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Rail Highway Crossing Accident Causation Study, Vol. I

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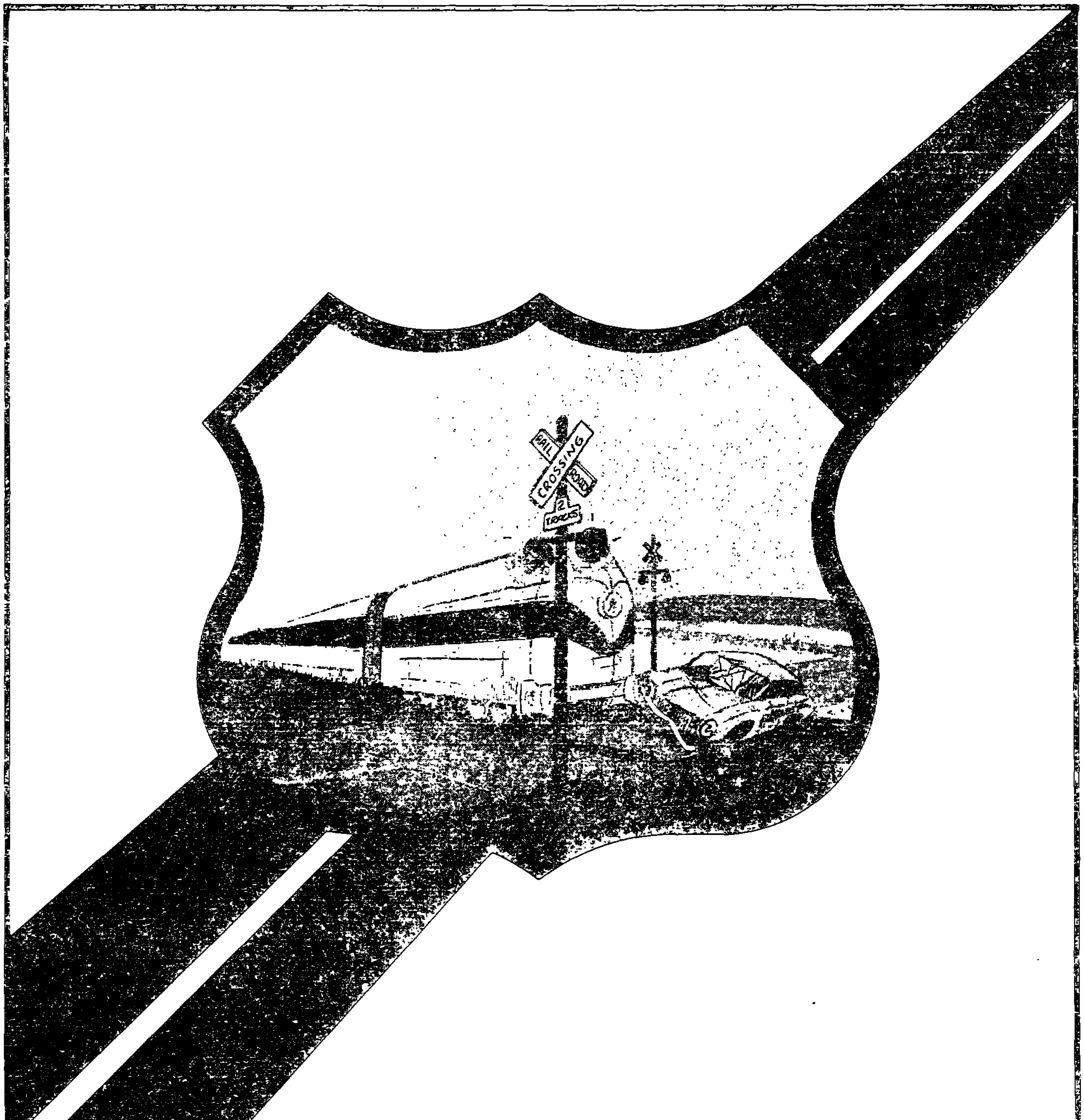
Report No.
FHWA/RD-81/082

Executive Summary

Final Report
August 1982



FOREWORD

This summarizes a research study performed to identify the factors that contribute to accidents at rail-highway crossings. Only accidents at crossings with flashing lights and crossbucks were considered during the study.

The research was performed by Input Output Computer Services, Inc. (IOCS) for the Federal Highway Administration (FHWA) under contract DOT-FH-11-9682.

