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HUMAN FACTORS COUNTERMEASURES TO IMPROVE HIGHWAY-RAILWAY INTERSECTION SAFETY

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16. Abstract

A field demonstration study in support of the evaluation of alternative railway-highway grade crossing accident countermeasures was conducted.

Guidelines were provided for the development of countermeasure concepts, the selection of candidate countermeasures, countermeasures evaluation methods, and experimental design and procedures.

Investigations of the causative factors of accidents showed that maintenance of protective warning devices, driver attention and driver expectancy were precipitating and predisposing factors in accidents.

An appraisal of inherent driver safety potential was made which included driver education and licensing, safety programs and law enforcement, attitude and habit components of railway-highway safety and psychophysiological capabilities and limitations.

A broad base of data was obtained in a demonstration field study conducted in five states. Information was obtained on driver behavior, knowledge and attitude. Three data collection procedures were used: the Traffic Evaluator System, time-lapse photography, and motorist response to questionnaires. An extensive analysis was performed on the data obtained to suggest countermeasures concepts and to determine target populations for effective countermeasures intervention.

Measures of driver performance were developed which were shown to be sensitive to countermeasure intervention. Under restricted conditions, driver looking behavior, crossing speed and speed decrease were shown to be sufficient and valid measures of performance to evaluate the effectiveness of a countermeasures intervention.

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SUMMARY

This project was a field demonstration study undertaken to support a subsequent evaluation of alternative rail-highway grade crossing accident countermeasures. The objectives included:

- identification of causative factors in grade crossing accidents.
- appraisal of inherent driver safety potential.
- development and refinement of instrumentation and data collection and analysis procedures applicable for field evaluation of grade crossing accident countermeasures.
- development and validation of measures of driver behavior useful for countermeasures evaluation.
- application of techniques to nine grade crossings.
- analysis of the field data with emphasis on its implications for various countermeasures concepts, and
- development of guidelines for the projected definitive evaluation of grade crossing accident countermeasures.

A review of rail-highway intersection accidents was undertaken. While crossings with active devices constitute only 22 percent of all at-grade crossings, 41 percent of fatalities and injuries occur at these crossings. Severity of accident does not appear to be related to whether the crossing has active or passive protection. The data on driver familiarity with the crossing is somewhat limited but suggests most accidents involve familiar drivers. Malfunctioning or poor maintenance of protective or warning devices, driver inattention, and driver expectancy of no train when one is actually present based on previous experience at the crossing are noteworthy of the precipitating and predisposing factors cited in some accident case histories.

An appraisal of inherent driver safety was undertaken to assist development of the field study design and the human factors of countermeasures applications. Six major categories of factors which contribute to inherent driver safety potential are discussed. These are:

- Driver education
- State licensing procedures
- Safety programs
- Law enforcement
- Attitude and habit components of railway-highway safety
- Psychophysiological capabilities and limitations

Nine railway-highway grade crossings were included in this study. They were selected to provide a broad range of crossing types. Included were three passive crossings, two active crossings with high train volumes, and four active crossings matched by physical characteristics as nearly as was possible. The matched crossings were located in Virginia, Texas, Michigan, and California to permit investigation of regional differences.

All crossings were instrumented with an automated system for collection of time and position data on all vehicles (the Traffic Evaluator System.) This system provided speed and acceleration data as well as the relationships between adjacent vehicles such as time and space headways. It was also used to record events such as the covert observation of driver looking behavior, activations of crossing signals, train arrival times and train speed readings obtained with speed measuring radar.

Time lapse photography was used to provide a backup to the Traffic Evaluator System and to provide a record of motorist behavior during train approaches and during the operation period of signals.

Selected drivers were stopped well past the grade crossing with the assistance of police officers and a structured interview/questionnaire was administered. Drivers were selected at random as well as were those drivers who stopped at the crossing both with and without signal activations. The questionnaire was matched with the behavior record obtained by the Traffic Evaluator System.

