible explanation for the driver's behavior.

In addition to the three types of decision error, figure 7 illustrates the event sequences for four types of recognition errors and two types of action errors. Figure 6 depicts the similar event sequences and driver errors associated with crossings having flashing light warning devices.

Discussion of Contributing Factors

This section explains the criteria for the selection of contributing factors and discusses the selection of factors contributing to human recognition and decision errors at crossings with flashing light and crossbuck warning devices. Action errors are not discussed because the event sequence accident types assigned to the accident sample included only decision and recognition errors.

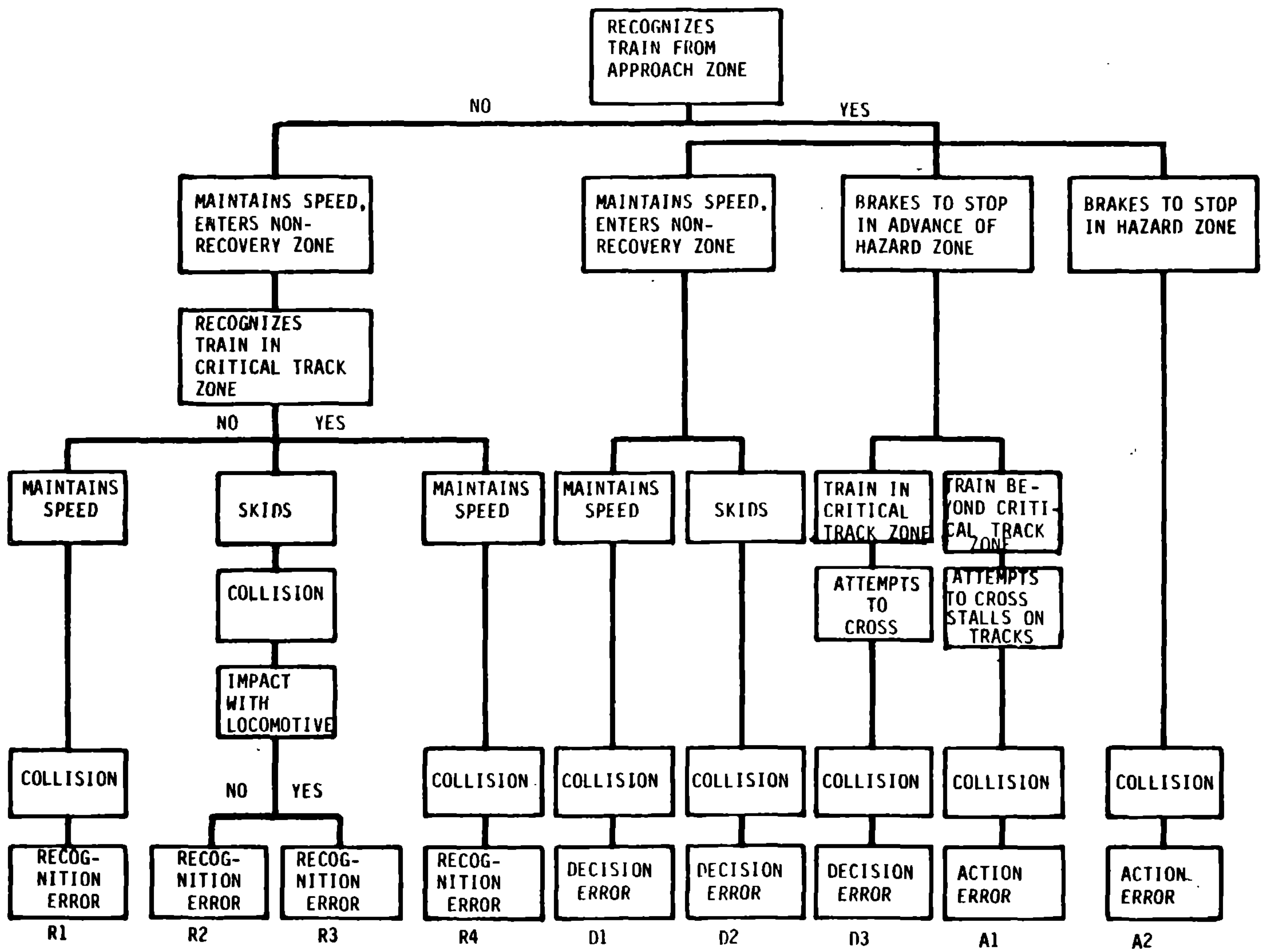


Figure 6. Logic Flow Chart for Driver Error Flashing Light Warning Devices.

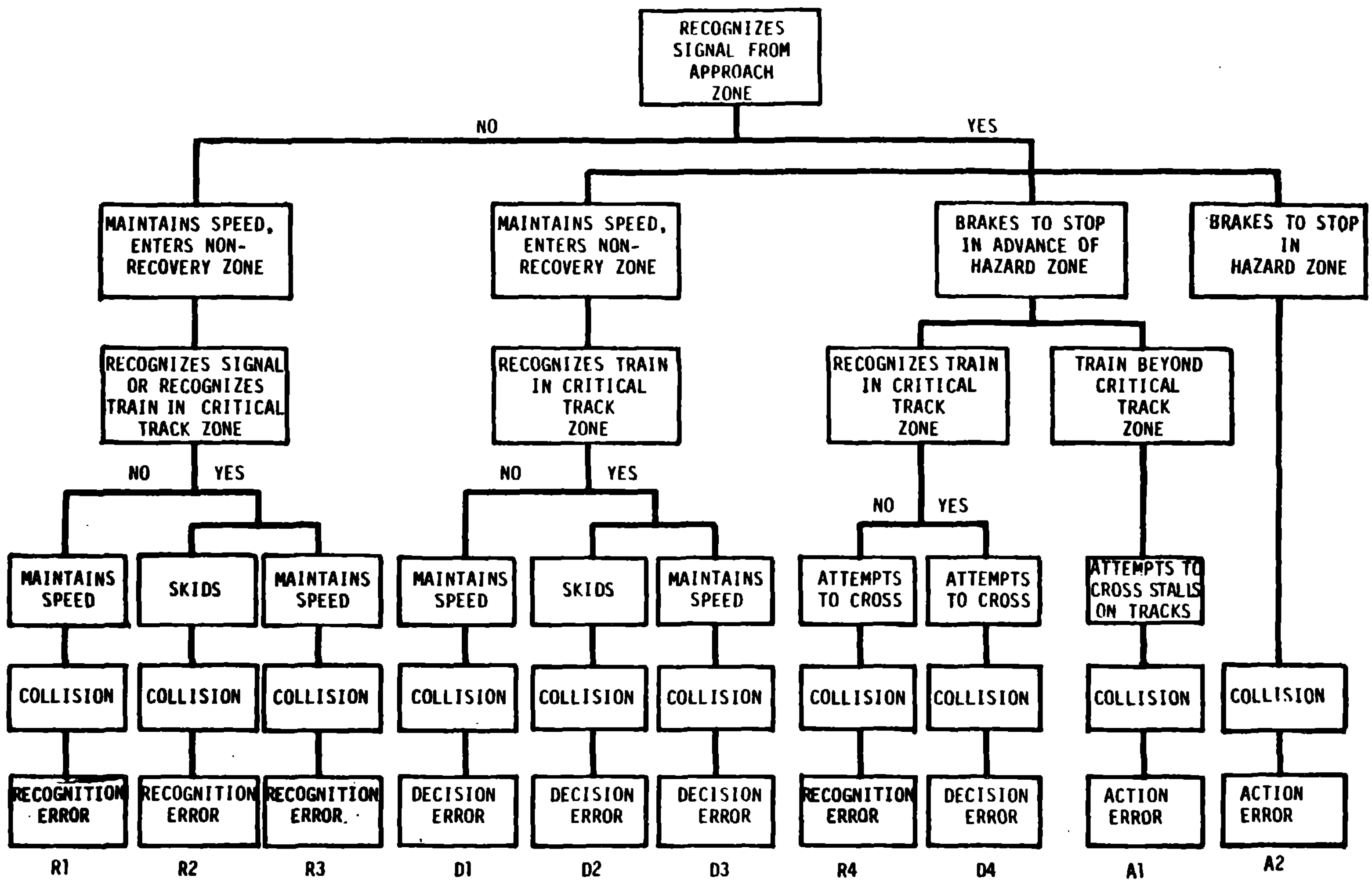


Figure 7. Logic Flow Chart for Driver Error Crossbuck Warning Devices.

The term contributing factors is used in lieu of causal factor. Causal factor could be interpreted to denote that the factor was the cause of the accident and once it was present an accident must occur or conversely, in its absence an accident would not occur. Rather, contributing factors are used to denote a set of prevailing conditions, which when present, can lead to or be associated with a type of accident.

The selection of the possible contributing factors was a dynamic process. It was initially based on the requirements of the study, the literature review, the analysis of factors in the Rail-Highway Crossing Accident/Incident and Inventory Bulletin (2) and on a review of the Wisconsin accident reports. Based on knowledge gained in the accident site investigation and from the accident analysis the lists of contributing factors were modified.

At the beginning of the study it was decided that the logistics of the study would not allow interviews of the drivers involved in accidents to ascertain their familiarity with the crossing nor their attitudes and understanding of signs, signals, train operations and potential hazards of the crossing. Nor was it possible to ascertain the driver's knowledge and interpretation of laws pertaining to the rail highway crossing at which the accident occurred or with rail highway crossings in general. Previously completed studies were reviewed to obtain general indications of the impact of these factors on rail highway crossing accidents.

As discussed in Chapter 2 there were sufficient previous studies that indicated that a majority of the drivers were familiar with rail highway crossings at which they were involved in accidents. The matching of drivers licenses to the state in which the accident occurred or the matching of addresses on drivers licenses with the accident location would not denote but only suggest familiarity with the rail highway crossing. Sanders, Kolsrud et. al. (4) in surveying drivers involved in accidents and the National Transportation Safety Board in their detailed accident reports (8) both indicated that the large majority of drivers were familiar with the rail highway crossing at which they were involved in an accident. Based on these previous studies, this study assumes driver familiarity with the crossing.

Driver attitudes and understanding are not explicitly examined via driver interview but are implicitly indicated by citing certain conditions which may impact driver attitudes and understanding. Sanders in Human Factors Countermeasures (4), discussed in Chapter 2, examined the issues of credibility, extended warning time and expectancy through the interview of 1556 drivers at nine different crossing locations. In this study (Rail Highway Crossing Accident Causation) the analysis of actual accidents includes driver characteristics such as inexperienced, elderly, and truck drivers and conditions such as extended warning time* at flashing light devices and expectancy at crossbuck devices. Based on these driver characteristics and conditions the driver may form certain attitudes, with regard to one or various crossings, which are then superimposed on the decision making process.

Chapter 2 discusses the laws pertaining to flashing light and crossbuck warning devices and crossings. Whether drivers involved in accidents were familiar with the law(s) could not be ascertained without interviewing the driver. An analysis of accident event sequences vis-a-vis the Uniform Vehicle Code's

---

*For this study extended warning time was defined as signal activation in excess of 30 seconds prior to the arrival of the train.

requirement for motorist stopping at rail highway crossings would show that certain drivers were not obeying the law. An analysis of the Uniform Vehicle Code's requirement on driver approach speed (to rail highway crossings) may indicate that the driver may not have sufficient information regarding actual and potential hazards. It was decided that the problem may not so much be due to lack of knowledge or disobedience of the law but rather negative reinforcement contrary to the law and a lack of information regarding potential hazards. The contributing factors include extended warning time, multiple tracks, heavy traffic, low train volume and second train which present problems of credibility, competing inputs and expectancy. The emphasis of the accident analysis will be on factors which negatively or positively reinforce drivers' driving habits though possible countermeasures may include law enforcement if that suggestion is warranted.

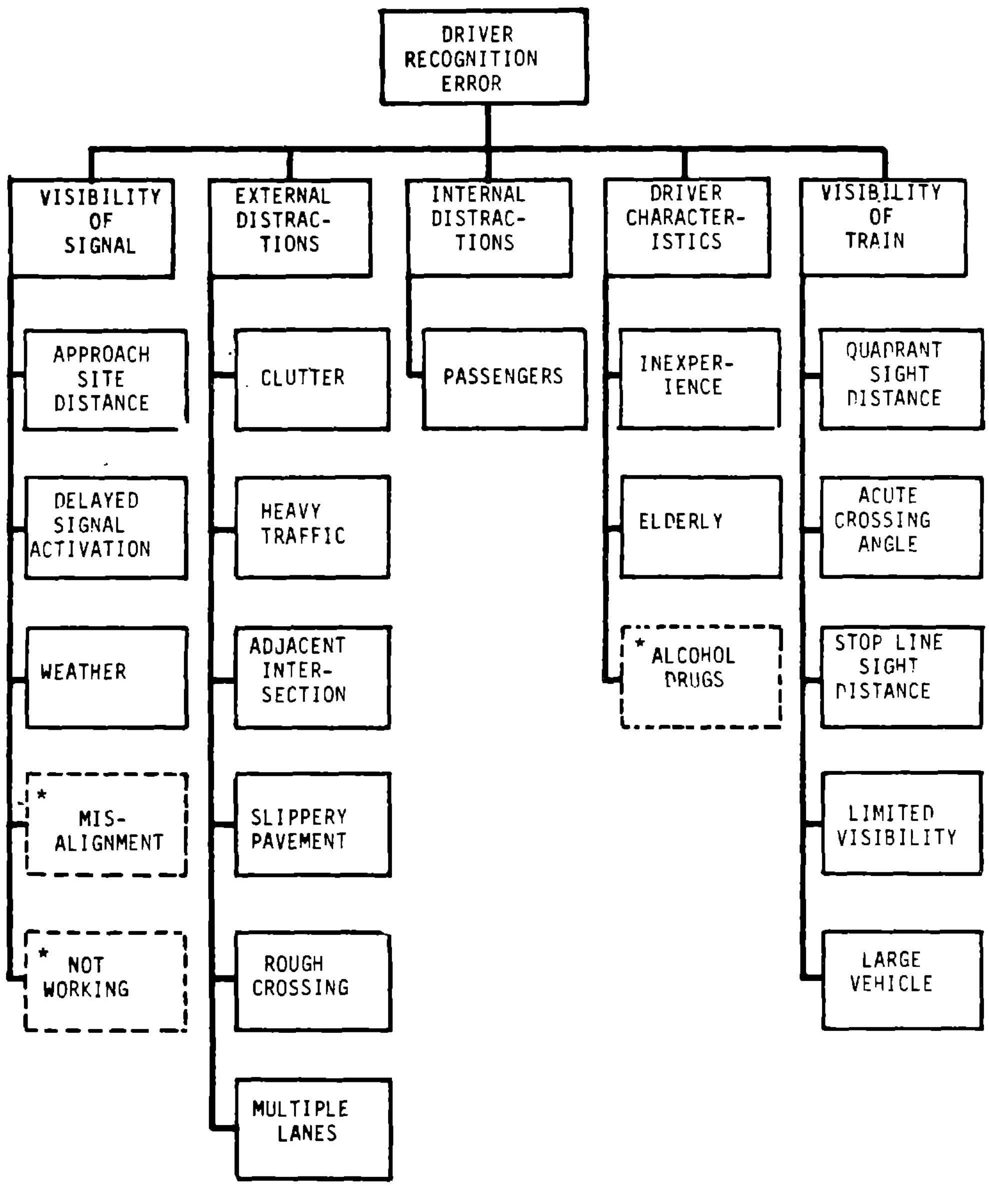
The actual contributing factors selected and the criteria for their selection are discussed in the next two sections.

Contributing Factors - Flashing Light Warning Devices

Figures 8 and 9 show the contributing factors for accidents at crossings with flashing light warning devices. At these crossings the emphasis is on the interaction and reaction of the driver with/to the signal from the approach zone and with the signal and/or train from the nonrecovery zone. The emphasis of the study is on driver recognition and decision errors with regard to the signal and the train.

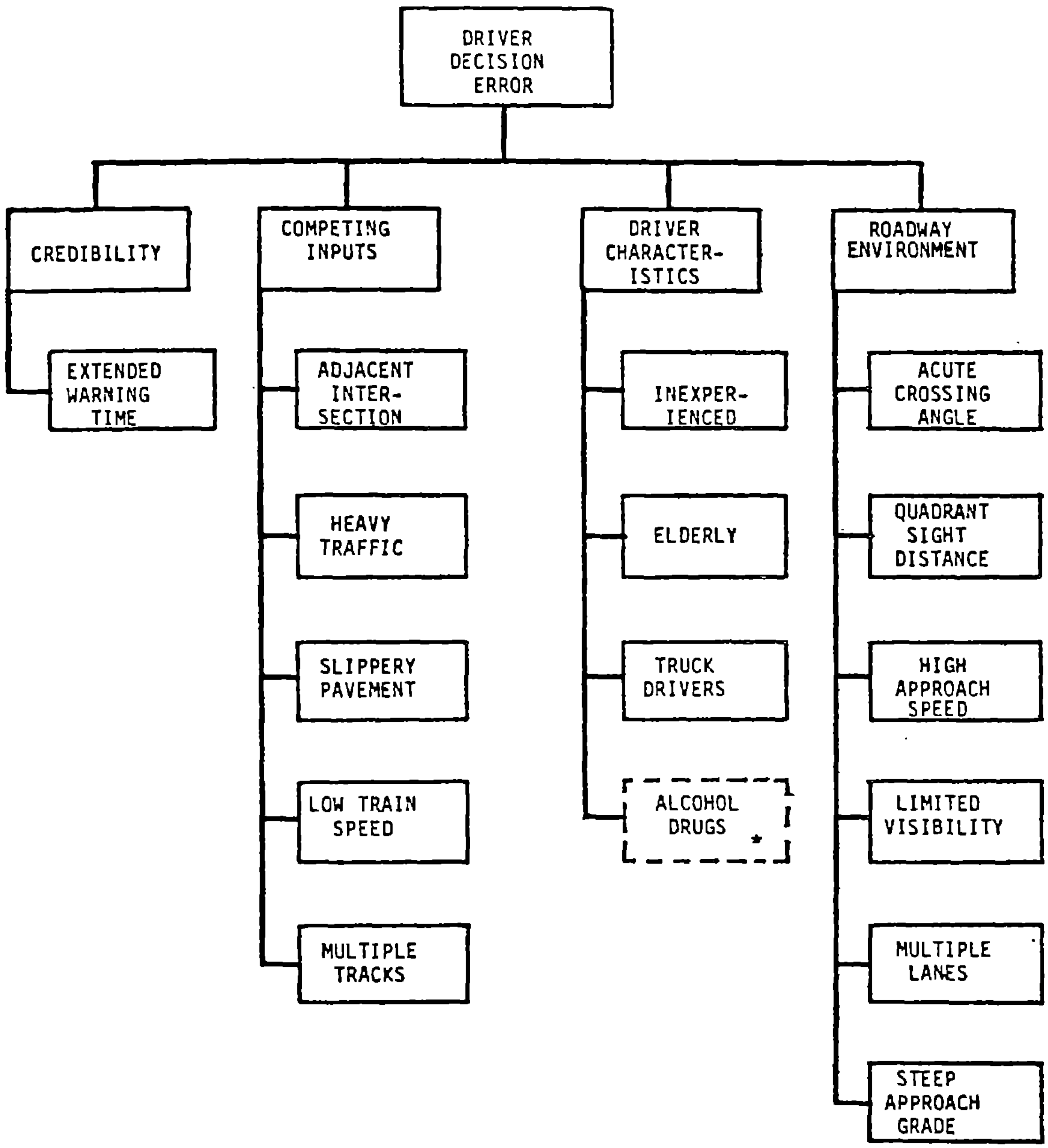
Driver Recognition Errors

Visibility of the signal, external distractions (competing stimuli), internal distractions, driver characteristics and visibility of the train are the five categories of factors contributing to driver recognition errors. See figure 8.



* Contributing factors not part of the accident analysis

Figure 8. Contributing Factors to Driver Recognition Flashing Light Warning Devices.



* Contributing factor not part of this accident analysis.

Figure 9. Contributing Factors to Driver Decision Error Flashing Light Warning Devices.

Visibility of the Signal. The signal could be obscured by foliage, man made objects such as buildings, poles and other signs and/or more temporary obstructions such as parked vehicles or snow banks. This is an approach sight distance factor.

Delayed signal activation would occur when the signal is activated by a train on a spur or switching track which only has an island circuit. Island circuits are located near the point where the track crosses the roadway and, without an advance circuit, the flashing light is activated only when the train is about to cross the road. Another case of only the island circuit activating the signal occurs when with advance circuits a switch train crosses the roadway and island circuit deactivating the signal and then backs up and only activates the signal via the island circuit.

Severe weather conditions such as heavy rain, snow or fog may obscure the activated flashing light. The sun's position behind the signal, causing a motorist to avert his eyes, also falls into this category.