Based on the accidents investigated at crossings with crossbucks, the study findings indicate, 82 percent of the accidents involved driver recognition errors. In these accidents, drivers were unable to recognize the train or the crossing from the approach zone. In the sample of accidents at crossings with flashing lights, 62 percent involved driver decision errors. IOCS identified possible countermeasures in the categories of education, enforcement, and engineering.

Sufficient copies of this report are being distributed to provide a minimum of one copy to each FHWA Regional office, one copy to each FHWA Division office, and three copies to each State highway agency. Direct distribution is being made to the Division office.

Charles F. Scheffey
Director, Office of Research

NOTICE

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16. Abstract

This volume synopsizes the investigation of contributing factors of accidents at crossings with flashing light and crossbuck warning devices. The data sources utilized, accident site investigation and methodology for the accident analysis are briefly discussed.

Accident type event sequences and their contributing factors are presented. 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.

Possible countermeasures, grouped by education, enforcement and engineering, are analyzed and discussed.

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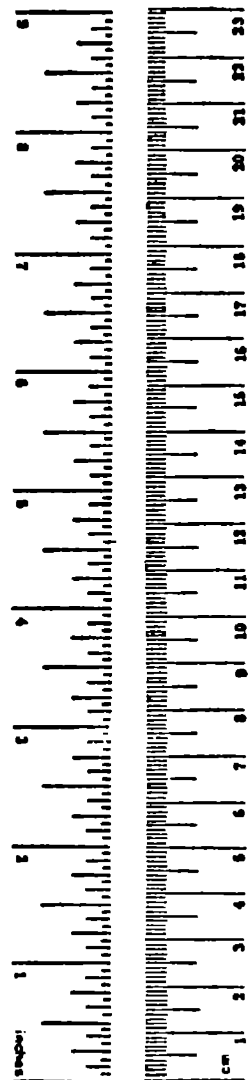
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

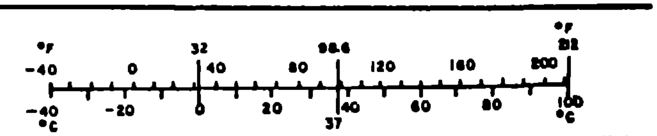
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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



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)*. 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 concepts for use in constant warning time detection circuits.

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.

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

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.

This study utilizes 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 errors.

Scope of Study

The scope of the study is limited to crossings with crossbuck and flashing light warning devices. These crossing types 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.

Accidents involving alcohol were excluded from the study. It was felt that the lack of sufficiently detailed information in State accident reports would prevent a meaningful study of the alcohol-involved driver.

In addition, stalled vehicle accidents or accidents involving standing vehicles were eliminated. The focus of this study was to determine what factors cause an approaching driver to be involved in a vehicle-train accident.

Data Sources Utilized

The study utilized crossings in North Carolina and Wisconsin as field survey sites. There were a number of reasons for their selection. First and most importantly, the State accident reports provided good information and the accident reports were fairly complete. Second, the reports were accessible. Both States agreed to provide photo copies 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, information on competing stimuli, and average daily traffic and train volume information.

It was decided that a combination of the United States Department of Transportation - Association of American Railroads (U.S. DOT-AAR) Crossing Inventory Information data base, the Federal Railroad Administration (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. The U.S. DOT - AAR Crossing Inventory Information data base and the Rail-Highway Grade Crossing Accident/Incident data base included all crossings in the United States. This meant that the study team could easily match crossings from these data bases with the State accident report crossings.

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 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 served as a check against the State accident reports. Finally, the site visits allowed the measurement of quadrant, approach and stop line sight distances necessary to determine the type of driver error involved in the accidents being reconstructed. In addition, the site survey would provide information on environmental conditions such as sharp curves, adjacent intersections, and steep approach grades.

Accident Site Investigation

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 occured.

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 Users Guide to Positive Guidance (3) to meet the specific needs of the study.

Methodology for the Accident Analysis

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 for characterizing the critical sequence of events which preceded each accident. Each chart was structured with the event sequence proceeding from top to bottom. At each recognition, decision or action point, the alternative paths are identified. The chart therefore appears as a tree whose branches terminate with the collision between the vehicle and the train. Because each path 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 the figures has a unique identification, i.e., R1, R2, . . . D1, D2. The logic flow charts for accidents at crossings with flashing light and crossbuck warning devices are presented in Figures 1 and 2 respectively. These event sequences are referred to in the next two sections to identify the event sequence accident type to which the accidents are assigned.