Information collected during this study included categories of driver behavior, knowledge, and attitude. An extensive analysis was performed on the data obtained to suggest countermeasures concepts and to determine target populations for effective countermeasures intervention.

For the study design described in this report, measures of driver performance were shown to be sensitive to countermeasures intervention and were validated. Under restricted conditions, it was shown that driver looking behavior, crossing speed, and speed decrease were sufficient measures of driver performance to evaluate the effect of a countermeasure intervention.

The study provides guidelines for the development of countermeasures concepts and the selection of candidate countermeasures, development of countermeasure evaluation methods, and the development of experimental design and procedures.

Suggestions for Further Research

The investigations of accident causation revealed that the information available is not adequate to provide definitive answers to many questions about why railroad-highway accidents occur on a nationwide scale. It was discovered, however, that the accident histories of specific crossings may be obtained. It appears that there is frequently a recurrence of the same accident type. The nature of such accidents was found to frequently suggest modifications to individual crossings which would reduce or eliminate a major proportion of those accidents. There appears to be a need for research which would develop procedures for crossing evaluation and modification which would be performed and implemented on a local basis.

Such an accident site typology, or diagnostic procedure, would enable a traffic engineer to examine sites and determine the probability that the same type of accident would recur and define appropriate countermeasures.

Along the same lines, it was noted that a broad range of hazard index formulae exist throughout the country. The resulting ranking of crossings is generally the order in which improvements in the crossing environment are made. A nationwide standard method of determining a hazard index for crossings should be developed which would apply proper weights to all pertinent variables. It may be found that those crossings which exceed maximum limits should be closed until upgraded to reasonable standards.

This study formulated valid and sensitive measures of behavior for carefully selected types of grade crossings, particularly those which had restrictions to visibility along the approach. There is a need for the determination of measures to be applied to open crossings and those which have other characteristics, such as crossings reached immediately after a turn. That is, performance measures valid at crossings where near looking behavior and speed reduction are not necessarily related to the detection of a train hazard are needed.

The prescription of countermeasures to categories of grade crossing situations implies that accident reduction may be achieved by an increase in the mean performance of all or some subset of drivers using that crossing. If there is a relation between safer performance and accidents, the behavioral measures defined in this study should be able to rank crossings by accident occurence probability. This ranking should agree with the ranking obtained from actual accident history.

An experiment is indicated which would validate these (or other) performance measures on the basis of accident occurrence. This could be approached as a double-blind experiment in which mean driver safety indices are obtained for a large number of similar crossings and the resulting ranking compared to that obtained using actual accident data.

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CHAPTER I

INTRODUCTION

Background and Statement of the Problem

Over 70,000 people have lost their lives at railway-highway grade crossings in the past 50 years – over 15,000 people were killed in the last decade. The shock effect of this statistic alone is enough to warrant an intensive countermeasure effort. However, in some specific aspects, the problem is more severe than one might guess. For example, less than one percent of all highway accidents occur at railway-highway crossings but they result in 2.7 percent of the total fatalities. Consider also that the fatality-to-injury ratio for railway-highway accidents is 1:2.7 compared to 1:35 in general highway accidents. Thus, the violence of railway-highway grade crossing accidents is clearly evident. Table I-1 presents some summary statistics to help put the problem in perspective.

Programs aimed at reducing this problem have been underway for many years. These programs have generally involved either: (1) elimination of grade crossings, (2) installation or upgrading of warning or protective devices, and (3) attempts to increase driver railway-highway safety awareness. All of these programs are expensive and their payoff questionable in terms of benefits in relation to cost. This is particularly true when it is recognized that there are approximately 220,000 railway-highway crossings on public roads in the United States of which more than 175,000 are passive crossings, i.e., have no special warning or protective devices, and another 400,000 on private roads. Considering the cost of protective devices (see Table I-1), it is obviously not economically feasible to provide "active" protection at all crossings. In addition, because of the limited amount of motor vehicle and train traffic at many crossings, even minimal active protection is probably not warranted. It is within the context of this background that the National Highway Traffic Safety Administration and the Federal Railroad Administration have undertaken a comprehensive research program to "refine further the understanding of the causal factors in motor vehicle/train accidents and to develop and demonstrate selected improvements which will achieve a safer environment for traffic at the railway-highway intersection." A specific project within this program is concerned with "Human Factors Countermeasures to Improve Highway-Railway Intersection Safety."