Misalignment of flashing lights so that they are not conspicuous enough to attract the driver's attention in the approach zone could be a problem. Neither the resources nor the technical equipment were available to test this phenomenon. Had the equipment been available, the signals may have been realigned since the accident under regular maintenance procedures.

Signal lights not working is not a major problem according to the Rail-Highway Crossing Accident/Incident and Inventory Bulletin (2). There is also a definition or judgment problem when one light of a signal or one light set at a crossing with multiple light sets is not operating. When the state accident reports indicated a signal malfunction the accident was not included in the indepth accident investigation sample.

External Distractions. External distractions or competing stimuli could produce information overload which prevents the motorist from recognizing the activated signal. Clutter differs from approach sight distance obstruction in that the signal is visible but not readily recognizable due to inputs from other signs and signals. Heavy traffic, adjacent intersections, multiple lanes, rough crossings and slippery pavement are all factors which may, separately or in combination, have prior claim to the driver's attention. Rough crossing was checked when in the opinion of the site investigators, the crossing surface diverted the attention from the hazard to the roadway. The contributing factors category was checked for slippery pavement when this was reported on the North Carolina and Wisconsin accident reports. The accident analysis did consider ice and snow covered roads as presenting additional problems to the motorist.

Slippery pavement could also be listed under Visibility of Signal if ice and snow covered roads impact the approach zone and critical decision point to which the signal is normally set. The approach zone is calculated to account for stopping under wet pavement conditions. Ice and snow covered roads would require greater stopping distances than those required by wet pavement. Therefore, the approach zone and critical decision point would have to be further away from the crossing to allow for the increased stopping distance required for the same vehicle speed. While many drivers reduce speed when there are ice/snow covered roadways not all reduce their speed sufficiently to counteract the greater stopping distance required.

Internal Distractions. This category involves factors, such as interaction with passengers, attention to a radio and day dreaming, which compete with and may have prior claim to the driver's attention and thereby interfere with his recognition of the signal. The presence of passengers is on the accident record. Other distractions may not be known unless volunteered during an accident investigation.

Driver Characteristics. Characteristics selected were inexperience, through the surrogate of under 22 years of age, and elderly, over 65 years of age. The influence of alcohol and drugs are considered an adverse driver characteristic but accidents involving these were not included in the indepth accident analysis sample due to sample size restrictions.

Visibility of the Train. Limited quadrant sight distance, may not allow the driver to see the approach of the train from the approach zone. If the driver does not recognize the signal, limited quadrant sight distance does not allow for a secondary indication of the hazard. Stop line sight distance, is a problem when drivers stop for the signal and attempt to identify whether or not it is safe to cross.

Acute crossing angle (less than 75 degrees), darkness and the cab configuration of large vehicles are factors which could prohibit the driver from either recognizing the train or judging its rate of closure.

Driver Decision Error

Credibility, competing inputs, driver characteristics and roadway environment are the four contributing factor categories that could affect driver decision errors. (See figure 9.)

Credibility. There may be many subjective credibility criteria. One objective or measurable criterion is extended warning time, whereby the driver sees the activated signal for an extended period of time without seeing a train.

Malfunctioning signals are another aspect of credibility but, with regard to on-site visits of previous accident sites, this factor is not readily ascertainable.

In lieu of track circuit schematic data which was not readily available from the railroads for all accidents, the warning time was calculated by measuring the track circuit distance and calculating the warning time based on the speed of the train involved in the accident, assuming a standard track circuit (the flashing light is activated when the locomotive crosses the circuit). When the project team's results were matched against data received from certain railroads the figures showed only small discrepancies insufficient to change the results of the analysis. For this study extended warning time was defined as signal activation in excess of 30 seconds prior to the arrival of the train.

Competing Inputs. Adjacent intersections and heavy traffic may lure the driver into moving with the traffic flow, keep him moving to avoid blocking traffic or cause him to fear a rear end collision if he stops too suddenly. A slippery pavement may present the motorist with the dilemma of skidding, loss of control, or being unable to stop and hitting the train and thereby sway his decision to try and beat the train.

Low speed trains, defined in this study as trains traveling at less than 16 miles per hour, may cause the driver to decide he can beat the train. They also contribute to the extended warning time. Multiple tracks may cause the driver to not realize the hazard because he focused on the empty tracks. Multiple tracks may also denote switching movements and parked rail cars which he mistakes for the hazard or the train that activated the signal. They may also, because of switching movements, contribute to extended warning time.

Driver Characteristics. Driver characteristics are the same as for driver recognition errors. Truck drivers were included because in a preliminary analysis of the accident data, patterns involving trucks/truck drivers revealed themselves.

Roadway Environment. Limited quadrant sight distance would not allow for a view of the approaching train. The reinforcement may be needed when there is a credibility problem with regard to the signals.

Acute crossing angle and limited visibility (darkness, fog, heavy rain or snow) may prohibit either a view of the train or an accurate estimate of the rate of closure for drivers approaching or stopped at the crossing.

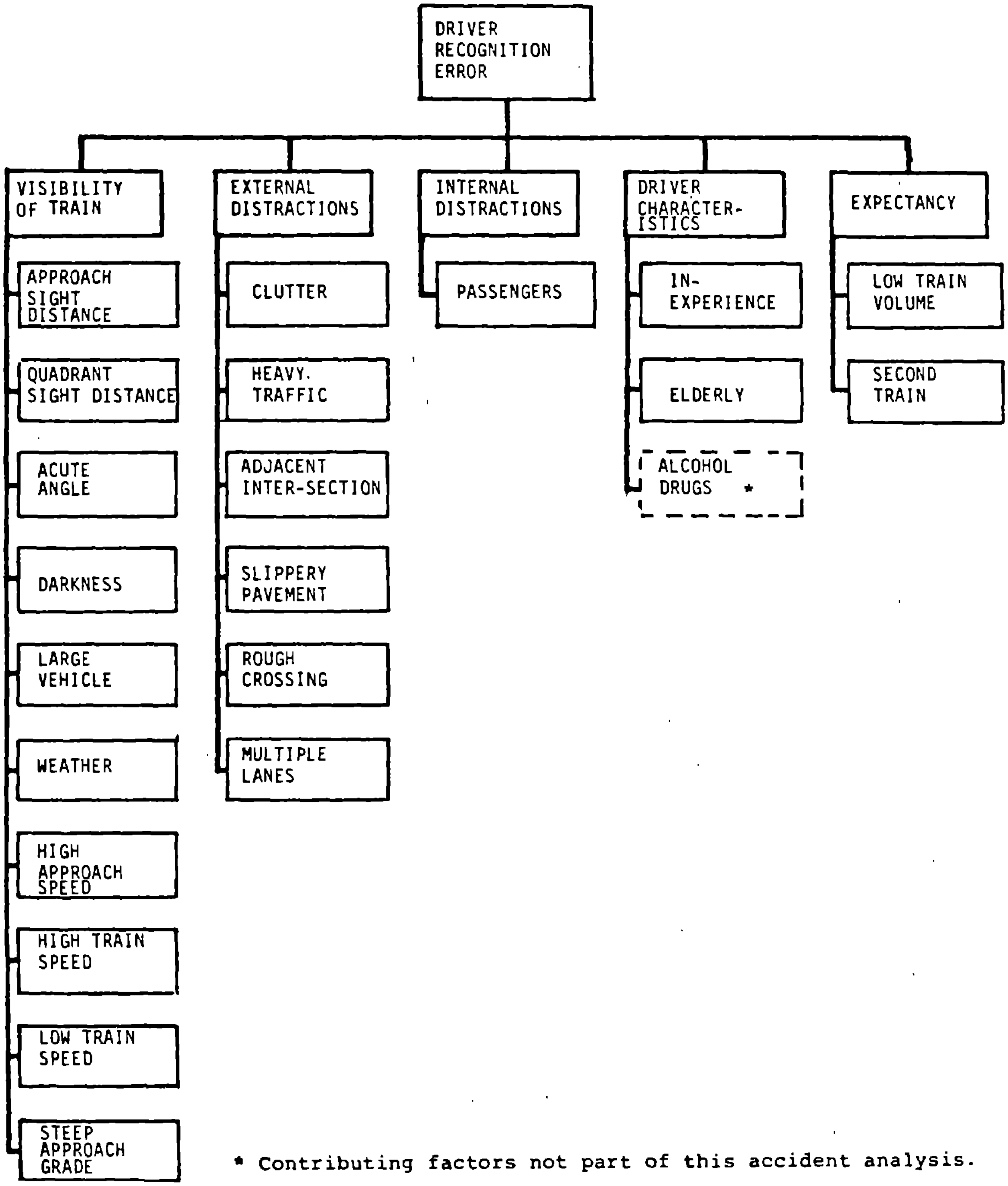
Multiple lanes, steep approach grade and high speed approach may act as competing inputs or as factors in prohibiting a view of the train.

Contributing Factors - Crossbuck Warning Devices

Figures 10 and 11 show the contributing factors for accidents at crossings with crossbuck warning devices. At these crossings the emphasis is on the interaction and reaction of the driver with/to the train when the driver is in the approach and nonrecovery zones. The approach and nonrecovery zone measurements are based on the posted speed limits.

Driver Recognition Error

Visibility of the train, external distractions, internal distractions, driver characteristics and expectancy are the driver recognition error categories for accidents at crossings with crossbuck warning devices and are shown in figure 10.



* Contributing factors not part of this accident analysis.

Figure 10. Contributing Factors to Driver Recognition Error Crossbuck Warning Devices.

Visibility of the train. Limited approach sight distance, limited quadrant sight distance, steep approach grade, and acute angle may obscure the visibility of the train. The cab configuration of large vehicles approaching acute angle crossings may present a unique problem. Adverse weather, heavy rain, snow or fog, may create visibility problems. Darkness may be a problem if the train is moving slowly toward or already standing on the crossing. Darkness, acute crossing angle and low speed trains may present unique problems in judging the train's rate of closure.

External Distractions — see Flashing Light Warning Devices

Internal Distractions — see Flashing Light Warning Devices

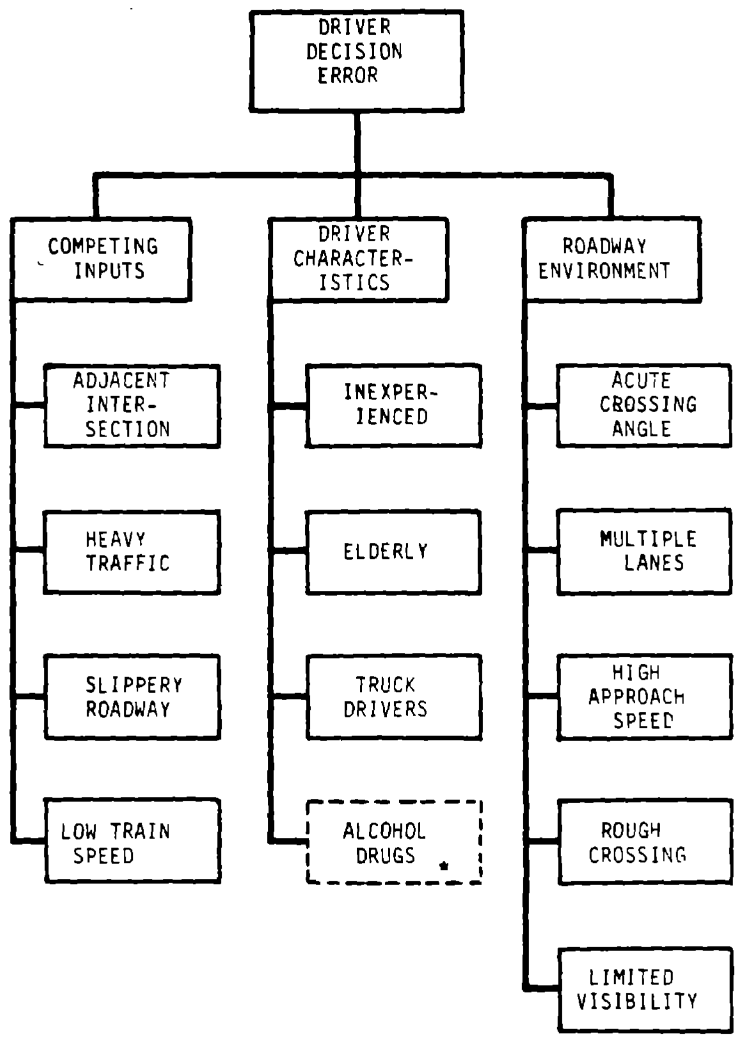
Driver Characteristics — see Flashing Light Warning Devices

Expectancy. At crossings with low train volume drivers may rarely or never see trains or see trains at only certain periods of the day. They may not expect a train and therefore not look for it. This is an example of the problem of over familiarity.

Another type of expectancy problem deals with the appearance of a second train. The driver may recognize and make a decision with regard to a train and then become involved in an accident with a second train that he did not expect nor look for.

Driver Decision Error

Competing inputs, driver characteristics and roadway environment are the driver decision error categories for accidents at crossings with crossbuck warning devices and are shown in figure 11.



* Contributing factor not part of this accident analysis

Figure 11. Contributing Factors to Driver Decision Error - Crossbuck Warning Devices.

The rationale for the use of these categories of contributing factors are explained in the section dealing with driver decision errors at flashing light crossing devices*. The differences in the contributing factors for decision error accidents at flashing lights versus crossbuck crossings are due to the different primary hazard indications, the signal and the train, respectively. Credibility of the signal is a flashing light phenomena. Multiple tracks, limited quadrant sight distance and steep approach grade which in flashing light accidents contribute to decision errors, contribute to recognition errors at crossings with crossbuck warning devices. These factors prohibit recognition of the train at a crossing with passive warning devices.

*Rough crossing was checked when, in the opinion of the site investigators, the crossing surface diverted the attention from the hazard to the roadway.

CHAPTER 7. ACCIDENT CAUSATION - FLASHING LIGHT WARNING DEVICES

The accidents at crossings with flashing light warning devices were analyzed based on the two step approach discussed in Chapter 6. The accident types and contributing factors are discussed and evaluated to ascertain contributing factors patterns. The data is summarized and the countermeasures are grouped by education, enforcement and engineering.

Accident Types and Contributing Factors

The logic flow chart for accidents at flashing light warning devices (Figure 6) was used to analyze the accident event sequence and group the accidents by accident type, i.e., R1 R2, etc. Most accidents were assigned to one accident type. For accidents where the data was insufficient to select between two accident types, that accident is assigned to both types. For example, accident type R1A has a total of five accidents assigned exclusively to it and two accidents assigned to R1A and another accident type. This is indicated by "5/2", with North Carolina "3/1" and Wisconsin "2/1".

The data from the accident site investigation, the state accident report, the FRA accident report and the U.S. DOT-AAR inventory report were analyzed to select the contributing factors for each accident. The contributing factors were then analyzed for contributing factors patterns. Where two patterns were discernible for the same accident type, their contributing factors were listed separately, i.e., R1A, R1B.

Figures 12 through 22 present the patterns of contributing factors derived from the analysis of the indepth accident investigation sample. The description for each figure consists of four parts: event sequence, contributing factors pattern, discussion and possible countermeasures.

The event sequence provides a description of the events leading to the accident and were taken from the logic flow chart for that accident type.

The figure on the right hand side of each page indicates the contributing factors for the accident type under discussion. Where the occurrence of the contributing factor is strong (appearing in 50 percent or more of the accidents) the factor is crosshatched. Where the contributing factor is moderate or weak (occurring in less than 50 percent of the accidents) the factor has diagonal hatching. Where the contributing factor is not present, the factor has neither crosshatching nor hatching.

The Contributing Factors Pattern section lists those factors which represent a pattern. They are primarily though not exclusively the strong (crosshatched) factor. For example, while the individual external distraction factors may or may not be strong, the external distraction group of factors may present a strong pattern. The numerical designation follows that used in designating accidents. "In R1A elderly driver 3/2" refers to the presence of the elderly driver factor in three accidents exclusively in R1A and in two accidents which appear in R1A and in another accident type.

The discussion describes the contributing factors pattern indicated in the factors list and shown on the accompanying figure. It presents a short verbal summarization of the possible rationale for a pattern of factors to contribute to an accident. Where there are only one or two accidents or where the factors are dispersed and do not show a strong occurrence, there may not be a contributing factors pattern and therefore little to discuss.

Possible Countermeasures. The possible countermeasures are suggested based on their relationship to the event sequence accident type and the contributing factors pattern and not with regard to their viability as a solution to the universe of all rail highway crossing accidents.

The possible countermeasure offered for an accident type may provide remedies from different perspectives, e.g., the driver (education and enforcement), the crossing environment (warning device modifications), and the train (reflectorization). The countermeasures should not be considered an all inclusive list but rather an example of types of countermeasures. For internal distractions, there does not seem to be an effective countermeasure unless one desires to list education in paying attention while driving in general.

Where no strong pattern of contributing factors appears either due to the dispersal of factors or the small number of occurrences it may not be relevant to discuss possible countermeasures.

ACCIDENT TYPE R1A

North Carolina 3/1
Wisconsin 2/1

Event Sequence

Driver does not recognize signal from approach zone
Maintains speed, enters nonrecovery zone
Does not recognize signal nor train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

Elderly drivers 3/2
External distractions - clutter 2/1, heavy traffic 3/1 adjacent intersections 4/1, slippery pavement 3/0, and rough crossings 1/1
Limited quadrant sight distance 5/1

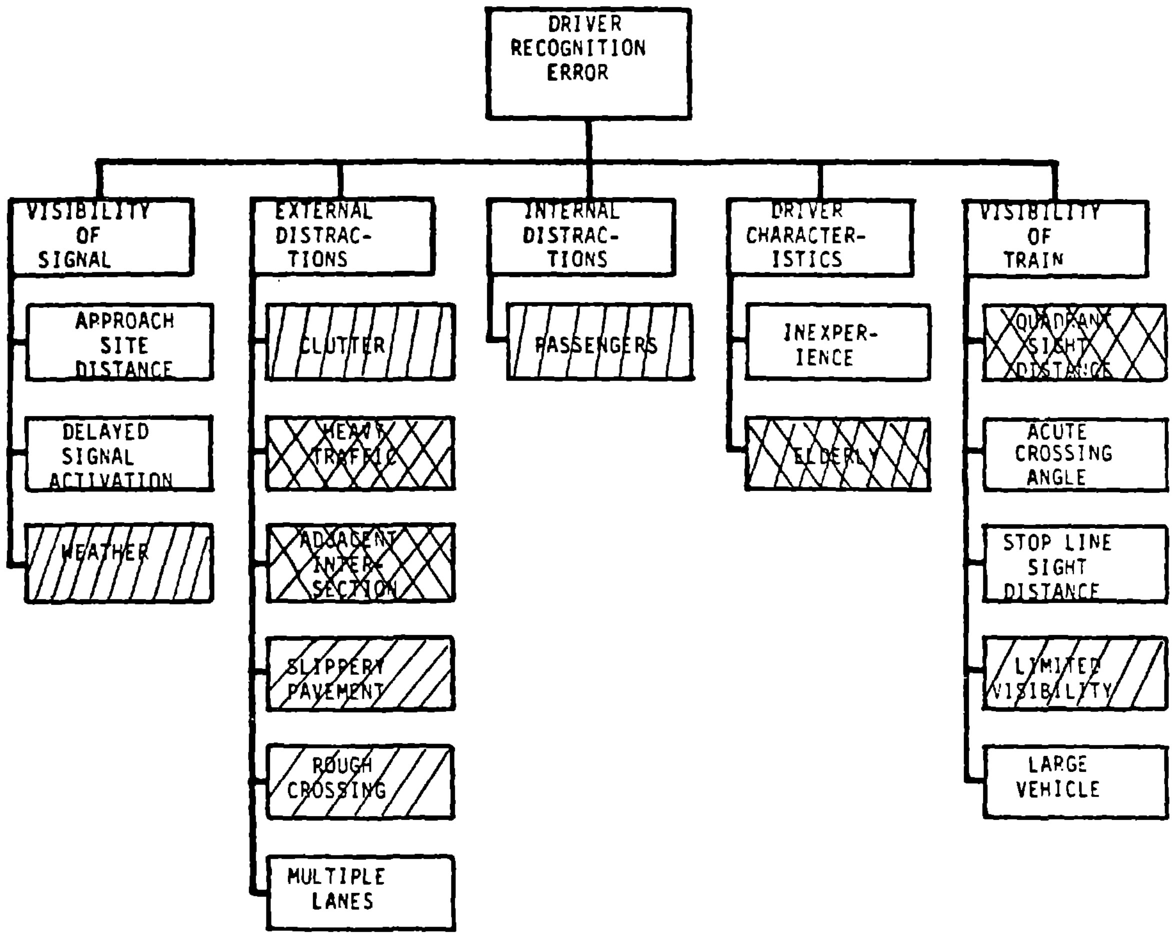
Discussion

Elderly drivers have greater difficulty in dealing with multiple inputs. They may be concentrating on the continuous, primary inputs - external distractions - and thereby not be able to either look for, nor assimilate, the flashing light warning. Restricted quadrant sight distance prohibited sight of the train.