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 the factors in the Rail-Highway Crossing Accident/Incident and Inventory

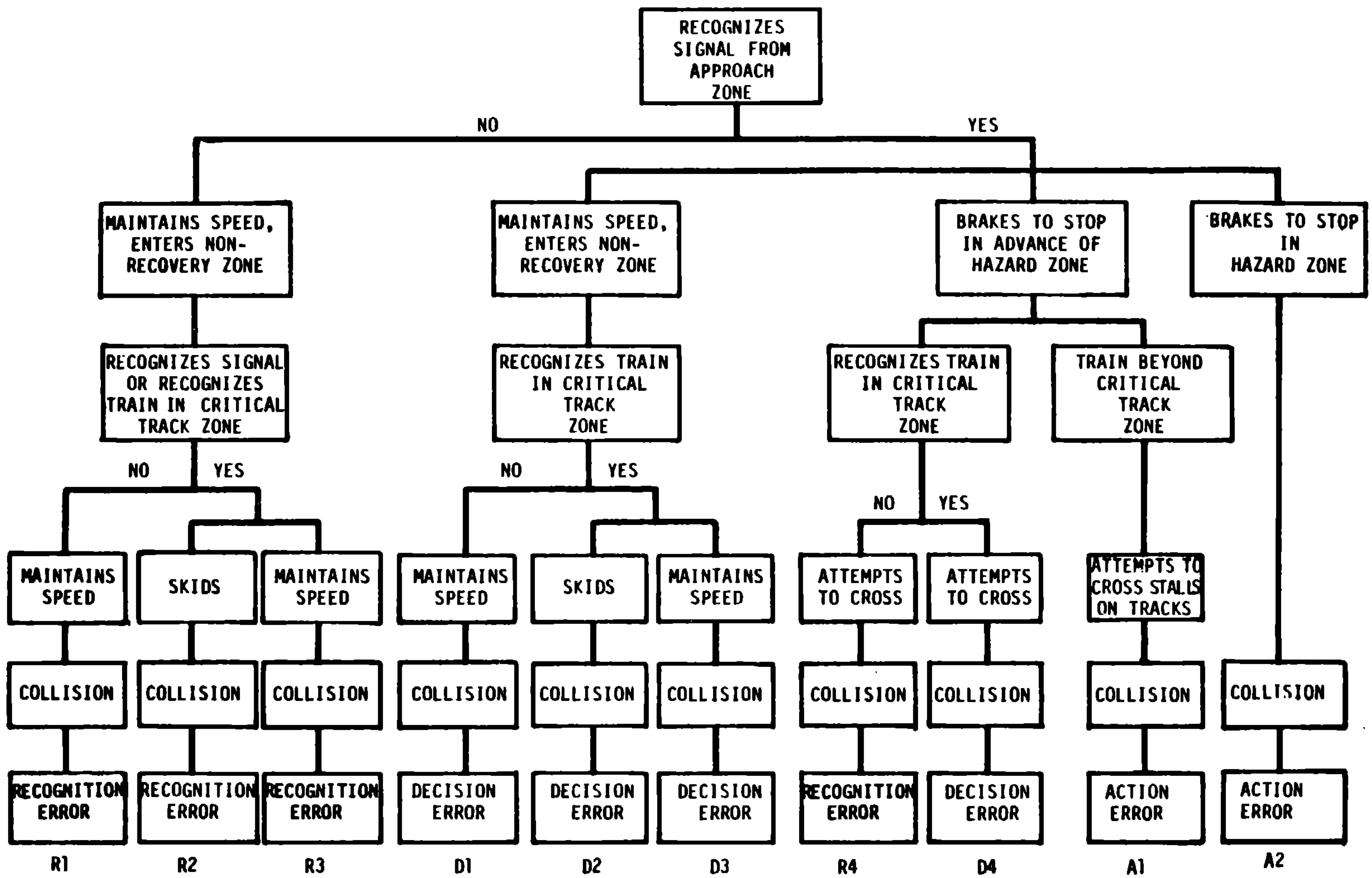

Figure 1. Logic Flow Chart for Driver Error Flashing Light Warning Devices.