Table 1–1

Some Summary Statistics Concerning
the Highway-Railway Grade Crossing Safety Problem

- There are approximately 220,000 highway-railway intersections in the United States.
- Fewer than 44,000 crossings have special warning or protective devices.
- The motorist's view of the track may be clear or completely obscured.
- The allowed speed limits, both vehicular and rail, vary from zero (stop sign) to 80 miles per hour or more.
- Over 1,500 deaths and 3,000 injuries occur annually at U.S. grade crossings.
- Economic losses in excess of $300 million result from crossing accidents.
- The least costly active protective device now possible, single-track, flashing lights, is likely to cost $15,000 to $20,000.
- Typical gate installations involving a few minor complications can cost from $25,000 to $100,000.
- In 1969, there were 3,572 vehicle-train accidents
    - They resulted in 1,381 deaths and 3,578 injuries. In 2/3 of the cases, the train struck the vehicle causing 75 percent of the deaths.
    - In 1/3 of the cases, the vehicle struck the train.
    - In 42 percent of the cases, the crossing was protected by lowered gates, trainmen, watchmen, and audible or visual signals.
    - In 58 percent of the cases, the crossing was protected by a signal or sign that did not indicate the approach of a train.
    - 62 percent occurred in daylight and 68 percent in clear weather.
    - 77.5 percent of the vehicles were automobiles; 21.5 percent were trucks, and one percent were buses and motorcycles.

From a human factors point of view, the problem of reducing accidents at railway-highway intersections may be defined as a decision making problem. Simply stated, the problem is to increase the probability that drivers approaching railway-highway intersections will make the proper decision. This decision in basic terms is either to stop safely short of the crossing, or to proceed safely over the crossing. Driver decisions, generally speaking, can be favorably influenced by increasing the adequacy of their (1) inherent or long-term information, or (2) immediate or short-term information (see Figure 1-1). Inherent or long-term information is a function of attitudes and knowledge shaped by such things as education and training, licensing procedures, law enforcement practices, and public safety promotional campaigns. Immediate or short-term information is a function of the vehicle/train dynamics, signs, and displays in the vicinity of the site, traffic control devices specific to the site, and other site specific countermeasures designed to influence driver behavior.