Possible Countermeasures

Increase signal conspicuity - 12 inch roundels, strobes, cantilevered flashing lights. This countermeasure would be most effective in areas which have a high proportion of elderly drivers and/or approaches with strong and numerous types of external distractions.

Emphasis on driver education for elderly drivers.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 12. Contributing Factors to Driver Recognition Error (R1A) - Flashing Light Warning Devices.

ACCIDENT TYPE R1B

North Carolina
Wisconsin 3/1

Event Sequence

Driver does not recognize signal from approach zone
Maintains speed, enters non-recovery zone
Does not recognize signal nor train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

Visibility of signal obscured - backhoe parked in front of signal 1/0, high snow banks may have obscured signal 0/1, delayed signal activation due to the possibility of train on a spur track activating an island signal circuit 1/0, sun behind top of warning device possibly interfering with driver's vision 1/1

External distractions - clutter 1/1, heavy traffic 0/1, and slippery pavement 1/1

Discussion

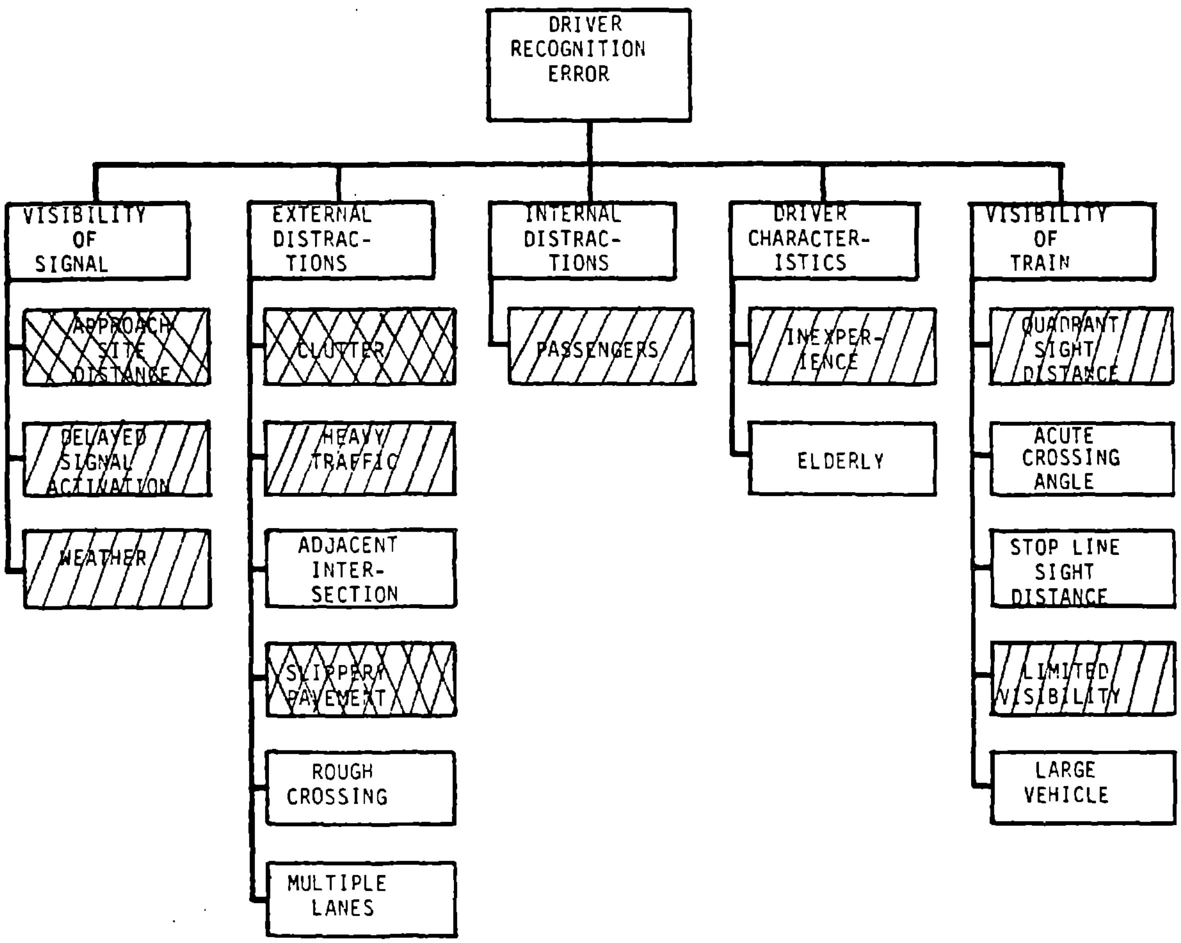
The strongest group of contributing factors was visibility of signal obscured. External distractions may have divided the drivers' attention. Heavy traffic especially when the signal is obscured, could have caused the driver to react with the traffic flow and follow the driver in front of him over the crossing.

Possible Countermeasures

Enact or enforce parking restrictions in front of warning devices.

Establish policies with regard to piling snow in front of warning devices or tracks.

Flag trains across the road when they are on tracks covered by island circuits.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 13. Contributing Factors to Driver Recognition Error (R1B) - Flashing Light Warning Devices.

ACCIDENT TYPE R2

North Carolina 1/0
Wisconsin 1/1

Event Sequence

Driver does not recognize signal from approach zone
Maintains speed, enters nonrecovery zone
Recognizes signal or train in critical track zone
Skids; Collision

Contributing Factors Pattern

Visibility of signal obscured - heavy rain and fog 1/0, snow 0/1, the third accident involved an inexperienced driver who drove the posted speed on a snow and ice covered road, crested a ridge, saw the signal but could not stop on downward sloping grade 1/0

Slippery pavement 2/1

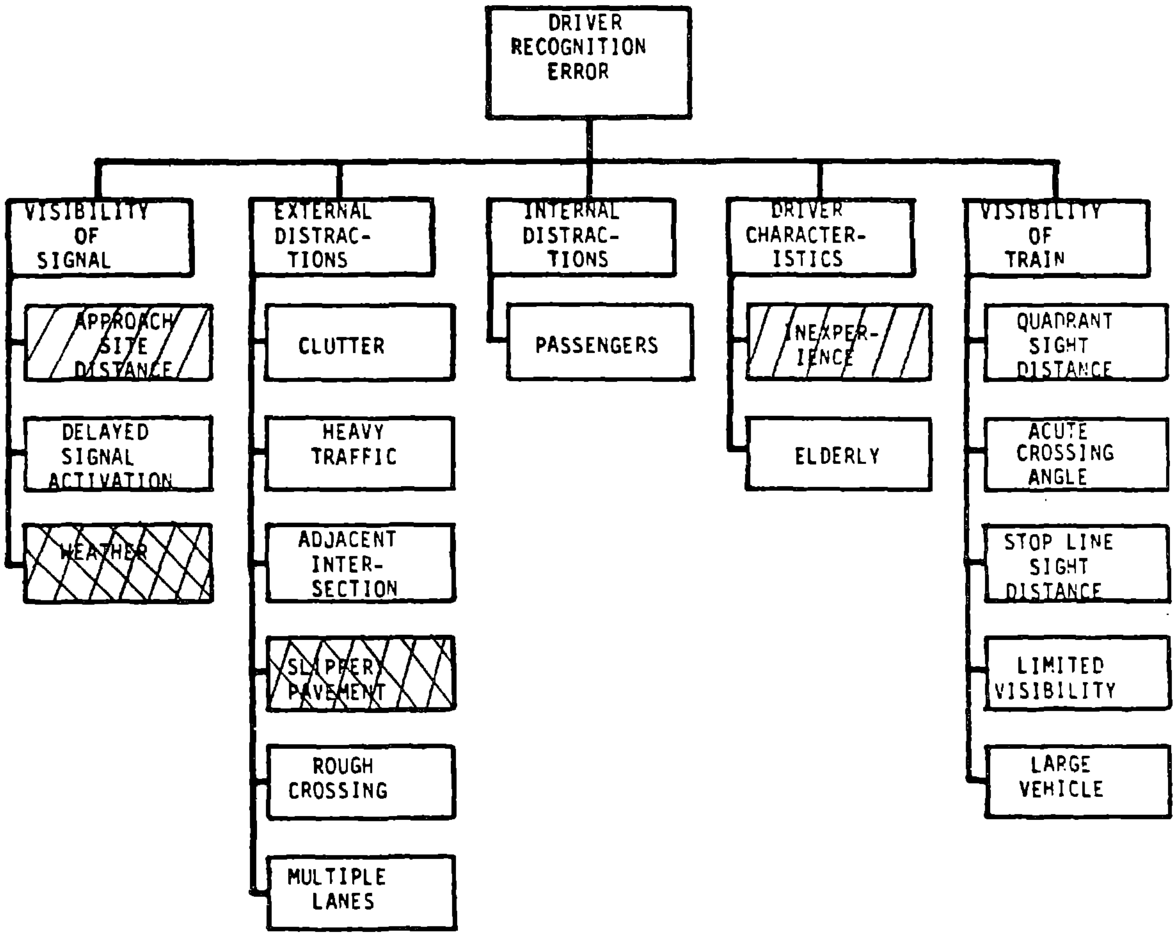
Discussion

The strongest group of contributing factors was that the visibility of the signal was obscured. Slippery pavement should not have impacted two accidents since the drivers did not respond in the normal approach zone which is calculated to account for wet pavement. In the third accident, the effective approach zone, due to ice and snow, was beyond the visibility of the signal. In the approach zone, measured under normal conditions, the driver did see the signal but could not stop.

Possible Countermeasures

Provide driver education with emphasis on the need to reduce speed under limited visibility and braking conditions.

If a larger sample were to indicate that the normal approach zone is rendered ineffective due to the greater stopping distance required by ice and snow, active advanced warning signals should be considered.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 14. Contributing Factors to Driver Recognition Error (R2) - Flashing Light Warning Devices.

ACCIDENT TYPE R3

North Carolina
Wisconsin 1/1

Event Sequence

Driver does not recognize signal from approach zone
Maintains speed, enters nonrecovery zone
Recognizes signal or recognizes train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

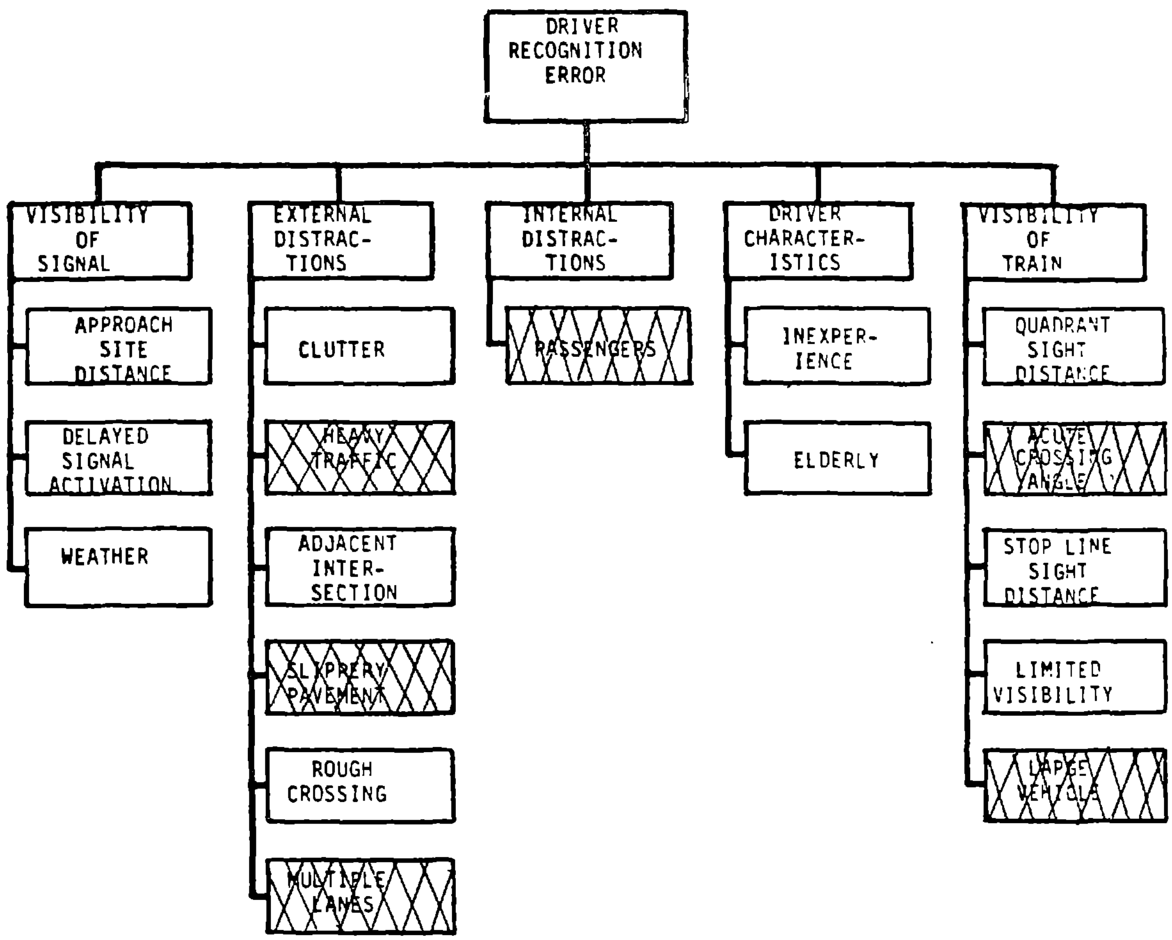
None due to small sample size

Discussion

No pattern established. One accident occurred on a multilane highway with heavy traffic and a slippery pavement 0/1. The other accident involved a large vehicle containing passengers crossing an acute angle crossing 1/0

Possible Countermeasures

None - no contributing factors pattern.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 15. Contributing Factors to Driver Recognition Error (R3) - Flashing Light Warning Devices.

ACCIDENT TYPE R4 | North Carolina
Wisconsin 3/0

Event Sequence

Driver recognizes signal from approach zone
Brakes to stop in advance of hazard zone
Does not recognize train in critical track zone
Attempts to cross; Collision

Contributing Factors Pattern

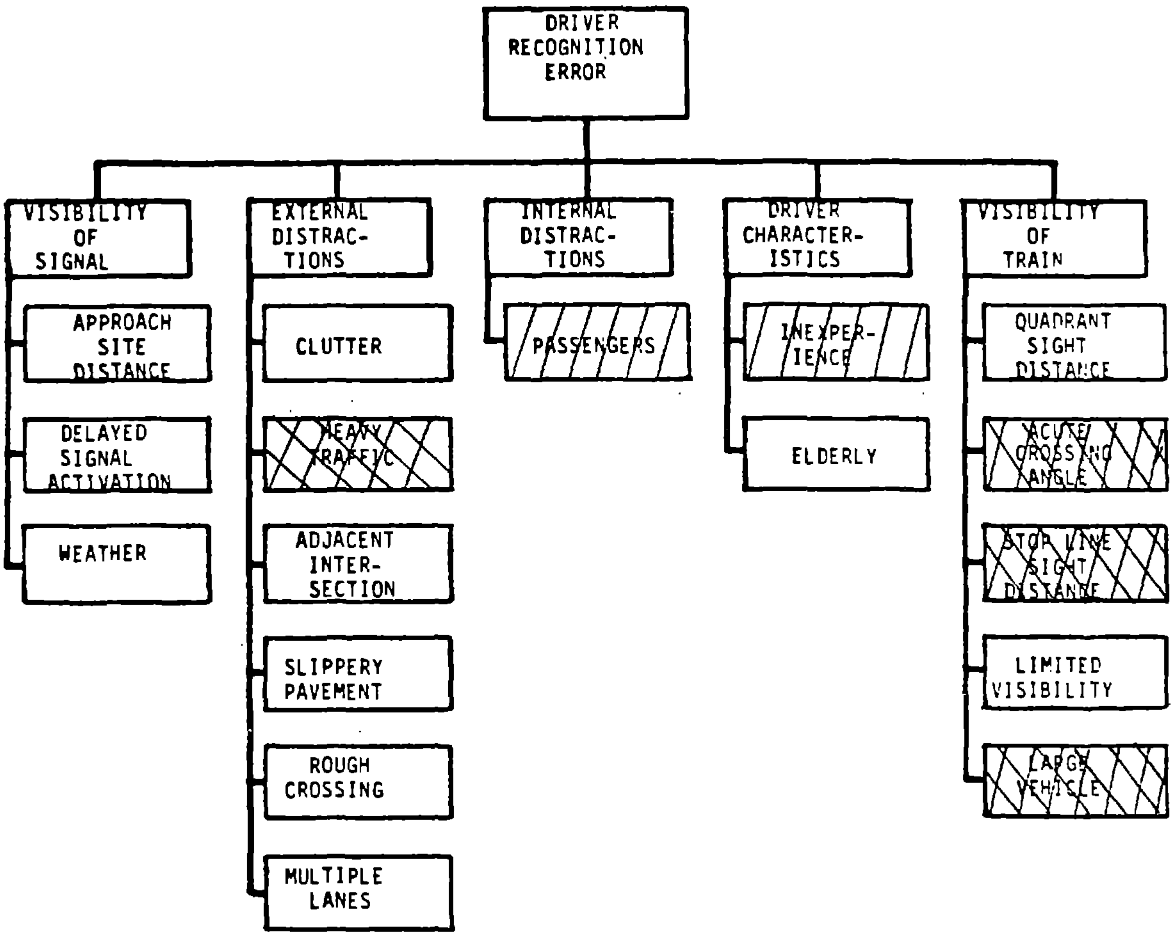
Limited stop line sight distance 3/0
Large vehicle and an acute crossing angle 2/0
Heavy traffic 2/0

Discussion

This accident type is unique in that the driver recognized and decided correctly with respect to the flashing light but made a recognition and decision error with regard to the train. Stop line sight distance, large vehicles and acute crossing angles which presents a sight geometry problem contributed to the failure to recognize the train. The extended warning time of the signal, which leads to driver impatience, and heavy traffic caused the driver to decide to proceed while the signal was still flashing.

Possible Countermeasures

Wisconsin law requires truck drivers not to proceed until the device stops working. Extended warning time would provide a negative reinforcement of this law. Countermeasures could include education or enforcement with respect to truck drivers or the installation of gates at crossings with acute angles frequented by truck traffic.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 16. Contributing Factors to Driver Recognition Error (R4) - Flashing Light Warning Devices.