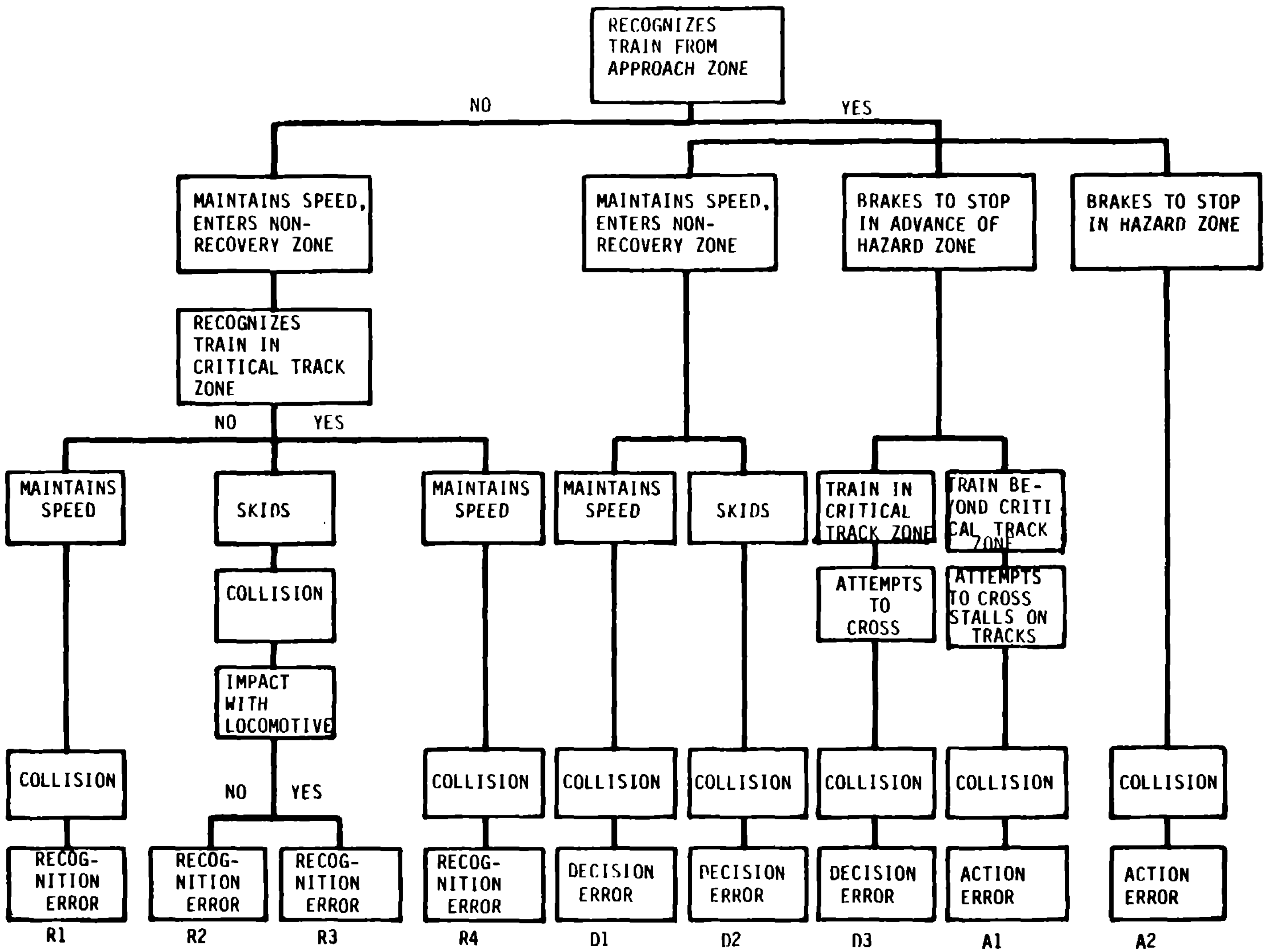

Figure 2. Logic Flow Chart for Driver Error Crossbuck Warning Devices.

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 crossings with flashing light warning devices, visibility of the signal, external distractions, internal distractions, driver characteristics (elderly, inexperienced and truck drivers) and visibility of the train were the five categories of factors contributing to driver recognition errors. Each category was composed of several individual factors. For example, external distractions included clutter, heavy traffic, adjacent intersection, slippery pavement, rough crossing and multiple lanes. Credibility, competing inputs, driver characteristics and roadway environment were the four contributing factors categories associated with driver decision errors.