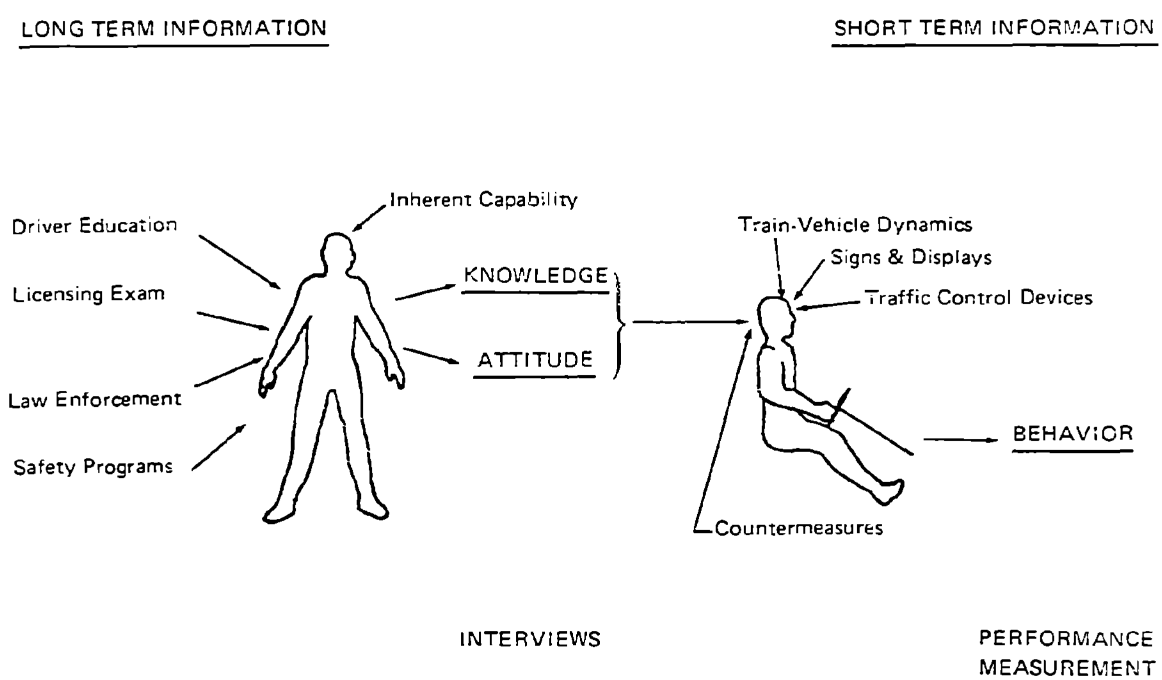

Figure 1-1. Factors influencing driver decision making

In order to prescribe the most effective characteristics of long-term and short-term information and their implications for countermeasures, it is necessary to try and understand causal factors, driver behaviors and attitudes, and measures of effectiveness for evaluating countermeasures. That is essentially what this project is about. It is probably axiomatic to say that this is a very complex research area. Perhaps this point is best summarized in an RFP prepared and issued by NHTSA which reads as follows:

> Research in this area is particularly difficult for several reasons. First, because vehicle/train accidents are so infrequent, it is necessary to develop intermediate or secondary criteria to evaluate the effectiveness of any changes in the system. These criteria must be relevant, measurable, and free from experimentally introduced biases. Second, because railway-highway intersections can vary along so many safety relevant dimensions, it may be very difficult to establish truly comparable sets or groups of intersections where the effectiveness of new devices, etc. can be evaluated or compared in a controlled or "before and after" setting. Finally, the introduction of improved safety features at one intersection may influence the behavior of drivers at all intersections, thus further complicating the interpretation of results.

Objectives and Approach

This project is primarily a field demonstration to define the problems, to develop solution concepts, and to determine the feasibility of the instruments, experimental protocol, and analytic techniques. The primary product is an experimental plan for a subsequent definitive study to evaluate the cost effectiveness of solution concepts. The objectives of this project can be stated as below:

Develop:

1. Causative factors from a review of railway-highway intersection accidents.
2. A description of the driver's inherent safety potential.
3. Instrumentation and methods for measuring driver behavior, knowledge, and attitudes.
4. Human factors countermeasures concepts.

Demonstrate:

1. The effectiveness of the instrumentation and methodology as tools for extensive study of driver behavior, knowledge, and attitudes.
2. The effectiveness of human factors countermeasures in improving railway-highway safety.

Recommend:

1. Countermeasures which are cost-effective in modifying driver behavior at railway-highway crossings through either:
   a. overt devices or physical changes at railway-highway intersections, or
   b. changing driver attitudes and safety awareness
2. A plan for field evaluation of countermeasures concepts which are feasible.

The above objectives were planned in a four-phase study project. The following is a brief description of each phase and the interaction between phases.

Phase I was a review of a selected sample of accidents in order to determine causative factors. The results of Phase I were applied in Phase II to sharpen the criteria for site selection, experimental measures and instrumentation, and to help in the determination of driver behavior and attitudes as well as human factors countermeasures concepts.

One of the principal goals to be met in Phase II was the establishment of human factors norms with respect to driver knowledge, attitude, and behavior. In the overall scheme of the research, these norms will serve as standards of comparison for "before" and "after" studies of specific grade crossing sites. In addition, Phase II provided measures of effectiveness that, together with the field experimental findings of Phase III (validation study), supported the planning of large scale field experimentation (Phase IV).