ACCIDENT TYPE D1A

North Carolina 2/0
Wisconsin 2/2

Event Sequence

Driver recognizes signal from approach zone
Maintains speed, enters nonrecovery zone
Does not recognize train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

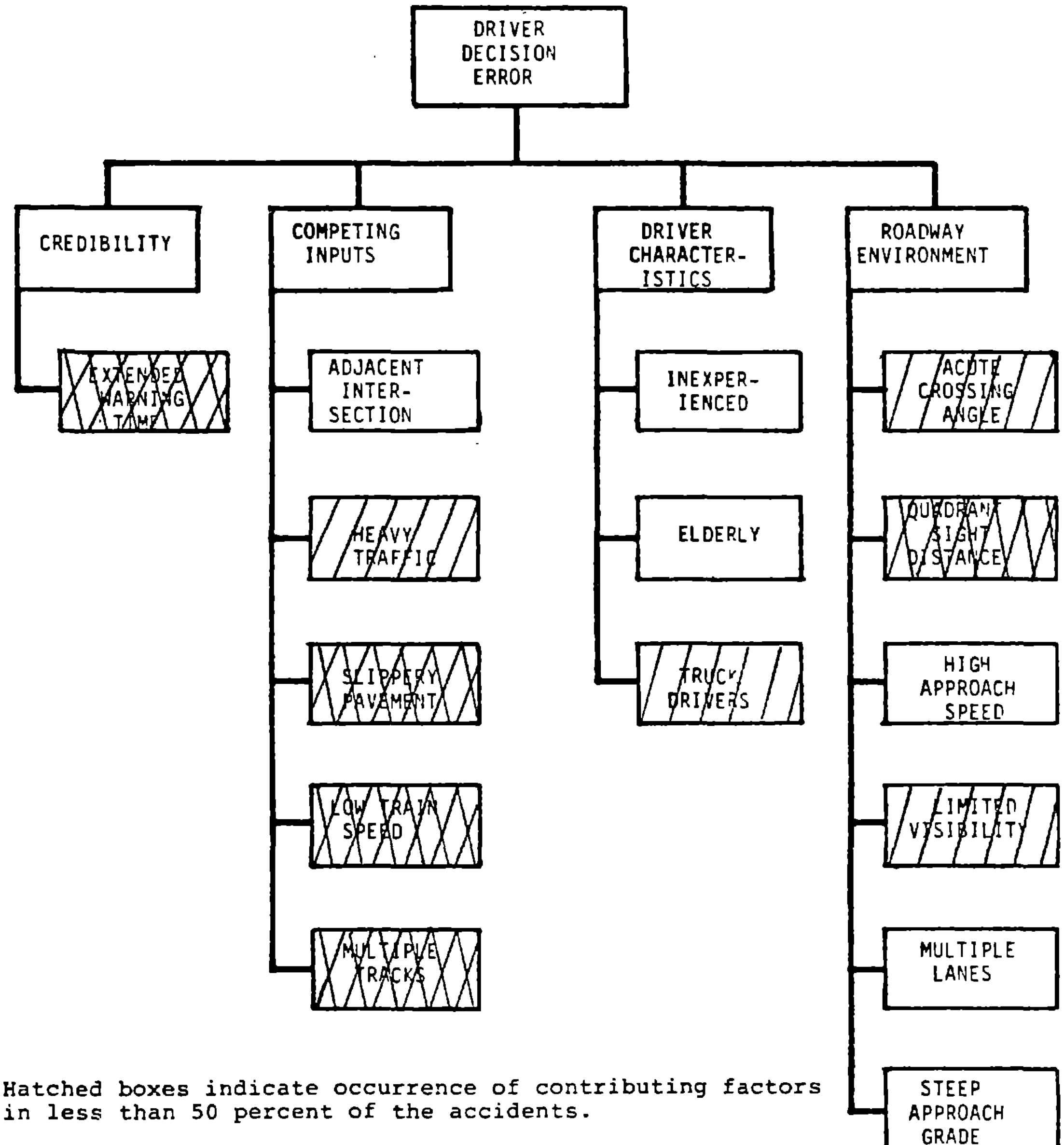
Extended warning time 4/2
Low train speed 4/0
Multiple tracks 4/0
Limited quadrant sight distance 4/1
Slippery pavement 2/1

Discussion

Extended warning time, multiple tracks, and low speed trains, may present a credibility problem. Limited quadrant sight distance prohibits positive reinforcement of the warning devices. The slippery pavement may be coincidental or may have prompted the driver to maintain speed and beat the slow train as opposed to skidding if he tried to stop.

Possible Countermeasures

Use gates at multiple track crossings.
Provide constant warning time detection circuits.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 17. Contributing Factors to Driver Decision Error (D1A) - Flashing Light Warning Devices.

ACCIDENT TYPE D1B

North Carolina 2/1
Wisconsin

Event Sequence

Driver recognizes signal from approach zone
Maintains speed, enters nonrecovery zone
Does not recognize train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

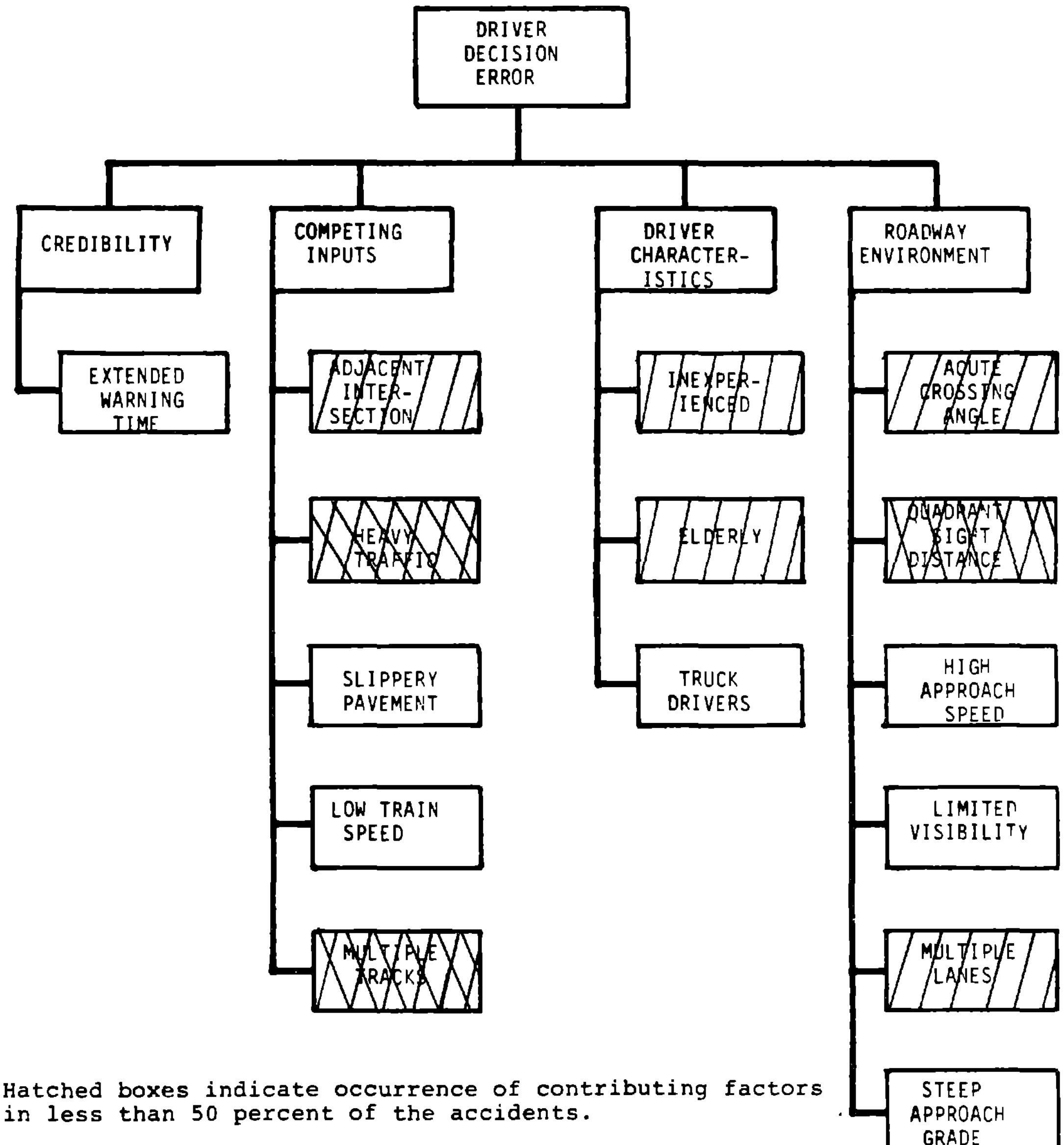
Driver characteristics - inexperienced 1/0, elderly 0/1
Competing inputs - heavy traffic 1/1, adjacent intersection 1/0
Limited quadrant sight distance 2/1
Multiple tracks 1/1

Discussion

Competing inputs - heavy traffic, adjacent intersections or low train volume may cause drivers, especially those elderly or inexperienced, to ignore signal devices. Limited quadrant sight distance does not allow sight of the hazard to positively reinforce the signal.

Possible Countermeasures

Provide driver education or enforcement of laws.
Use gates at multiple track crossings.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 18. Contributing Factors to Driver Decision Error (D1B) - Flashing Light Warning Devices.

ACCIDENT TYPE D2

North Carolina 5/0
Wisconsin 2/1

Event Sequence

Driver recognizes signal from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Skids; Collision

Contributing Factors Pattern

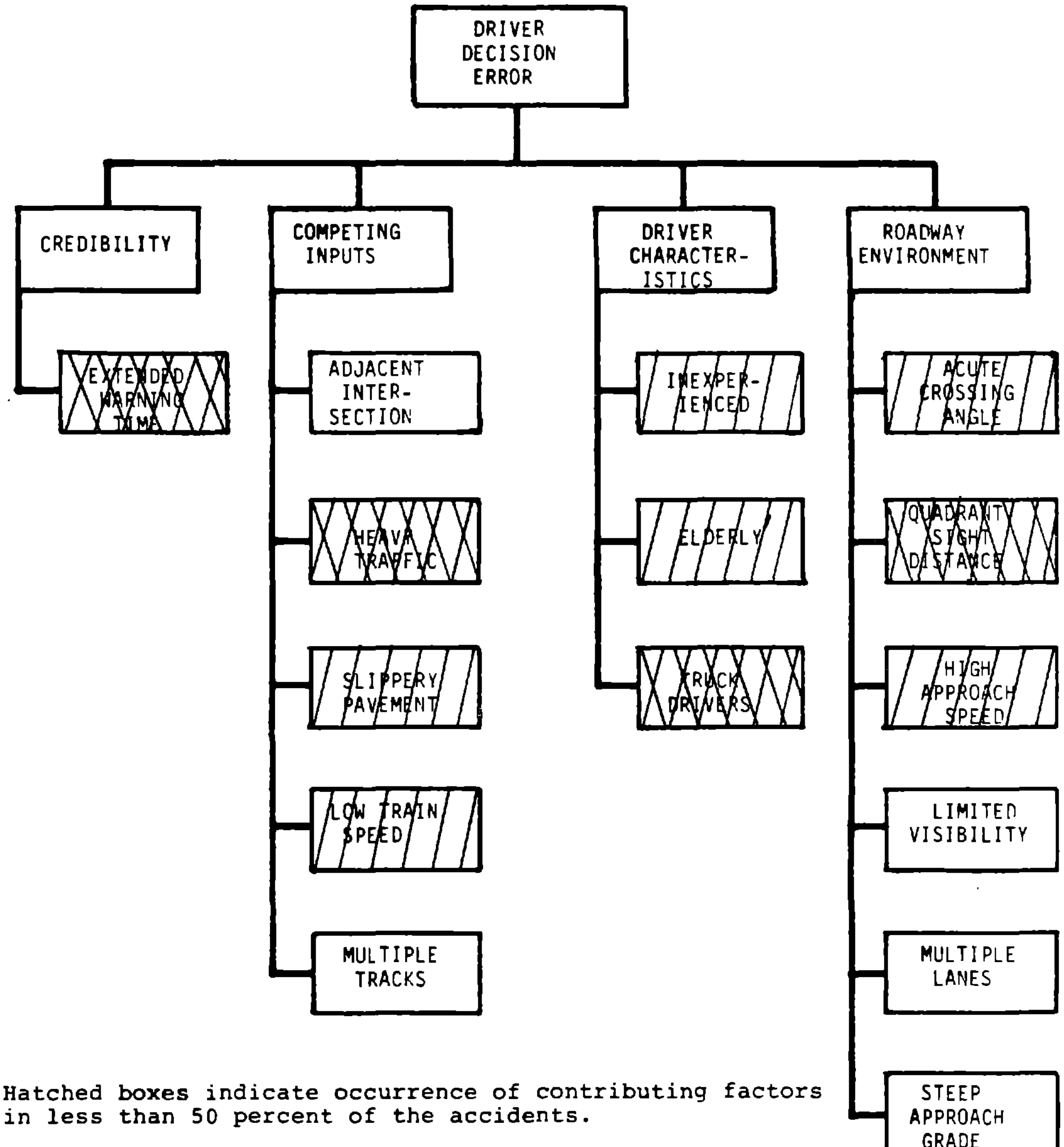
Extended warning time 6/1
Limited quadrant sight distance 6/0
Driver characteristics - truck driver 4/1, inexperienced 1/0, elderly 1/0
Heavy traffic 3/1

Discussion

Extended warning time promotes a credibility problem. Limited quadrant sight distance does not allow for positive reinforcement of the signal. The decision to stop is postponed until the train is recognized at which time it is too late to stop.

Possible Countermeasures

Provide constant warning time detection circuits.
Provide driver education for truck drivers.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 19. Contributing Factors to Driver Decision Error (D2) - Flashing Light Warning Devices.

ACCIDENT TYPE D3A

North Carolina 1/0
Wisconsin 3/2

Event Sequence

Driver recognizes signal from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

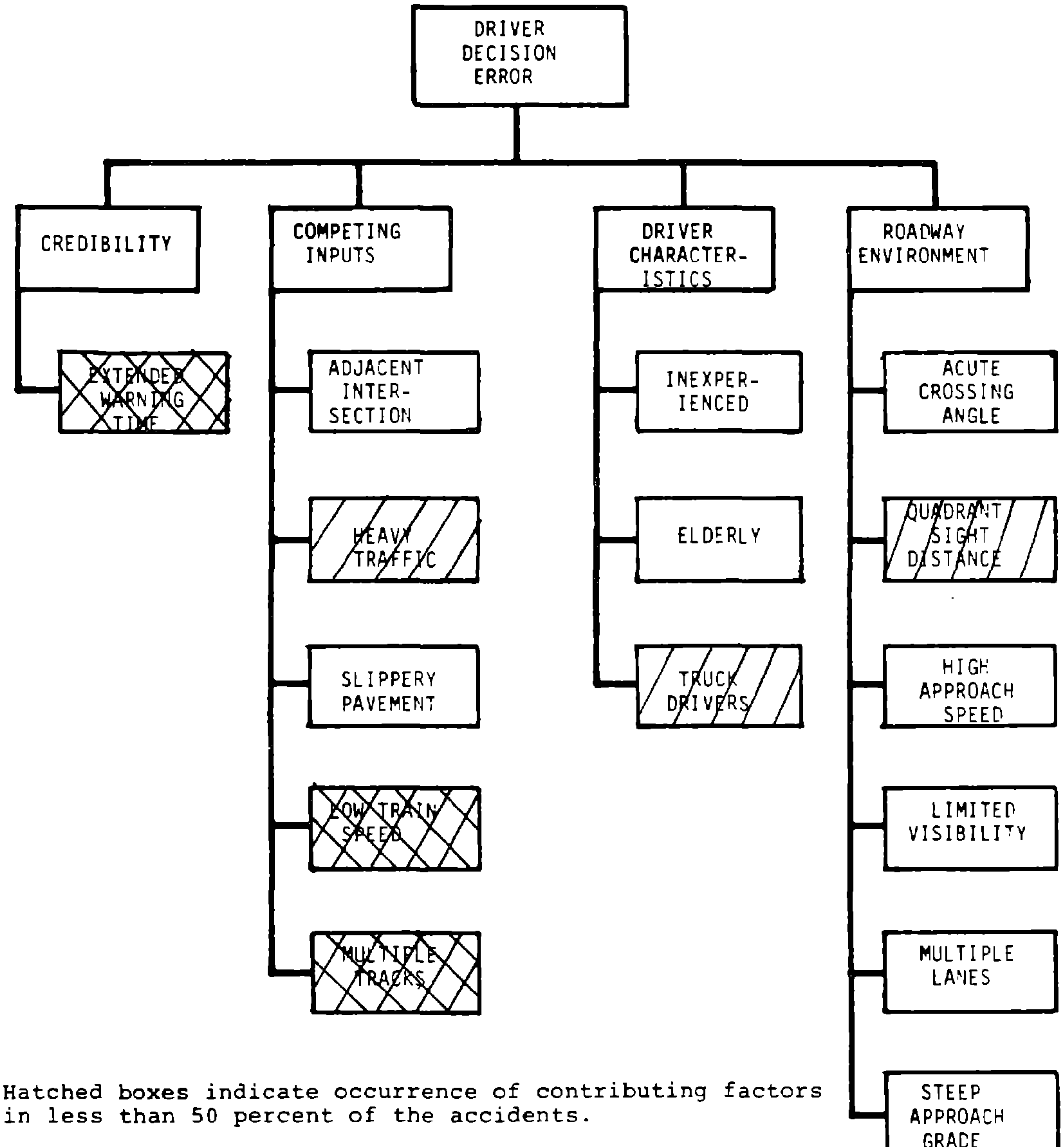
Extended warning time 3/2
Low speed train 4/1
Multiple track 2/1

Discussion

Extended warning time, multiple tracks, low speed trains present a credibility problem. When the train appears after the driver has already entered the nonrecovery zone he attempts to beat the train or maintain speed because there is inadequate space to stop.

Possible Countermeasures

Provide constant warning time detection circuits.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 20. Contributing Factors to Driver Decision Error (D3A) - Flashing Light Warning Devices.

ACCIDENT TYPE D3B

North Carolina 2/0
Wisconsin 2/1

Event Sequence

Driver recognizes signal from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Maintains speed; Collision

Factors

Extended warning time 3/1
Driver characteristics - inexperienced 3/0, elderly 0/1, admitted risk taking 1/0
Limited quadrant sight distance 2/1
Adjacent intersection 2/1
Heavy traffic 2/1
Slippery pavement 2/1

Discussion

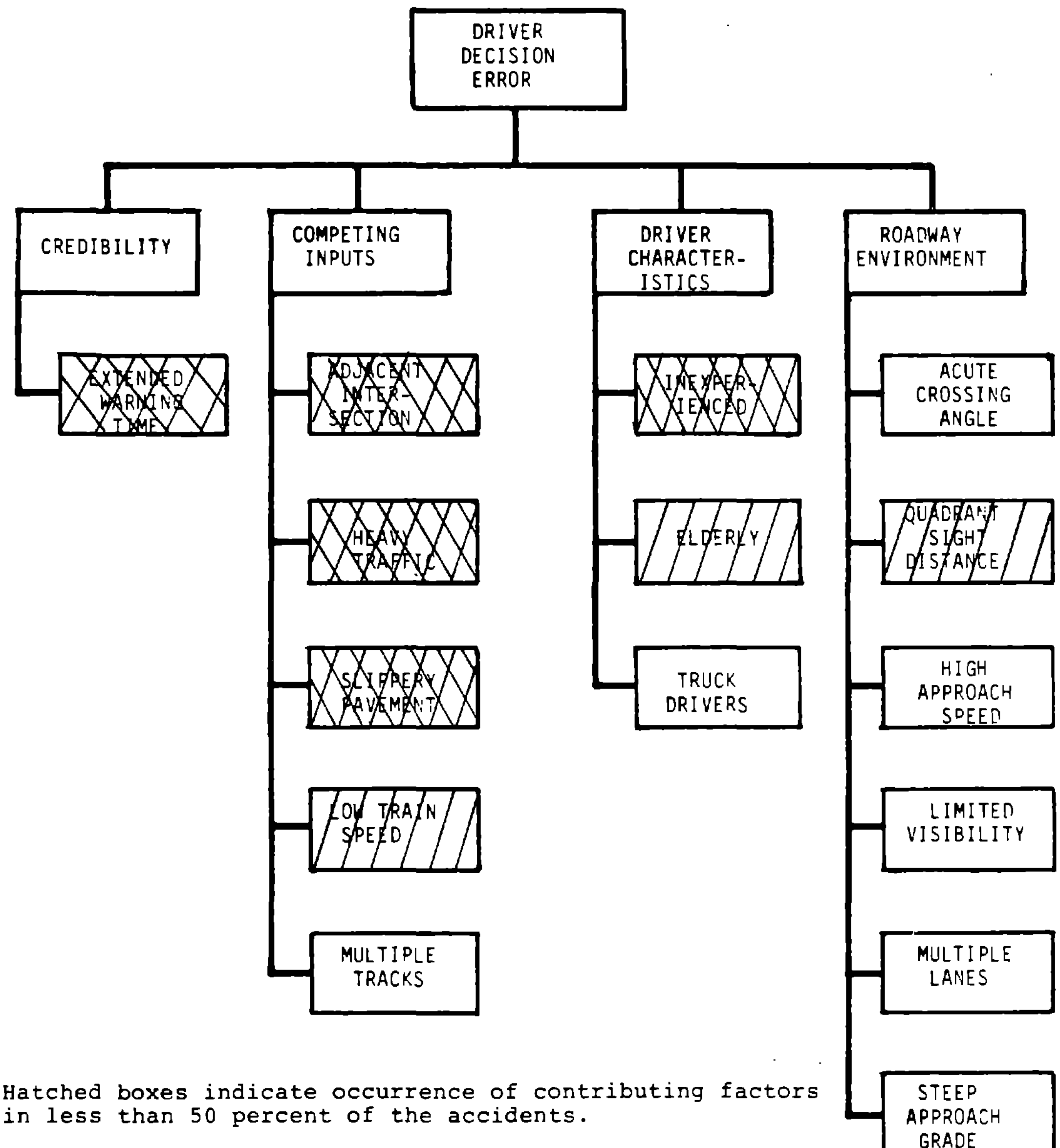
Extended warning time and driver characteristics, especially inexperienced drivers, combine to form a group of drivers who attempt to beat the train.

On the other hand, inexperienced drivers may not have the experience to evaluate among competing inputs, heavy traffic, adjacent intersection and slippery pavement, and the flashing light warning device. In cases of heavy traffic they could tend to follow the lead of other drivers.

Possible Countermeasures

Provide driver education, especially for inexperienced drivers.