At crossings with crossbuck warning devices, the driver recognition error contributing factors categories included visibility of the train, external distractions, internal distractions, driver characteristics and expectancy. Driver decision errors categories were competing inputs, driver characteristics, and roadway environment.

The event sequence, which led to the accident, was analyzed for each accident to determine the accident type. Then an evaluation was made regarding those factors from the lists of contributing factors which were judged to contribute to the accident. The accidents were then grouped by accident type and the contributing factors analyzed to ascertain contributing factors patterns. Where a contributing factor occurred in 50 percent or more of the accidents within a given accident type, that factor was considered as part of the contributing factors pattern associated with that accident type. The exception was cases where an individual factor did not occur in 50 percent of the accidents, but various factors within a contributing factors group showed a repeated presence. For example, while the individual external distraction factors may or may not be strong, the external distraction group of factors often represented a strong pattern.

Accident Analysis - Flashing Lights

The contributing factors patterns for accidents at crossings with flashing light warning devices are summarized in Table 1. Included are the accident type, number of accidents, percent of sample, the accident type event sequence, and the contributing factors pattern. Where two patterns were discernible, the accident types and their contributing factors pattern are listed separately (i.e., R1A, R1B). Most accidents were assigned to one accident type. For accidents where the data was insufficient to select between two accident types, that accident was assigned to both types. For example, accident type R1A has a total of five accidents assigned exclusively to it, and two accidents assigned to both R1A and another accident type, i.e., 5/2.

Table 1. Accident Event Sequences and Contributing Factors Patterns - Crossings with Flashing Light Warning Devices.

Accident Type(1) / Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) / Contributing Factors Pattern
RECOGNITION ERROR: TYPE R1A	5/2	14
Driver does not recognize signal from approach zone; Maintains speed; enters nonrecovery zone; Does not recognize signal nor train in critial track zone; Maintains speed; Collision.		Elderly drivers External distractions Limited quadrant sight distance

Table 1. Accident Event Sequences and Contributing Factors Patterns Crossings with Flashing Light Warning Devices (continued).

Accident Type(1) Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) Contributing Factors Pattern
RECOGNITION ERROR: TYPE R1B 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.	3/1	8 Visibility of signal obscured External distractions
RECOGNITION ERROR: TYPE R2 Driver does not recognize signal from approach zone; Maintains speed; enters nonrecovery zone Recognizes signal or train in critical track zone; Skids; Collision.	2/1	6 Visibility of signal obscured Slippery pavement
RECOGNITION ERROR: TYPE R3 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.	1/1	3 None due to small sample size
RECOGNITION ERROR: TYPE R4 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	3/0	7 Limited stop line sight distance Large vehicle and an acute crossing angle Heavy traffic

Table 1. Accident Event Sequences and Contributing Factors Patterns Crossings with Flashing Light Warning Devices (continued).

Accident Type(1) / Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) / Contributing Factors Pattern
DECISION ERROR: TYPE D1A	4/2	12
Driver recognizes signal from approach zone; Maintains speed, enters nonrecovery zone; Does not recognize train in critical track zone; Maintains speed; Collision.		Extended warning time(4) Low train speed Multiple tracks Limited quadrant sight distance Slippery pavement
DECISION ERROR: TYPE D1B	2/1	6
Driver recognizes signal from approach zone; Maintains speed, enters nonrecovery zone; Does not recognize train in critical track zone; Maintains speed; Collision.		Driver characteristics Competing inputs Limited quadrant sight distance Multiple tracks
DECISION ERROR: TYPE D2	7/1	17
Driver recognizes signal from approach zone; Maintains speed, enters nonrecovery zone; Recognizes train in critical track zone; Skids; Collision.		Extended warning time Limited quadrant sight distance Driver characteristics Heavy traffic
DECISION ERROR: TYPE D3A	4/2	12
Driver recognizes signal from approach zone; Maintains speed, enters nonrecovery zone; Recognizes train in critical track zone; Maintains speed; Collision		Extended warning time Low speed train Multiple tracks

Table 1. Accident Event Sequences and Contributing Factors Patterns Crossings with Flashing Light Warning Devices (continued).