The overall objectives of the project have already been described. The specific objectives met in Phases I and II were:

- Better understand the driver population and the behavior it displays at grade crossings.
- Define a set of "safety oriented" behavioral measures that are both operationally meaningful and capable of reliable experimental measurement.
- Isolate a set of driver characteristics that can serve as nonredundant predictors of driving performance.
- Determine the extent to which the observed behavior or predictor variables can be used to develop and evaluate railway-highway countermeasures.
- Suggest the most cost-effective set of measures applicable to countermeasures design and evaluation.

At the outset of the project, it was presumed that there would be a coherent pattern of driver behavior at railway grade crossings which, when determined, would provide a base for prescriptive recommendations in the form of countermeasures. The image of a coherent pattern included what might be called an ideal behavioral sequence. The "safe" driver would be decelerating during the approach to the grade crossing from the point of awareness. If the crossing site had passive warning devices, velocity would drop to a level whereby the driver could make a thorough visual and auditory scan. The scanning process would be manifested by appropriate head movements and actions such as rolling down the window and turning down the radio or turning off the air conditioner to enhance auditory perception of warning signals. At crossings guarded by active warning devices, the scanning process could be more expeditious on the assumption that attention could be focused on the warning devices as such and that the absence of a positive warning would be sufficient basis for a relatively expeditious passage through the grade crossing. In instances where the active warning was on, the ideal profile would include a complete stop well back from the intersection. Allowances would be made for subsequent progress through the crossing in the absence of an obvious hazard since such acts are generally legal.

Ideally, there would be a major segment of the driver population following the "safe" sequence plus some segments showing deviant profiles. The assumption was that the behavior, attitudes, knowledge, and demographic characteristics of the deviant class would identify the target population toward which countermeasures would be directed, and further, these characteristics would suggest the class of countermeasures to be prescribed.

In fact, the empirical observations did confirm the initial assumptions, although the population was in no way sharply divided. For example, there was an almost universal tendency to decelerate during an approach to a grade crossing. The measures identified during Phase II of this contract were refined to identify subjects exhibiting high and low risk behavior and attitudes. Classes of countermeasures with potential value were identified. Hypotheses were then developed which, as confirmed or rejected, identified the potential value of classes of countermeasures.

CHAPTER 2

REVIEW OF RAILWAY-HIGHWAY ACCIDENTS

It has been estimated that 75 to 80 percent of all highway accidents occur at intersections. The railway-highway grade crossing possesses certain intersection characteristics that appear to be particularly hazardous. For instance:

1. Seventy-eight percent of the at-grade crossings (approximately 164,280) do not have active warning devices.[7]
2. Passive railroad grade crossing devices generally do not require, nor do they elicit, a characteristic driver response (e.g., as stop signs do).
3. Sight distance is frequently inadequate at the crossings.[3]
4. One of the users of the crossing (the train) is generally incapable of taking effective evasive action.
5. The mass differential between the crossing users is extreme.

This chapter will explore the extent to which the factors such as the above attribute to highway grade crossing accidents. A few cautionary remarks should be made before discussing the accident data. The accident frequency at a given location must be evaluated in light of the number of vehicles exposed to the supposed hazard. In the simplest case, we might predict the probability of a train/vehicle accident as some multiplicative function of the average train and vehicle volume. Unfortunately, the frequency of trains at a crossing is seldom considered in the reporting or analysis of accident data. Problems associated with the lack of exposure data are particularly evident when comparing the efficiency of various traffic control devices (e.g., passive versus active) whose installation is often based on train and vehicle volumes.

Table 2-1 displays the number of persons killed and injured at grade crossings in 1971 as a function of the traffic control at the crossing. Crossings with active devices account for 41 percent of the fatal and injury accidents while only representing 22 percent of the nation's at-grade crossings. It is likely that the almost 200 percent over-representation of these crossings is the result of heavier train and traffic volume. In addition, crossings having an accident history are more likely to be converted to active traffic control devices.