Provide constant warning time detection circuits.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 21. Contributing Factors to Driver Decision Error (D3B) - Flashing Light Warning Devices.

ACCIDENT TYPE D4

North Carolina 2/0
Wisconsin

Event Sequence

Driver recognizes signal from approach zone
Brakes to stop in advance of hazard zone
Recognizes train in critical track zone
Attempts to cross; Collision

Contributing Factor Pattern

Limited visibility - darkness 1/0, fog 1/0.
Low train speed 1/0
Extended warning time 1/0
Inexperienced driver 1/0
Acute crossing angle 1/0

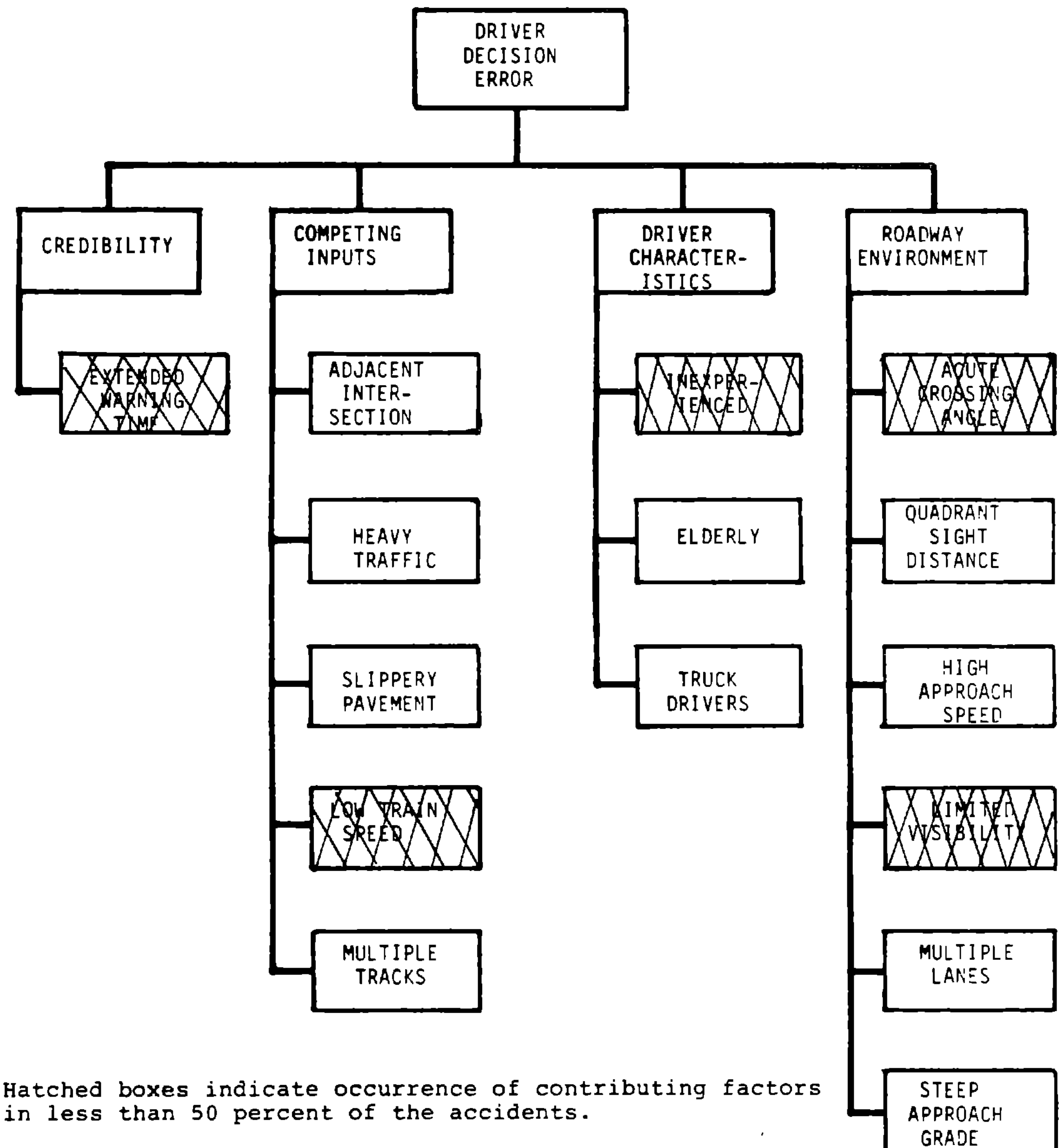
Discussion

The limited visibility makes it extremely hard for the driver to judge train movement or rate of movement even though he saw the train.

A larger sample may show a contributing factors pattern where extended warning time induces a driver to make his own decision when he sees the train. Limited visibility in combination with inexperienced drivers, acute crossing angle and low train speed may affect the ability of the driver to make the proper decision.

Possible Countermeasures

Provide constant warning time detection circuits.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 22. Contributing Factors to Driver Decision Error (D4) - Flashing Light Warning Devices.

Summary of Accident Analysis and Countermeasures

The accident types, contributing factors patterns and possible countermeasures for accidents at flashing light warning devices are summarized and discussed.

In our sample of accidents at crossings with flashing light warning devices 38 percent had an event sequence indicating driver recognition error and 62 percent indicating driver decision error.

Accidents due to driver recognition errors had the following contributing factors patterns:

- Elderly drivers, external distractions and limited quadrant sight distance (R1A).
- Visibility of signal obscured and external distractions (R1B).
- Visibility of signal obscured and slippery pavement (R2).
- Limited stop line sight distance, large vehicle, acute crossing angle, and heavy traffic (R4).

In the driver decision error accident types six contributing factors patterns were discerned:

- Extended warning time, low train speed, multiple tracks, limited quadrant sight distance and slippery pavement(D1A).
- Driver characteristics, competing inputs, limited quadrant sight distance and multiple tracks (D1B).
- Extended warning time, limited quadrant sight distance, driver characteristics and heavy traffic (D2).

- Extended warning time, low train speed and multiple tracks (D3A).

- Extended warning time, driver characteristics, limited quadrant sight distance, adjacent intersections, heavy traffic, and slippery pavement (D3B).

- Limited visibility, low train speed, extended warning time, inexperienced driver and acute crossing angle (D4).

The contributing factors patterns for the accidents due to recognition errors are somewhat different from one another. Two accident types that involve obscured visibility of the signal account for 14 percent of the accident sample and have different causes for the obscured visibility of the signal.

Five of the six contributing factors patterns include extended warning time. If the recognition error accidents involving motorists who stop and then proceed are included, a total of six accident types involve extended warning time. This is discussed further in the next section dealing with possible countermeasures.

Tables 8 and 9 present the possible education, enforcement and engineering countermeasures for accidents at flashing light warning devices. Though the countermeasures are briefly discussed it is not the intent nor within the scope of the study to analyze the feasibility of the various alternatives.

<u>Education</u>

A review of the contributing factors patterns show various driver characteristics factors - elderly, inexperienced, truck drivers - are included in the patterns. Education may be an effective countermeasure for specific types of accidents

Table 8. Accident Types and Contributing Factors Patterns
Education and Enforcement Countermeasures
Crossings with Flashing Light Warning Devices.

	Accident Type	Contributing Factors Pattern	Countermeasures: Education	Countermeasures: Enforcement
R1A	Driver does not recognize signal or train	Elderly drivers External distractions Limited quadrant sight distance	Elderly drivers	———
R2	Driver recognizes signal and/or train from non-recovery zone; Skids	Visibility of signal obscured - weather Slippery pavement	General	———
R4	Driver stops Does not recognize train Attempts to cross	Limited stop line sight distance Large vehicles Acute crossing angle Heavy traffic	Truck drivers	Truck drivers
D1B	Driver recognizes signal Maintains speed Does not recognize train Maintains speed	Driver characteristics Competing inputs Limited quadrant sight distance Multiple tracks	Elderly Inexperienced	General

Table 8. Accident Types and Contributing Factors Patterns Education and Enforcement Countermeasures Crossings with Flashing Light Warning Devices (continued).

	Accident Types	Contributing Factors Pattern	Countermeasures Education	Countermeasures Enforcement
D3B	Driver recognizes signal Maintains speed Recognizes train Maintains speed	Extended warning time Inexperienced drivers Limited quadrant sight distance Competing inputs	Inexperienced	———
D2	Driver recognizes signal Maintains speed Recognizes train Skids	Extended warning time Truck drivers Heavy traffic Limited quadrant sight distance	Truck drivers	Truck drivers

Table 9. Accident Types and Contributing Factors Patterns
Engineering Countermeasures
Crossings with Flashing Light Warning Devices.

	Accident Type	Contributing Factors Patterns	Countermeasures: Install Gates	Countermeasures: Increase Signal Conspicuity	Countermeasures: Constant Warning Time
R1A	Driver does not recognize signal or train	Elderly driver External distractions Limited quadrant sight distance		X	
R4	Driver stops Does not recognize train Attempts to cross	Limited stop line sight distance Large vehicle Acute crossing angle Heavy traffic	X		
D1A	Driver recognizes signal Maintains speed Does not recognize train Maintains speed	Extended warning time Low train speed Multiple tracks Limited quadrant sight distance Slippery pavement	X		X
D1B	Driver recognizes signal Maintains speed Does not recognize train Maintains speed	Driver characteristics Competing inputs Limited quadrant sight distance Multiple tracks	X		
D4	Driver recognizes signal Breaks to stop Recognizes train Attempts to cross	Limited visibility Low train speed Extended warning time Inexperienced driver Acute crossing angle			X

Table 9. Accident Types and Contributing Factors Patterns
Engineering Countermeasures
Crossings with Flashing Light Warning Devices (continued).

	Accident Type	Contributing Factors Patterns	Countermeasures: Install Gates	Countermeasures: Increase Signal Conspicuity	Countermeasures: Constant Warning Time
D2	Driver recognizes signal Maintains speed Recognizes train Skids	Extended warning time Limited quadrant sight distance Truck drivers Heavy traffic			X
D3A	Driver recognizes signal Maintains speed Recognizes train Maintains speed	Extended warning time Low speed train Multiple track	X		X
D3B	Driver recognizes signal Maintains speed Recognizes train Maintains speed	Extended warning time Inexperienced driver Limited quadrant sight distance Competing inputs			X

involving specific groups of drivers. The specificity of the audience and the message may be less costly and have a greater impact than a general education campaign. The elderly driver may benefit from an approach that can assist in the recognition of rail highway signals and/or railroad trains. An education program aimed at truck drivers could include accident statistics for certain types of accidents. Driver education courses in high schools could include a section on risk taking at railroad crossings.

The contributing factors pattern for a recognition accident type includes a possible countermeasure involving driver education with emphasis on the need to reduce speed under limited visibility and braking conditions. This approach may be more valid in overall driver education campaigns rather than one geared toward rail highway safety.

Enforcement

Enforcement may be a possible countermeasure for certain types of rail highway crossing accident types, especially where the contributing factors pattern includes large vehicles. The renumeration and fatigue factors associated with trucking operations, and the severity of truck-train accidents, could suggest an enforcement countermeasure.

On the other hand the hierarchy of enforcement priorities may dictate that education programs and engineering changes which provide the driver with more information should be tried first.

Engineering

Engineering countermeasures include increasing signal conspicuity, installation of gates and the provision for constant warning time. Where neither the signal nor the train were recognized, and elderly drivers were involved, increased conspicuity of the signal may be required.

Gates may be the most effective countermeasure for driver decision error accidents at crossings with multiple tracks. Gates may also be effective where visibility of the train is obscured by stop line sight distance, and crossing angles and/or the cab configuration of some large vehicles using the crossing. The gates are an engineering change which aids the motorist in his decision making where external inputs could adversely impact the decision making process.

Five of the six contributing factors patterns for driver decision error accidents include the extended warning time factor. Extended warning time impacts the credibility of the warning of the flashing light devices. The other factors most frequently found with extended warning time in the contributing factors patterns are low train speed, limited quadrant sight distance, multiple tracks, heavy traffic, inexperienced drivers and truck drivers.

Low train speed at crossings where there are also high speed trains may be a cause of extended warning time and cannot in itself be easily rectified. Limited quadrant sight distance at crossings with active devices is a secondary factor which prohibits positive reinforcement of the flashing lights. Multiple tracks in certain locations are necessary for effective train operation and cannot be modified. Heavy traffic may be a negative reinforcement of the signal which already has a credibility problem. The driver involved in the accident may have been following a stream of cars whose drivers were also ignoring or taking a risk with regard to the signal with the extended warning time.

Extended warning time, and the credibility problem it presents, is the contributing factor for which a countermeasure is available - provide constant warning time detection circuits. Constant warning time flashing lights would provide the motorist with information that he could find more credible and be more prone to rely upon. An education countermeasure aimed at the general population or at inexperienced drivers and truck drivers could only provide information contrary to the information a driver receives in his interaction with the flashing light with extended warning time. How many educational messages would be required to effectively counteract a possible frequent experience with a warning device which operates way in advance of the arrival of the train.

Contributing factors patterns, which include both extended warning time and multiple tracks, have as possible countermeasures the provision of constant warning time detection circuits and the use of gates. There may be a decided advantage to utilizing both countermeasures simultaneously, constant warning time to provide credibility and gates to aid the motorist in his decision making function.

CHAPTER 8. ACCIDENT CAUSATION - CROSSBUCK WARNING DEVICES

The accidents at crossings with crossbuck warning devices were analyzed based on the methodology for the accident analysis. The contributing factors, contributing factors patterns, and possible countermeasures are discussed for each accident event sequence. The data is then summarized and grouped by education, enforcement and engineering countermeasures.

Accident Types and Contributing Factors

Figures 23 through 31 present the patterns of contributing factors derived from the analysis of the indepth accident investigation sample.

The presentation of the data is the same as for flashing light warning devices explained in the previous chapter. The logic flow chart for accidents at crossings with crossbuck warning devices is shown in Figure 7.

ACCIDENT TYPE R1A

North Carolina 8/0
Wisconsin 2/2

Event Sequence

Driver does not recognize train from approach zone
Maintains speed, enters nonrecovery zone
Does not recognize train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

Limited quadrant sight distance 9/0
Acute crossing angle 7/1
Low speed train 6/0
Expectancy - low train volume 5/0, second train 1/0

Discussion

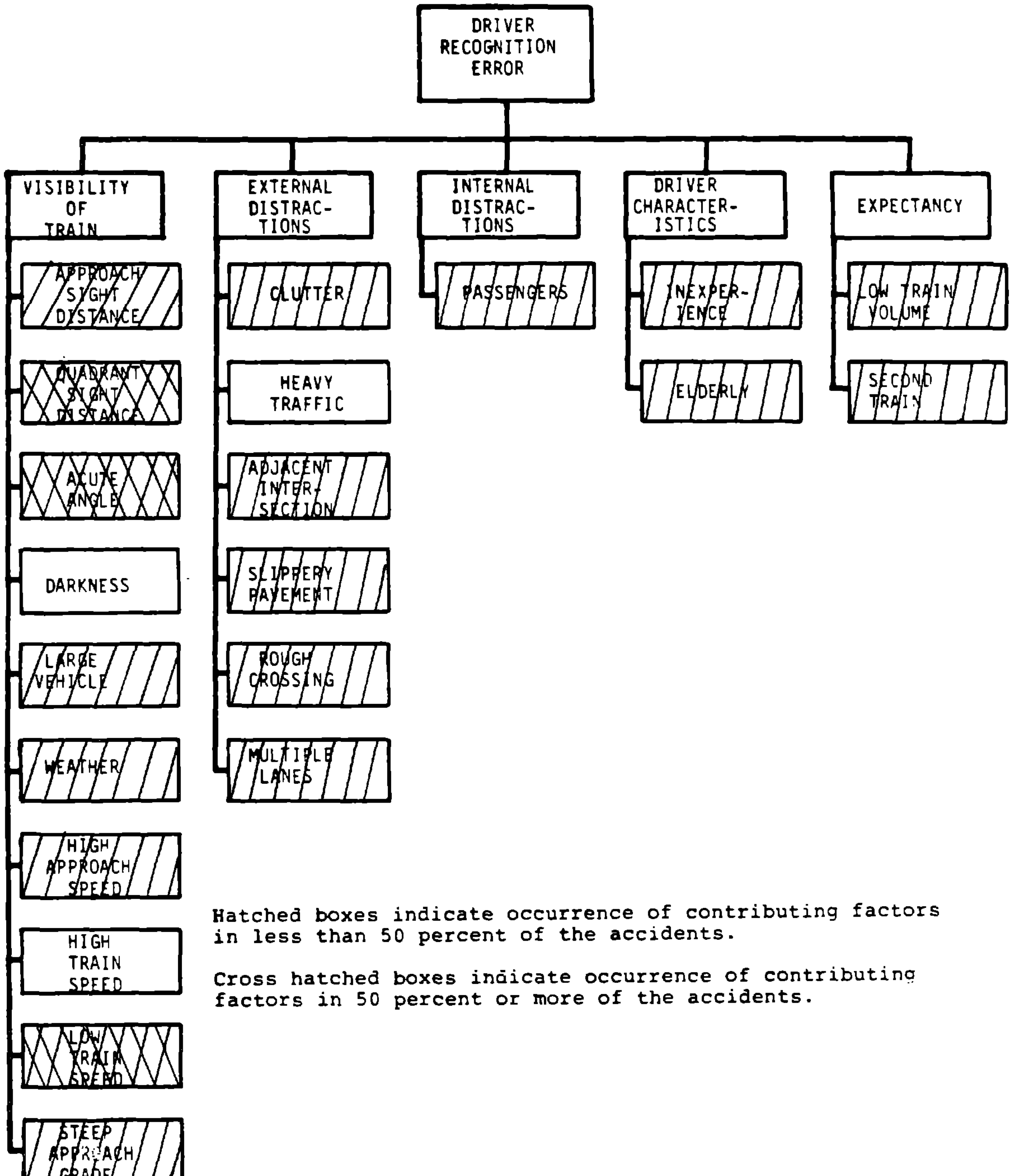
The most important contributing factors are limited quadrant sight distance and acute crossing angle which obscure visibility of the train. Obscured visibility of the train may combine with external distractions and/or low driver expectancy to divert and preempt the drivers attention away from a search for the train.

Possible Countermeasures

Increase awareness of the dangers at crossings with obscured visibility of the train by providing drivers with more informative advance warning signs.

Clear quadrant to provide better sight distance.

Install signals.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 23. Contributing Factors to Driver Recognition Error (R1A) - Crossbuck Warning Devices.

ACCIDENT TYPE R1B

North Carolina 1/0
Wisconsin

Event Sequence

Driver does not recognize train from approach zone
Maintains speed, enters nonrecovery zone
Does not recognize train in critical track zone
Maintains speed; Collision

Contributing Factors Pattern

None, sample too small

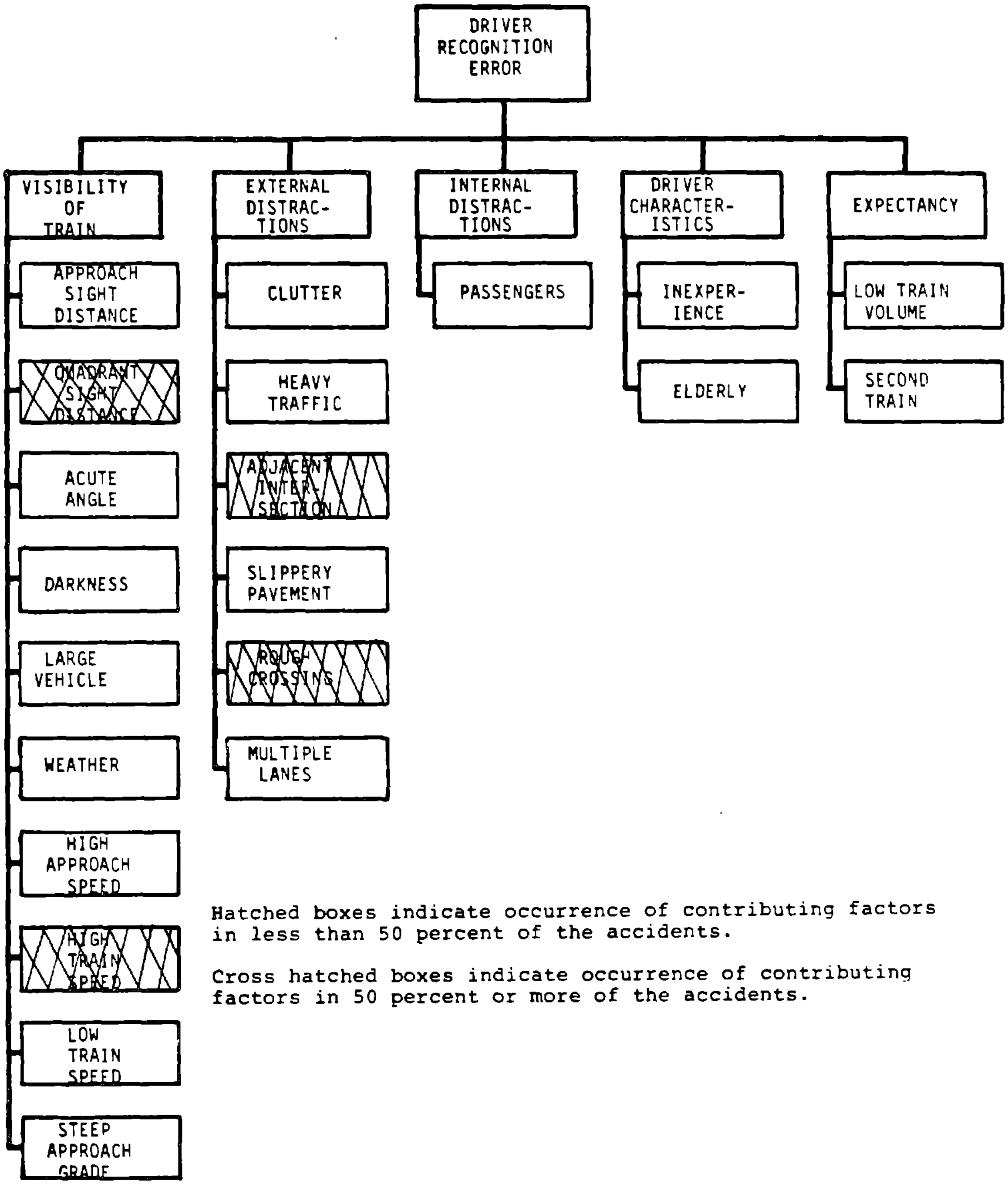
Discussion

No contributing factors pattern because of small sample size. The contributing factors are limited quadrant sight distance, high speed train, adjacent intersection and rough crossing. This accident is separated from those in R1A because it involved a high speed train.