Accident Type(1) / Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) / Contributing Factors Pattern
DECISION ERROR: TYPE D3B	4/1	10
Driver recognizes signal from approach zone; Maintains speed, enters nonrecovery zone; Recognizes train in critical track zone; Maintains speed; Collision		Extended warning time Driver characteristics Limited quadrant sight distance Adjacent intersection Heavy traffic Slippery pavement
DECISION ERROR: TYPE D4	2/0	5
Driver recognizes signal from approach zone; Brakes to stop in advance of hazard zone; Recognizes train in critical track zone; Attempts to cross; Collision		Limited visibility Low train speed Extended warning time Inexperienced driver Acute crossing angle

(1) Each path or branch in figure 1 identifies a unique event sequence, i.e., R1, R2, . . . D1, D2.

(2) X/Y refers to accidents assigned exclusively/accidents assigned to both this and another accident

(3) Total number of accidents in the flashing light warning device sample was 43.

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

Possible Countermeasures - Flashing Lights

In the 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. The discussion of possible countermeasures considers the percentage of accidents attributable to driver recognition and decision errors. The countermeasures are grouped by education, enforcement and engineering.

Education

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 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.

Accident Analysis - Crossbucks

The contributing factors patterns for accidents at crossings with crossbuck warning devices are summarized in Table 2.

Table 2. Accident Event Sequences and Contributing Factors Patterns - Crossings with Crossbuck Warning Devices.

Accident Type(1) / Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) / Contributing Factors Pattern
RECOGNITION ERROR: TYPE R1A	10/2	31
Driver does not recognize train from approach zone; Maintains speed; enters nonrecovery zone; Does not recognize train in critical track zone; Maintains speed; Collision.		Limited quadrant sight distance Acute crossing angle Low speed train Expectancy
RECOGNITION ERROR: TYPE R1B	1/0	3
Driver does not recognize train from approach zone; Maintains speed; enters nonrecovery zone; Does not recognize train in critical track zone; Maintains speed; Collision		None, sample size too small. This accident is separated from R1A because it involved a high speed train
RECOGNITION ERROR: TYPE R2A	5/0	14
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)		Darkness Inexperienced driver Slippery pavement

Table 2. Accident Event Sequences and Contributing Factors Patterns Crossings with Crossbuck Warning Devices (continued).

Accident Type(1) / Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) / Contributing Factors Pattern
RECOGNITION ERROR: TYPE R2B	2/0	5
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).		Driver characteristics High approach speed Passengers Limited quadrant sight distance Steep approach grade Slippery pavement
RECOGNITION ERROR: TYPE R3	7/0	19
Driver does not recognize train from approach zone; Maintains speed, enters nonrecovery zone; Recognizes train in critical track zone; Skids; Collision with locomotive.		Limited quadrant sight distance Low train volume Passengers
RECOGNITION ERROR: TYPE R4	3/1	10
Driver does not recognize train from approach zone; Maintains speed, enters nonrecovery zone; Recognizes train in critical track zone; Maintains speed; Collision.		Limited quadrant sight distance Limited approach sight distance Acute crossing angle Darkness High approach speed Steep approach grade
DECISION ERROR: TYPE D1	2/1	7
Driver recognizes train from approach zone; Maintains speed, enters nonrecovery zone; Maintains speed; Collision.		None, sample too small and factors dispersed

Table 2. Accident Event Sequences and Contributing Factors Patterns Crossings with Crossbuck Warning Devices (continued).

Accident Type(1) Accident Type Event Sequence	Number of Accidents(2)	Percent of Sample(3) Contributing Factors Pattern
DECISION ERROR: TYPE D2 Driver recognizes train from approach zone; Maintains speed, enters nonrecovery zone; Skids; Collision.	3/0	8 High approach speed Acute crossing angle Low train speed
DECISION ERROR: TYPE D3 Driver recognizes train from approach zone; Brakes to stop in advance of hazard zone; Train enters critical track zone; Driver attempts to cross; Collision.	1/0	3 None, sample too small

(1) Each path or branch in figure 2 identifies a unique event sequence, i.e., R1, R2, . . . D1, D2.

(2) X/Y refers to accidents assigned exclusively/accidents assigned to both this and another accident type.

(3) Total number of accidents in the crossbuck warning device sample was 36.

Possible Countermeasures - Crossbucks

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.

<u>Education</u>

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.

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. 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 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.

Enforcement

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.

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 where no engineering countermeasures. The contributing factors pattern included driver characteristics, high approach speed and passengers.

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.

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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.