Limited quadrant sight distance obscured visibility of the train and external distractions may have contributed to diverting the driver's search for the train which was approaching at a high rate of speed.

Possible Countermeasures

Install active warning devices. During the accident site investigation it was observed that gates were being installed at this crossing.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 24. Contributing Factors to Driver Recognition Error (R1B) - Crossbuck Warning Devices.

ACCIDENT TYPE R2A

North Carolina 2/0
Wisconsin 3/0

Event Sequence

Driver does not recognize train from approach zone

Maintains speed, enters nonrecovery zone

Recognizes train in critical track zone

Skids; Collision with train car (not locomotive)

Contributing Factors Pattern

Darkness 5/0

Inexperienced driver 3/0

Slippery pavement 3/0

Discussion

This accident type involves collisions between vehicles and trains already on the roadway as opposed to trains entering the roadway. Limited visibility due to darkness was the main contributing factor. Inexperienced drivers may be especially prone to this type of accident. Four crossings were not illuminated.

Slippery pavement may have been coincidental and not necessarily contributory. Had the driver recognized the train from the approach zone, he should have been able to stop in time as the approach zone calculation is based on wet pavement conditions.

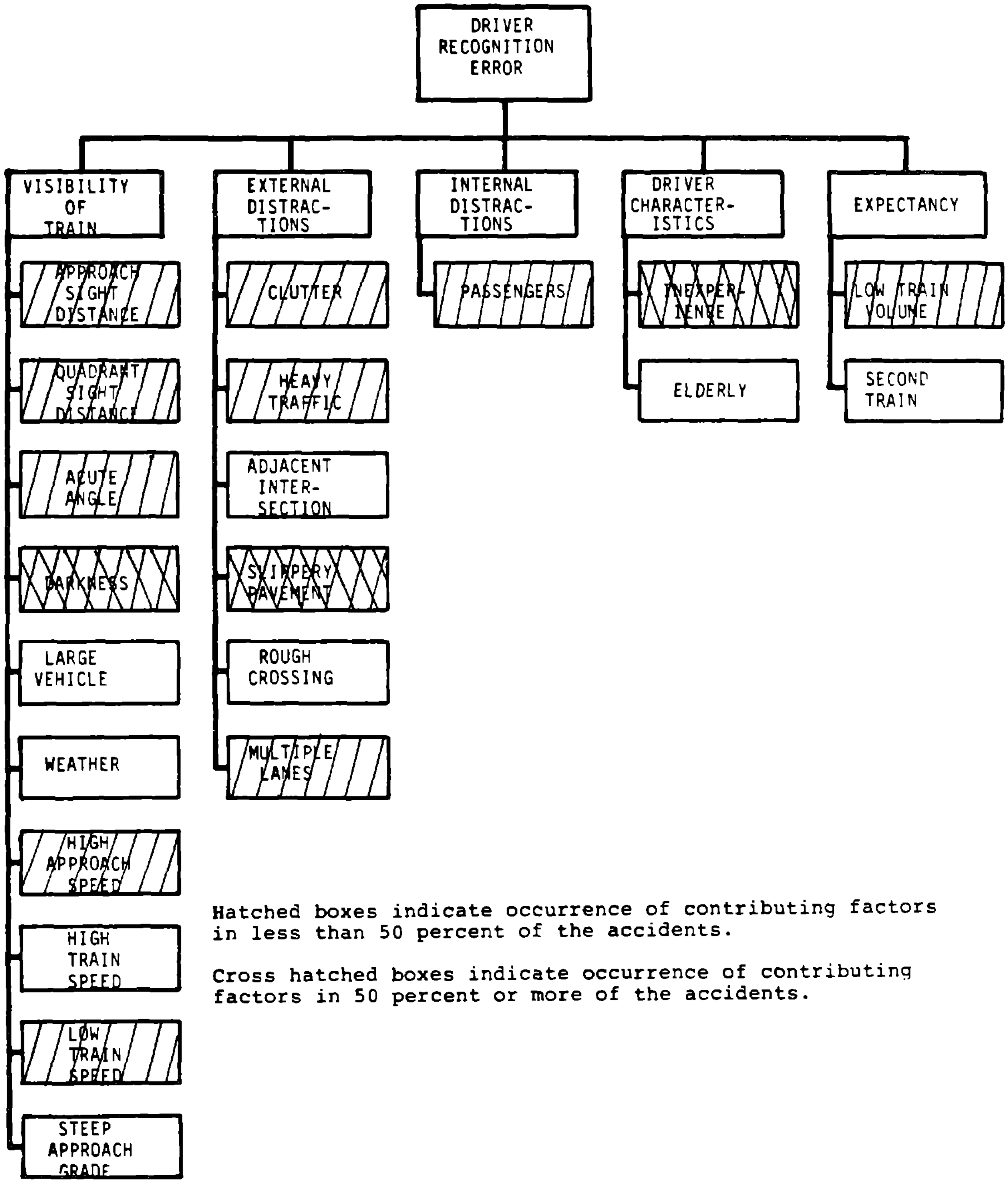
Limited approach sight distance was a factor in two cases and therefore may not necessarily be a strong contributing factor in this type of accident. Low train volume was a factor in two cases and expectancy may also not be a strong contributing factor.

Possible Countermeasures

Illuminate rail highway crossings which have passive warning devices.

Use more conspicuous on-train lighting or reflectorized rolling stock.

Provide driver education with emphasis on inexperienced drivers.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 25. Contributing Factors to Driver Recognition Error (R2A) - Crossbuck Warning Devices.

ACCIDENT TYPE R2B

North Carolina
Wisconsin 2/0

Event Sequence

Driver does not recognize train from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Skids; Collision with train car (not locomotive)

Contributing Factors Pattern

Driver characteristics - inexperienced 1/0, elderly 1/0
High approach speed 2/0
Passengers 2/0
Limited quadrant sight distance 2/0
Steep approach grade 2/0
Slippery pavement 2/0

Discussion

This accident type involves collisions between vehicles and trains already on the roadway as opposed to trains entering the roadway. This accident type is separated from R2A because of the approach speed and because the accidents occurred during the daylight.

In each of these accidents, vehicle speed was the most important contributing factor. In one case the driver was speeding in good driving conditions and in the other case, the driver was exceeding a safe speed for existing weather and environmental conditions.

Passengers may have provided internal distractions. Approach sight distance was clear and limited quadrant sight distance was coincidental since the train was already on the tracks.

Possible Countermeasures

Provide driver education with emphasis on excessive speed and danger to inexperienced and elderly drivers.

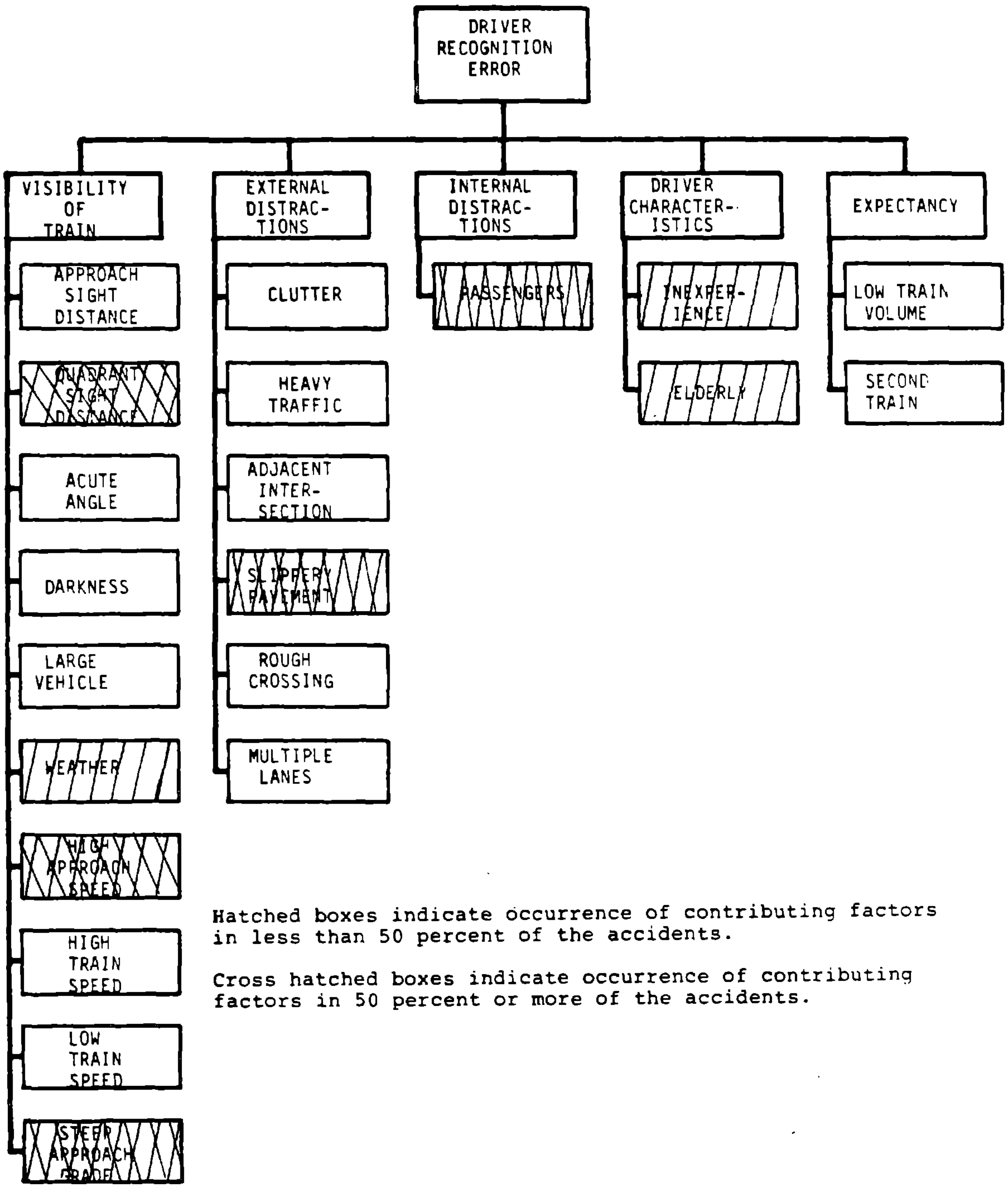


Figure 26. Contributing Factors to Driver Recognition Error (R2B) - Crossbuck Warning Devices.

ACCIDENT TYPE R3

North Carolina 4/0
Wisconsin 3/0

Event Sequence

Driver does not recognize train from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Skids; Collision with locomotive

Factors

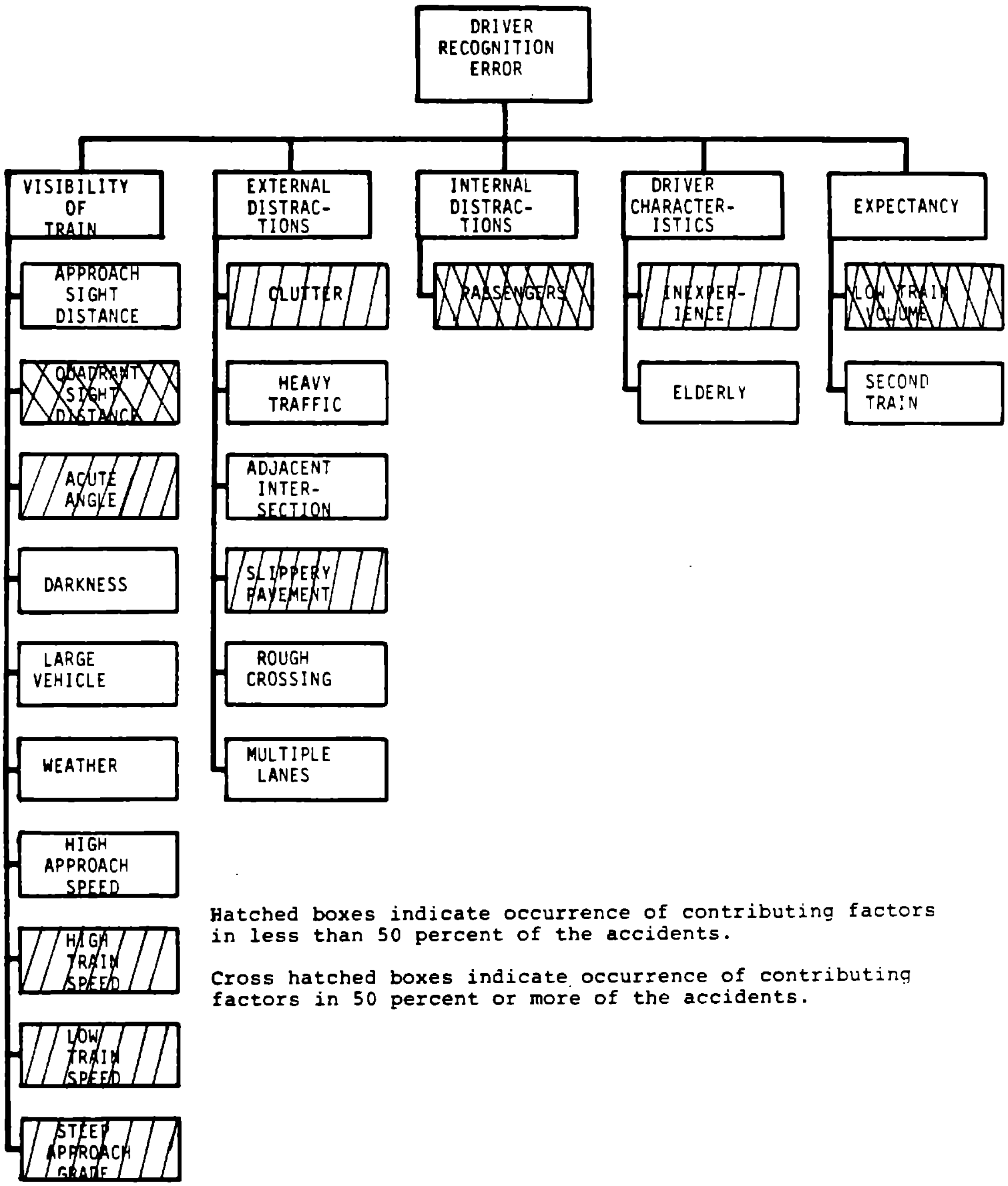
Limited quadrant sight distance 7/0
Low train volume 5/0
Passengers 4/0

Discussion

Two factors are important in this accident type - limited quadrant sight distance and low train expectancy. Internal distractions from passengers may also impact on the drivers' attention thereby causing delayed recognition of the train.

Possible Countermeasures

Clear quadrant sight distances where possible.
Install more informative advanced warning signs.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 27. Contributing Factors to Driver Recognition Error (R3) - Crossbuck Warning Devices.

ACCIDENT TYPE R4

North Carolina 2/0
Wisconsin 1/1

Event Sequence

Driver does not recognize train from approach zone
Maintains speed, enters nonrecovery zone
Recognizes train in critical track zone
Maintains speed; Collision

Factors

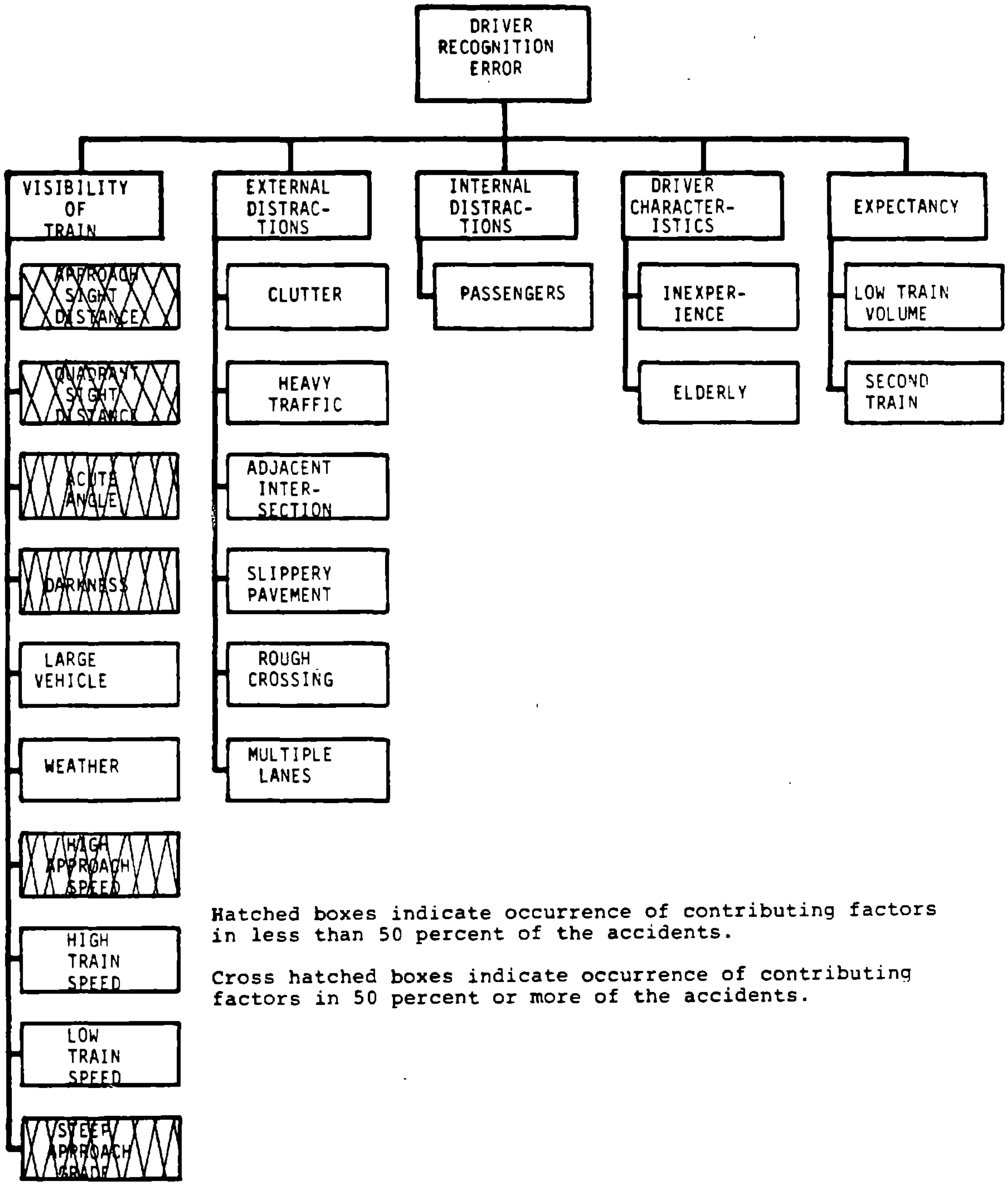
Limited quadrant sight distance 2/0
Limited approach sight distance 1/1
Acute crossing angle 2/1
Darkness 2/0
High approach speed 1/1
Steep approach grade 1/1

Discussion

Limited quadrant sight distance and limited approach sight distance are the important factors in this accident type. Sight distance conditions may cause the driver's train recognition to be delayed until the last moment. Darkness and acute crossing angle cause the driver to misjudge the rate of closure and feel he can beat the train and/or the high approach speed and the steep downward approach grade cause the driver to feel that he cannot stop in time.

Possible Countermeasures

Clear quadrant sight distance.
Install cantilevered flashing lights.
Illuminate crossing.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 28. Contributing Factors to Driver Recognition Error (R4) - Crossbuck Warning Devices.

ACCIDENT TYPE D1

North Carolina 1/0
Wisconsin 1/1

Event Sequence

Driver recognizes train from approach zone
Maintains speed, enters nonrecovery zone
Maintains speed; Collision

Contributing Factors Pattern

Driver characteristics - inexperienced 1/0, truck driver 1/0
Roadway environment - acute angle 1/0, high approach 1/0, darkness 1/0
Competing inputs - slippery pavement 1/1, low train speed 1/0, adjacent intersection 1/0

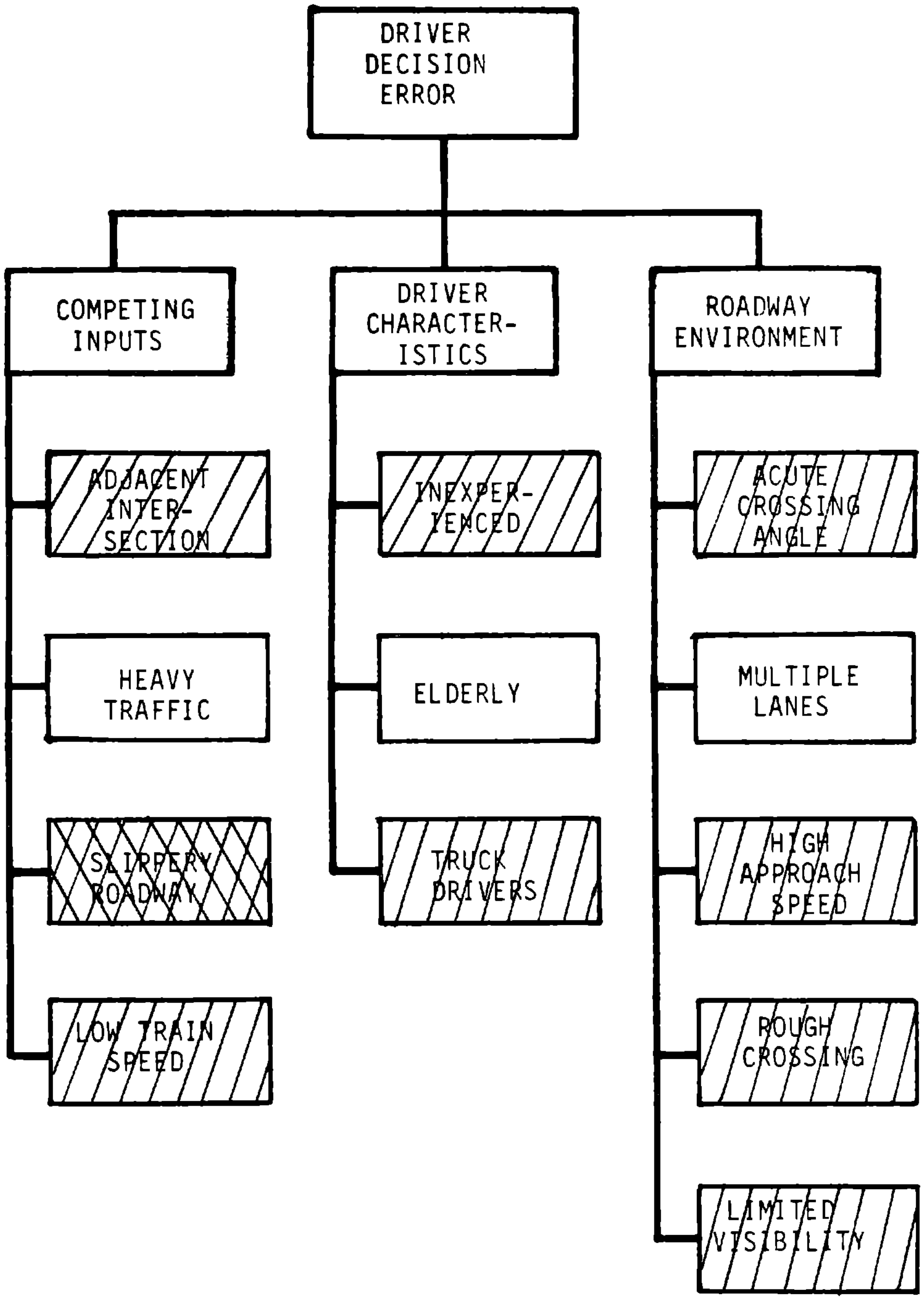
Discussion

This sample is rather small and factors are too dispersed to indicate a pattern.

This accident type involved drivers from whom risk-taking behavior would be anticipated. In each case, the train was in clear view from the approach zone. Possibly the combination of roadway environment, reinforced by competing inputs may have caused driver to misjudge rate of closure of train and attempt to beat it.

Possible Countermeasures

Provide education with emphasis on risk taking for inexperienced drivers and truck drivers.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 29. Contributing Factors to Driver Decision Error (D1) - Crossbuck Warning Devices.

ACCIDENT TYPE D2

North Carolina 2/0
Wisconsin 1/0

Event Sequence

Driver recognizes train from approach zone
Maintains speed, enters nonrecovery zone
Skids; Collision

Contributing Factors Pattern

High approach speed 3/0
Acute crossing angle 2/0
Low train speed 2/0

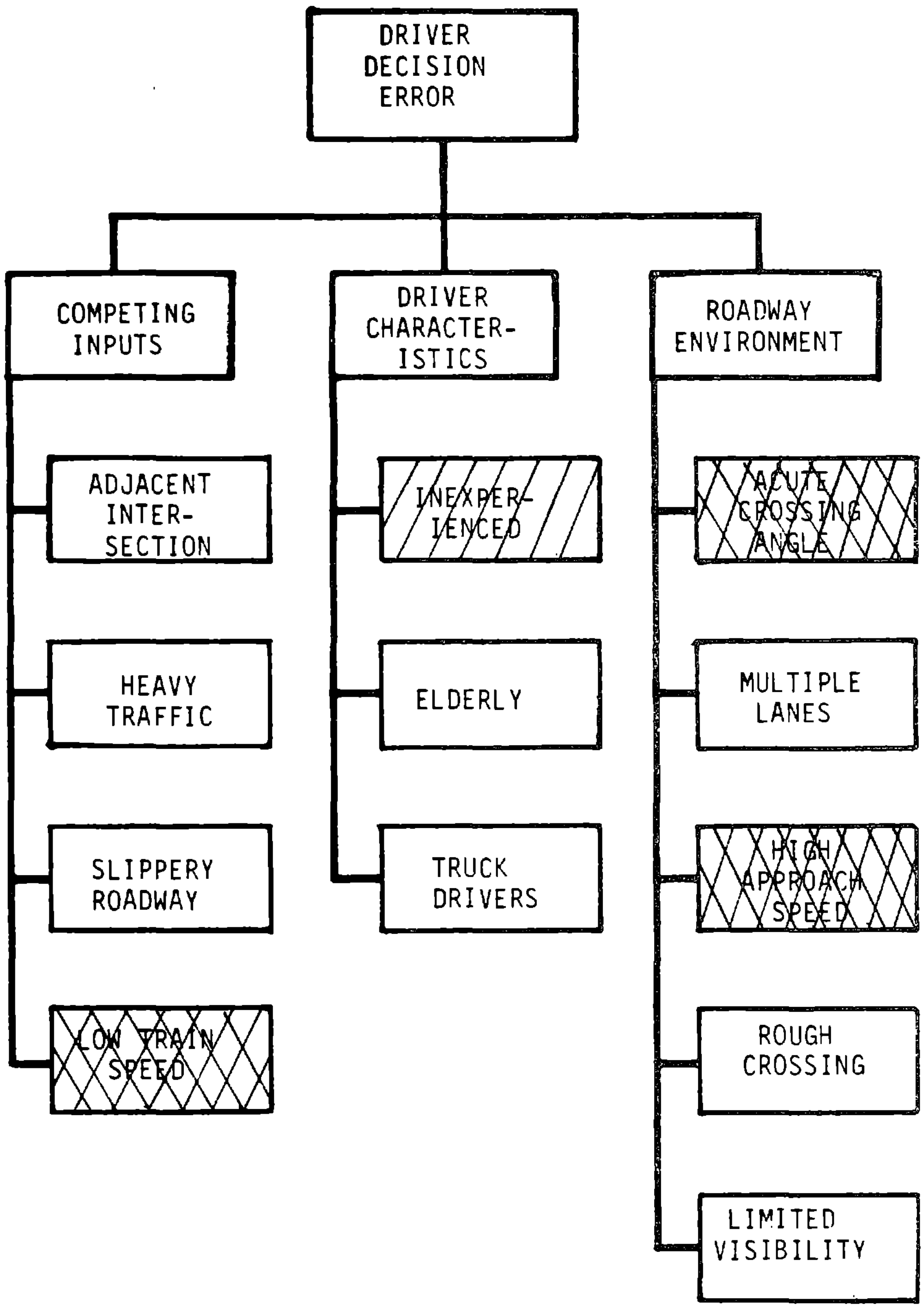
Discussion

In the approach zone where the driver first recognized the train the combination of high approach speed, low train speed and acute crossing angle may have caused the driver to misjudge the rate of closure. The high approach speed would have caused the approach zone to be farther from the crossing.

As the drivers entered the nonrecovery zone the rate of closure may have become more apparent causing them to realize that they couldn't beat the train and they attempted to brake in front of the train.

Possible Countermeasures

Provide better educational programs emphasizing rail highway crossing saftey.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 30. Contributing Factors to Driver Decision Error (D2) - Crossbuck Warning Devices.

ACCIDENT TYPE D3

North Carolina
Wisconsin 1/0

Event Sequence

Driver recognizes train from approach zone
Brakes to stop in advance of hazard zone
Train enters critical track zone
Driver attempts to cross; Collision

Contributing Factors Pattern

None, sample too small

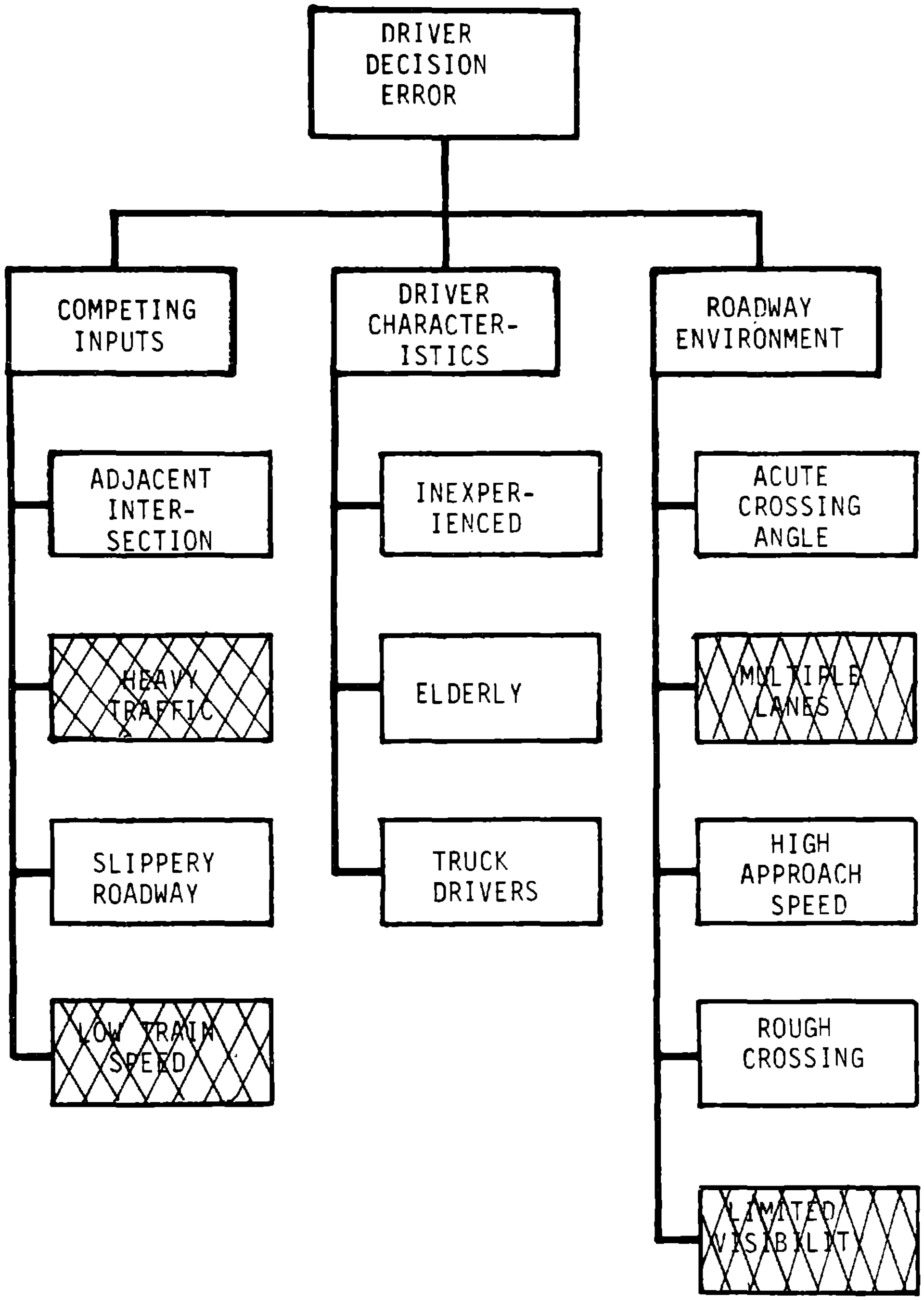
Discussion

While the small sample does not allow for a contributing factors pattern, this accident could be indicative of other accidents in a larger sample.

It may be especially difficult for a driver to judge the rate of closure of a low speed train in periods of darkness. A driver in heavy traffic on a multilane road may either not want to block traffic or may follow the lead of other drivers who traverse the crossing. This accident may have been caused by the drivers inability to judge and therefore allow his judgment to be influenced by external conditions.

Possible Countermeasures

Provide driver education.



Hatched boxes indicate occurrence of contributing factors in less than 50 percent of the accidents.

Cross hatched boxes indicate occurrence of contributing factors in 50 percent or more of the accidents.

Figure 31. Contributing Factors to Driver Decision Error (D3) - Crossbuck Warning Devices.

Summary of Accident Analysis and Countermeasures

The accident types, contributing factors patterns and possible countermeasures for accidents at crossbuck warning devices are summarized and discussed.

An evaluation of the preceding accident analysis indicates that 82 percent of the accidents had event sequences that involved driver recognition error and 18 percent involved driver decision error. In 82 percent of the accidents in the sample drivers were unable to recognize the train from the approach zone.

Accidents due to driver recognition errors had the following contributing factors patterns:

- Limited quadrant sight distance, acute crossing angle, low speed train and expectancy (R1A).
- Darkness, inexperienced driver and slippery pavement (R2A).
- Driver characteristics, high approach speed, passengers, limited quadrant sight distance, steep approach grade and slippery pavement (R2B).
- Limited quadrant sight distance, low train volume and passengers (R3).
- Limited quadrant sight distance, limited approach sight distance, acute crossing angle, darkness, high approach speed and steep approach grade (R4).

In the driver decision error accident types one contributing factors patterns was discerned:

- High approach speed, acute crossing angle, low train speed (D2).

Four of the recognition error accident types involved limited quadrant sight distance, one involved limited approach sight distance and two involved darkness. These three contributing factors all contribute to obscuring visibility of the train. Two contributing factors patterns involve driver expectancy and two involve inexperienced and elderly drivers. It is to these contributing factors that the possible countermeasures are mainly addressed.

Tables 10 and 11 present the possible education, enforcement and engineering countermeasures for accidents at crossbuck warning devices. Though the countermeasures are briefly discussed it is not the intent to analyze the feasibility of the countermeasures.

Education

Education countermeasures could be considered in a general approach; in aiding drivers in the driver decision making process; and in dealing with a specific type of accident - drivers who collided with trains already on the crossing.

Since the major contributing factors groups in the crossbuck accident sample dealt with factors prohibiting visibility of the train and train expectancy, it may be more advantageous to provide greater driver information rather than a general education approach.

Table 10. Accident Types and Contributing Factors Patterns
Education and Enforcement Countermeasures
Crossings with Crossbuck Warning Devices.

	Accident Type	Contributing Factors Patterns	Countermeasures: Education	Countermeasures: Enforcement
R2A	Driver only recognizes train in non-recovery zone; Skids	Darkness Inexperienced drivers Slippery Pavement	Inexperienced	———
R2B	Driver only recognizes train in non-recovery zone; Skids	Driver characteristics High approach speed Passengers	General	———
D2	Driver recognizes signal from approach zone Maintains speed, enters non-recovery zone; Skids	High approach speed Acute crossing angle Low train speed	General	———

Table 11. Accident Types and Contributing Factors Patterns
Engineering Countermeasures
Crossings with Crossbuck Warning Devices.

			Countermeasures			
	Accident Type	Contributing Factors Patterns	Alternative Warning Device	Clear Quadrant	Additional Motorist Information	Illuminate Crossing Reflectorize Railcars
R1A	Driver does not recognize signal or train	Limited quadrant sight distance Acute crossing angle Low train speed Expectancy	X	X	X	
R2A	Driver only recognizes train in non-recovery zone Skids; train on crossing	Darkness Inexperienced driver Slippery pavement			X	X
R3	Driver only recognizes train in non-recovery zone Skids; hits locomotive	Limited quadrant sight distance Low train volume Passengers		X	X	
R4	Driver only recognizes train in non-recovery zone Maintains speed	Limited quadrant sight distance Limited approach sight distance Acute crossing angle Darkness High approach speed Steep approach grade	X	X		

Aiding the driver in his decision making process could be undertaken by informing the driver about the difficulties in judging the rate of closure of the train. See the discussion for accident type D2. Since driver decision errors at crossbucks only contributed to 18 percent of the accidents, this approach would not cover very many accidents.

The contributing factors pattern for accidents where drivers collided with trains already on the crossing (R2) includes inexperienced drivers. For remedial measures, this accident type could be included with other accident types where a contributing factor is inexperienced drivers. Among all accidents in the sample which occurred at crossbuck crossings, inexperienced drivers were involved in over 30 percent of these accidents. It may be most effective if high school driver education programs included a section concerning rail highway crossing safety.

<u>Enforcement</u>

There are three constraints to using enforcement countermeasures. They involve clarity and enforceability of the law, type of driver error and law enforcement priorities.

Rail highway crossing laws are somewhat confusing especially when dealing with the crossbuck crossing. Many states require the driver to stop for trains which are sounding their horns or trains which are in clear view. These laws allow drivers to proceed across the tracks when the train doesn't present a hazard. The problem is nobody has really defined what constitutes a hazard to the motorist. As can be seen from the accident analysis and contributing factors patterns the visibility of the train is obscured in many cases.

Aside from the above, enforcement may be most effective in dealing with driver decision errors which comprise only 18 percent of the crossbuck accidents in the sample. Enforcement may not aid with driver recognition errors unless a standard such as a posted speed limit or a stop sign is the object of the enforcement. Also, in light of the many duties of local and state law enforcement agencies the use of enforcement to combat rail highway accidents may not be feasible from a priority standpoint.

Engineering

As discussed above, all five contributing factors patterns for driver recognition error involved visibility of the train. In two of these contributing factors patterns there was also an expectancy problem. The driver cannot recognize the train from the approach zone, and since he does not expect a train, he does not slow down sufficiently so that he can see the train from the lower-speed approach zone.

Possible countermeasures include the installation of active warning devices, the use of a stop sign with the crossbuck, clearing the obstructions to quadrant sight distance and providing additional motorist information - posted reduced speed limit, adding a speed advisory to the advanced warning sign, other types of advanced advisory signs, such as acute angle crossing, blind railroad crossing, etc. For brevity the countermeasures in Table 10 are condensed. Alternative warning device refers to stop signs or activated warning devices; additional motorist information includes various types of advisory signs and posted reduced speed limits; clear quadrant refers to removing the obstruction to quadrant sight distance.

Another possible countermeasure for the limited quadrant sight distance factor is a combination of posted reduced speed or speed advisory and the partial clearing of the obscured sight distance of the quadrants. This may only be feasible where permanent structures do not provide the obstruction. By reducing the speed limit on the approaches to the crossing, one effectively lessens the required quadrant sight distance needed, and the amount of clearing of the quadrant required.

Two of the five contributing factors patterns for driver recognition errors involved drivers who collided with trains already on the crossing. For that contributing factors pattern involving darkness, inexperienced driver and slippery pavement, the engineering countermeasures are illuminating the crossing and/or using reflectorization material on locomotives and railcars. For the other contributing factors pattern for this accident type there were no engineering countermeasures. The contributing factors pattern included driver characteristics, high approach speed and passengers.

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the study limitations that constrain generalization of the findings, conclusions and recommendations, and suggestions for further research.

Limitations of the Findings

The indepth accident analysis was performed for 79 accidents (36 crossbuck and 43 flashing lights accidents). Though the sample ideally should have been larger, the time required for conducting the accident site investigation, manually combining the information from the state accident report, the FRA accident report and the U.S DOT-AAR crossing inventory and resolving discrepancies in these data prohibited a larger sample. Although certain contributing factors patterns emerged for various accident event sequences,the size of the sample constrains generalizations from the sample to the universe of rail highway accidents.

When dealing with the universe of the rail highway crossing accidents,consideration must also be given to those accidents not included in the sample: those at other types of warning devices such as gates, flagmen, stop signs and special devices; those at flashing lights and crossbucks which involve reported alcohol and/or drug use and which involve cars stopped, standing or stalled on the crossing.

The magnitude of the various types of driver recognition and decision error may vary from the results of the sample to the universe of rail highway accidents as the exposure level of contributing factors varies. Different regions of the country may exhibit differing combinations of driver characteristics, weather, road conditions, external distractions and signal credibility. For example, accident type R1A at flashing light warning devices has an event sequence where the driver does not recognize the signal from the approach zone and does not recognize the signal nor the train from the nonrecovery zone. The contributing factors which appear in over 50 percent of the accidents in this accident type are elderly drivers, external distractions and limited quadrant sight distance. While the pattern may hold true for the universe of rail highway crossings, the relative significance of the accident event sequence may vary as the exposure level of elderly drivers to crossings with flashing lights, external distractions and limited quadrant sight distance varies.

Conclusions and Recommendations

The analysis of accidents in the indepth accident investigation sample indicated that there are many different event sequences connected with accidents at rail highway crossings. These event sequences involved different contributing factors patterns. When possible countermeasures for rail highway accidents are evaluated their effectiveness should be judged with regard to their relevance to the contributing factors patterns.

A review of the contributing factors patterns associated with the accident event sequences indicate that in many instances the driver did not receive sufficient information.

At crossings with flashing light warning devices 62 percent of the accidents in the sample involved driver decision error. Of the six contributing factors patterns, five involved extended warning time of the signal. Extended warning time may cause the flashing lights to lose credibility with driver. Competing inputs may then gain greater impact in the driver decision making process. In cases of limited quadrant sight distance the driver may decide to take his chances or wait until he sees the train, in cases of heavy traffic he may decide to follow the traffic flow, where there is clear sight distance and a view of the train the driver may decide to attempt to beat the train.

A possible countermeasure for extended warning time is the installation of constant warning time track circuits. The provision of constant warning to the driver may restore a credibility in the signal which may outweigh other inputs to the driver decision making process.

The type of countermeasure differs for other contributing factors patterns. Certain driver recognition errors, where the event sequence indicates that the driver saw neither the signal nor the train from the approach and nonrecovery zones or saw the signal only from the nonrecovery zone, may require more conspicuous warning devices.

At crossings with crossbuck warning devices 82 percent of the accidents in the sample involved driver recognition errors. The driver was unable to recognize the train from the approach zone. In three of the four accident types the contributing factors pattern included the obscured visibility of the train factors group. In two of these patterns the train expectancy group was also present.

The possible countermeasures all involve providing more information to the driver. One possible countermeasure involves the use of reduced speed signs or speed advisory signs and clearing obstructions to quadrant sight distance for the lowered speed approach zone.

If educational countermeasures are utilized they may be more effective if they are aimed at specific subsets of the driving population. Certain types of drivers - elderly, inexperienced and truck drivers - show a strong presence in contributing factors patterns of different accident event sequences. Focusing the educational countermeasure to subsets of drivers and types of accident event sequences could produce a greater impact.

Further Research

Based on the work undertaken for the project, the evaluation of data sources and the analysis of accident reports, three suggestions for further research are presented.

It would have been informative to utilize the accident analysis methodology on a much larger data base. Regretably, a data base containing the information used in the indepth accident investigation sample does not exist. When the FRA Rail-Highway Crossing Accident/Incident reporting format is reviewed, consideration should be given to gathering additional data either for the accident report or the crossing inventory form. Accident data elements that may prove valuable, without presently considering the cost and feasibility of their acquistion, are accident event sequence data, presence and length of skid marks, vehicle approach speed, age, sex and alcohol/drug use. Additional data that may be valuable for the U.S. DOT-AAR crossing inventory are approach, quadrant and stop line sight distance, track circuit information and range of warning times for each track, posted speed limit, approach grade and angle of crossing. The type of development - urban, rural, commercial, industrial - could be modified by an expanded site environmental description. To the data already present such as type of roadway, number of lanes and average annual daily traffic, actual angle of crossing, distance to nearest intersection, and sight distance restrictions could be added.

In the selection of the indepth accident analysis sample, many accidents where not selected for the sample because the vehicles were stopped, standing or stalled on the crossing. The Rail-Highway Crossing Accident/Incident Bulletin (2) lists 2014 accidents or 17 percent of the total accidents in 1978 which involve vehicles standing on the crossing. The comparable figures for 1979 (16) are 2763 accidents or 25 percent of the total accidents. A review of the North Carolina and Wisconsin accident reports indicate that these accidents may be due to alcohol use, action errors, vehicle failures or environmental factors such as rough roadway, ice and snow on the crossing or entrapment due to traffic signals and signs. An indepth accident analysis, utilizing the methodology developed for this project, may indicate contributing factors patterns and possible countermeasures for these types of accidents.

In driver decision errors at crossings with flashing light warning devices four of the five contributing factors patterns included the factor extended warning time which is associated with credibility of the signal. The Rail-Highway Crossing Accident/Incident and Inventory Bullentin (2) lists 596 accidents in 1978 where motorists drove around or through gates. An analysis of these accidents may indicate whether extended warning time could be a strong contributing factor. If this is the case then a possible countermeasure may be to equip gates with constant warning time detection circuits.

APPENDIX A

FIELD SURVEY PROCEDURES
FOR
RAIL HIGHWAY FLASHING LIGHT CROSSINGS

STEP #1 Photograph the crossing inventory number board. This photograph should be the first picture in the photo series for each crossing.

STEP #2 Measure the angle between the railroad tracks and the center line of the roadway. The angle to be measured is the angle which falls in the right hand approach quadrant.

STEP #3 Begin crossing site drawing.

STEP #4
A. Locate all positions of signs, roads, commercial drives, hillcrests, etc.

B. Measure the distance from the crossing to the decision point.

C. Measure the distance from the crossing to the minimum stopping point.

D. Measure the distance from the crossing to the beginning of the nonrecovery zone.

E. Measure the distance from the crossing to the beginning of the approach zone.

STEP #5 Take photographs from the beginning of the approach zone. Include the entire crossing and the accident quadrant in photograph. These pictures will be numbers 2 and 3 in the crossing series. Check crossing signal visibility from this point.

STEP #6 A. Measure the accident quadrant sight distance along the tracks as seen from the beginning of the nonrecovery zone.

B. Take four photographs of the crossing from the beginning of the nonrecovery zone. These photos will be numbers 4, 5, 6, and 7 in the crossing series. Check crossing signal visibility from this point.

STEP #7 Locate track circuit and measure its distance from the edge of the roadway. Compute the warning time based on circuit distance and reported train speed.

STEP #8 Take a photograph of the target pole from the minimum stopping distance for the estimated vehicle approach speed. The target pole should be placed at the estimated train position. This photograph will be number 8 in the crossing series. Check crossing signal visibility from this point.

STEP #9 Take a photograph of the target pole from the calculated driver decision point. The target pole should be placed at the estimated train position. This photograph will be number 9 in the crossing series. Check crossing signal visibility from this point.

STEP #10 List all impressions concerning the site's characteristics. Check for visibility problems, competing stimuli problems, etc.

STEP #11 Finish crossing site drawing.

STEP #12 Determine which driver failure occurred for each accident. List all reasons.

APPENDIX B

FIELD SUMMARY PROCEDURES FOR RAIL HIGHWAY CROSSBUCK CROSSINGS

STEP #1 Photograph the crossing inventory number board. This photograph should be the first picture in the photo series for each crossing.

STEP #2 Measure the angle between the railroad tracks and the center line of the roadway. The angle to be measured is the angle which falls in the right hand approach quadrant.

STEP #3 Begin crossing site drawing.

STEP #4 A. Locate all positions of signs, roads, commercial drives, hillcrests, etc.

B. Measure the distance from the crossing to the decision point.

C. Measure the distance from the crossing to the minimum stopping point.

D. Measure the distance from the crossing to the beginning of the nonrecovery zone.

E. Measure the distance from the crossing to the beginning of the approach zone.

STEP #5 Take 2 photographs from the beginning of the approach zone. Include the entire crossing and the accident quadrant in photograph. These pictures will be numbers 2 and 3 in the crossing series.

STEP #6 A. Measure the accident quadrant sight distance along the tracks as seen from the beginning of the nonrecovery zone.

B. Take four photographs of the crossing from the beginning of the nonrecovery zone. These photos will be numbers 4, 5, 6, and 7 in the crossing series.

STEP #7 Take a photograph of the target pole from the minimum stopping distance for the estimated vehicle approach speed. The target pole should be placed at the estimated train position. This photograph will be number 8 in the crossing series.

STEP #8 Take a photograph of the target pole from the calculated driver decision point. The target pole should be placed at the estimated train position. This photograph will be number 9 in the crossing series.

STEP #9 List all impressions concerning the site's characteristics. Check for visibility problems, competing stimuli problems, etc.

STEP #10 Finish crossing site drawing.

STEP #11 Determine which driver failure occurred for each accident. List all reasons.

REFERENCES

1. Federal Railroad Administration and Federal Highway Administration, Report to Congress: Railroad-Highway Safety, Part II: Recommendations for Resolving the Problem, Washington, D.C.: August, 1972.

2. Federal Railroad Administration, Rail-Highway Crossing Accident/Incident and Inventory Bulletin No. 1 Calendar Year 1978, Washington D.C.: Government Printing Office, October, 1979.

3. Schoppert, D. W. and Hoyt, D. W., Factors Influencing Safety at Highway-Rail Grade Crossings, Washington, D.C.: Highway Research Board, National Cooperative Highway Research Program Report No. 50, 1968.

4. Sanders, J. H., Kolsrud, G. S., and Berger, W. G., Human Factors Countermeasures to Improve Highway-Railway Intersection Safety, Falls Church, Va: Biotechnology, Inc., Final Report, Contract No. DOT-HS-190-2-300, July, 1973.

5. Peterson, D. D., and Boyer, D. S., Feasibility Study of In-Vehicle Warning Systems, Rockville, Md: Tracor Jitco, Inc., Final Report Contract No. DOT-HS-256-3-752, May, 1975.

6. Canalog Logistics Ltd., et al., Study to Define the Requirements for Railway Level Crossing Protection Acceptable for Train Operations at Speeds Up to 200 Km/h, Montreal, Que: Transport Canada Research and Development Centre, Contract No. OST77-00069, August, 1978.

7. Wigglesworth, E.C., "Epidemiology of Road-Rail Crossing Accidents," Journal of Safety Research, Vol. 11, No. 4 (Winter 1979): 162-71.

8. National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Louisiana and Arkansas Railroad Freight Train and a L. V. Rhymes Tractor - Semitrailer at Goldonna, Louisiana, December 28, 1977; Washington, D. C.: 1978. (NTSB-RHR-78-1)

National Transportation Safety Board. Railroad/Highway Accident Report, Seaboard Coast Line/Amtrak Passenger Train/Pickup Truck Collision, Plant City, Florida, October 2, 1977; Washington, D.C.: 1978. (NTSB-RHR-78-2)

National Transportation Safety Board. Highway Accident Report, Usher Transport, Inc., Tractor-Cargo-Tank-Semitrailer Overturn and Fire, State Route 11, Beattyville, Kentucky, September 24, 1977; Washington, D.C.: 1978. (NTSB-HAR-78-4)

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of an Amtrack/Atchison, Topeka and Santa Fe Railway Train and a Tractor-Cargo Tank Semitrailer, Marland, Oklahoma, December 15, 1976; Washington, D.C.: 1977. (NTSB-RHR-77-3).

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Burlington Northern Freight Train With a Bus, Stratton, Nebraska, August 8, 1976; Washingon, D.C.: 1977. (NTSB-RHR-77-1)

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Chicago, Rock Island and Pacific Railroad Company Freight Train with an Automobile, Des Moines, Iowa, July 1, 1976: Washington, D.C.: 1977. (NTSB-RHR-77-2)

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Baltimore and Ohio Freight Train with a Pickup Truck, Beckemeyer, Illinois, February 7, 1976; Washington, D.C.: 1976. (NTSB-RHR-76-3).

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Crown-Trygg Construction Company Truck with an Amtrak Passenger Train, Elwood, Illinois, November 19, 1975; Washington, D.C:, 1976. (NTSB-RHR-76-2).

National Transportation Safety Board. Railroad Accident Report, Collision of Reading Company Commuter Train and Tractor-Semitrailer, Near Yardley, Pennsylvania, June, 5, 1975; Washington, D.C.: 1976. (NTSB-RHR-76-4)

National Transportation Safety Board. Railroad/Highway Accident Report, Southern Pacific Transportation Company Freight Train/Automobile Grade Crossing Collision, Tracy, California, March 9, 1975; Washington, D.C.: 1976. (NTSB-RHR-76-1)

National Transportation Safety Board. Railroad/Highway Accident Report, Collision of a Southern Railway Work Train with a Polk District School Bus at Aragon, Georgia, October 23, 1974; Washington, D.C.: 1975. (NTSB-RHR-75-1).

National Transportation Safety Board. Railroad/Highway Accident Report, Penn. Central Freight Train/School Bus Collision Near Congers, New York, March 24, 1972; Washington, D.C.: 1975. (NTSB-RHR-73-1).

National Transportation Safety Board. Railroad/Highway Accident Report, Atchison, Topeka and Santa Fe Passenger Train No. 212 Collision with Stillwater Milling Company Motortruck at 116th Street North Grade Crossing Near Collinsville, Oklahoma, April 5, 1971; Washington, D.C.: 1972. (NTSB-RHR-72-1).

National Transportation Safety Board. Railroad/Highway Accident Report, Illinos Central Railroad Company Train No. 1 Collision with Gasoline Tank Truck at South Second Street Grade Crossing, Loda, Illinois, January 24, 1970; Washington, D.C.: 1971. (NTSB-RHR-71-1).

National Transportation Safety Board. Railroad/Highway Accident Report, Boston and Maine Corporation Single Diesel-Powered Passenger Car 563 Collision with Oxbow Transport Company Tank Truck at Second Street Railroad - Highway Grade Crossing, Everett, Massachusetts, December 28, 1966; Washington, D.C.: 1968. (NTSB/DOT).

National Transportation Safety Board. Waterloo, Nebraska, Public School School Bus, Union Pacific Railroad Company Freight Train Accidnet, Waterloo, Nebraska, October 2, 1967; Washington, D.C.: 1968. (NTSB/DOT).

National Transportation Safety Board. Southern Pacific Railroad Company Fruitridge Road Grade Crossing, Sacramento, California, February 22, 1967; Washington, D.C.: 1968. (NTSB/DOT)

9. Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways, Washington, D.C.: 1978.

10. National Committee on Uniform Traffic Laws and Ordinances, Uniform Vehicle Code and Model Traffic Ordinance, Muchie Company, Charlottesville, VA.: 1979.

11. Russell, Eugene R., Analysis of Driver Reaction to Warning Devices at a High Accident Rural Grade Crossing, West Lafayette, Ind.: Purdue University, Joint Highway Research project, Report No. JHRP-74-16, August, 1974.

12. California Public Utilities Commission, The Effectiveness of Automatic Protection in Reducing Accident Frequency and Severity at Public Grade Crossings in California, San Francisco, California: June, 1974.

13. Post, Theodore J., H. Douglas Robertson. A User's Guide to Positive Guidance, Federal Highway Administration, June 1977.

14. Baerwald, John E., Mathew J. Huger and Louis E. Keeper. Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers, Englewood Cliffs, N.J.: 1976.

15. Institute of Traffic Engineers, Dynamic Design for Safety: Seminar Notes, Arlington, Va., Contract No. FH-11-7503, October 1975.

16. Federal Railroad Administration, Rail-Highway Crossing Accident/Incident and Inventory Bulletin No. 2 Calendar Year 1979, Washington D.C.: Government Printing Office, 1980.

BIBLIOGRAPY

Aarens, Marc, et al., "Alcohol, Casualties and Crime," Berkley, California: University of California, November, 1977.

Canadian Transport Commission: Railway Transport Committee, Report on Eleven Train-Vehicle Accidents at Public Crossings at Grade of Canadian National Railways and CP Rail and in the Vicinity of Edmonton, Alberta During the Months November and December 1973, Ottawa, Ontario: August, 1975.

Federal Highway Administration, Railroad-Highway Grade Crossing Handbook, Washington, D.C.: Government Printing Office, December, 1979.

Fell, James C., "A Motor Vehicle Accident Causal System: The Human Element," Human Factors Journal, Volume 18, Number 1, February 1976, page 85.

Fell, James C., "A Motor Vehicle Accident Causal System: The Human Element," Washington, D.C.: National Highway Traffic Safety Administration Report No. DOT-HS-801-214, July, 1974.

Jakulic, S., et al., "Psychomotor Fitness of Healthy Drivers after Consumption of the Permitted Amount of Alcohol," Selected Translations of International Alcoholism Research, Rockville, Md: The National Clearinghouse for Alcohol Information, 1975.

Jones, Ralph K., "Alcohol and Highway Crashes: A Projection for the 1980s," The HSRI Research Review, Ann Arbor, Michigan: The University of Michigan Highway Safety Research Institute, Vol. 7, No. 5, March - April, 1977.

Kearney, Edward F., Drivers' Duties at Railroad Grade Crossings. Washington, D.C: National Committee on Uniform Traffic Laws and Ordinances, Government Printing Office, January, 1979.

Maddox, Julia and Eugene R. Russell, Compilation of States' Laws and Regulations on Matters Affecting Rail-Highway Grade Crossings, (Preliminary Draft) Kansas State University, Manhattan, Kansas: April 1980.

National Highway Traffic Safety Administration, Fatal Accident Reporting System 1978 Annual Report, Washington, D.C.: National Center for Statistics and Analysis, 1978.

Rogers, Earl F., "Courts Imply Responsibility beyond Acceptable Standards" American Transportation Builder, July/August 1979.

Ruden, Robert J., Burg, Albert, and McGuire, John P., Activated Advance Warning for Railroad Grade Crossings, Palo Alto, Ca.: JGM Associates, Inc., (Prepared for the Federal Highway Adm.) March, 1980.

Russell, Eugene R. and Konz Stephan, "Night Visibility of Trains at Rail-Highway Grade Crossings," Manhattan, Kansas: Kansas State University, December, 1979.

Sanders, James H., Speed Profiles and Time Delay at Rail-highway Grade Crossings. Falls Church, VA: Biotechnology, Inc., National Technical Information Service, Contract No. DOT-FH-11-7867, May 1972.

Sanders, James H., McGee, Hugh W., and Yoo, Chang S., Safety Features of Stop Signs at Rail-Highway Grade Crossings: Volume II Technical Report, Falls Church, Va.: Biotechnology, Inc., Contract No. DOT-FH-11-9192, March, 1978.

Schaeffer, M. S., "Alcohol and Rail-Highway Grade Crossing Accidents: A Preliminary Discussion," Cambridge, Mass: Transportation Systems Center, October 1978.

Treat, J. R., N. S. Tambs, et al., Tri-Level Study of the Causes of Traffic Accidents, Executive Summary, Bloomington, Indiana: Institute for Research in Public Safety, Indiana University, National Highway Traffic Safety Administration, May, 1979.

Treat, J. R., Et al., Tri-level Study of the Causes of Traffic Accidents: Final Report, Volume I: Causal Factor Tabulations and Assessments, Bloomington, Indiana: Institute for Research in Public Safety, Indiana University, Contract No. Dot-HS-034-3-535 (Prepared for NHTSA) May 1979.

☆U.S. GOVERNMENT PRINTING OFFICE: 1982 361-428/2257 1-3