Like most fatality and injury figures, the values presented in Table 2-1 are a gross underestimate of the total number of vehicle/train accidents. Data based on California's accident experience indicate that over 50 percent of the reported vehicle/train accidents do not involve a casualty as defined here.[5] Other estimates indicate that the number of reported vehicle/train accidents for 1971 is likely to be around 12,400.[10]

Table 2–1

Railway-Highway Casualty Accidents Involving Motor Vehicles, by Type of Crossing Protection, 1971[1]

Type of crossing protection at time of accident	Killed	Injured	Number of accidents	Number of crossings[2] on Dec. 31, 1970	Accidents per 100 crossings
Lowered gates	60	117	138	10,412	1.33
Audible & visible signal	265	648	673	29,960	2.25
Audible signal	10	22	24	1,273	1.89
Visible signal	178	468	481	4,601	10.45
Total Active	513	1,255	1,316	46.246	2.85
Signal or sign not of a type indicating approach of train	749	1,958	1,873	164,280	1.14
Grand total	1,262	3,213	3,189	210,526	1.51

[1]Adapted from Rail-Highway Grade-Crossing Accidents, DOT, Federal Railroad Administration Office of Safety, for the year ending December 31, 1971.

[2]On class I line-haul railroads and switching and terminal companies. Data for 1971 not available.

Note: Where more than one type of protection was afforded at the time of accident, the accident was classified according to the type first shown above.

An indication of the interaction between accident severity and the type of traffic control device can be seen in Table 2-1. The national statistics presented in this table support the conclusion that accident severity is not dependent on the presence of active or passive control devices.

Similarly, Table 2-2 displays the relation between active/passive devices and weather conditions.*

Although significantly fewer accidents occur during periods of rain or fog (possibly the combined effects of reduced exposure and slower operating speeds), weather does not appear to differentially affect the effectiveness of the two classes of traffic control devices.

*The accident sample presented in Table 2-2 was drawn from the HSRI University of Michigan's accident files and represents all the reported train/vehicle accidents in Oakland County, Michigan (1968-1970), Bexar County, Texas (1969-1970), and a five percent random sample of all the accidents in Texas (1969-1970). Thus there is a probable, but small, duplication built into this data (approximately 1.5 percent).

Table 2–2

Grade Crossing Accidents in Relation to Weather Conditions and Active/Passive Traffic Control

Weather	Traffic Control		
	Active	Passive	
Clear	171	113	$X^2 = 0.19$
Rain or Fog	23	12	

Table 2-3 shows the relation between weather conditions and accident severity.* Based on this rather small sample, it does not appear that accident severity is dependent on prevailing weather conditions.

Table 2–3

Relation Between Weather Conditions and Railway-Highway Accident Severity

Accident Severity	Weather		
	Clear	Rain, Snow, etc.	
Fatal	21	2	
Injured	94	13	$X^2 = 1.19$
Property Damage	141	26	

On a national basis (see Table 2-4), 68.76 percent of all 1971 railway-highway accidents occurred in clear weather. It should be noted that the statistics on road conditions from 23 states indicate that 69.9 percent of all motor vehicle accidents in 1971 occurred on dry road surfaces. Table 2-4 also reveals that a significantly higher proportion ($z = 3.33$, df 2264) of nighttime vehicle accidents occur during poor weather conditions. If we now look at vehicles that ran into a train, we find that over 50 percent of these accidents occurred after dark (as opposed to approximately 33 percent of vehicle struck accidents). In addition, a significantly larger proportion of the vehicle striking accidents occur under other than clear weather conditions (54 percent versus 36 percent for striking and struck, respectively). The above differences may reflect the difficulty drivers have in detecting the unilluminated railroad cars at night and during periods of poor visibility.

*HSRI, Oakland County, Michigan (1968-1970), Bexar County, Texas, (1969-1970), Texas (1969-1970). Seattle, Washington (1969).

Table 2–4

Weather Conditions and Railway-Highway Casualty Accidents Involving Motor Vehicles, 1971[1]

Weather	Number of Accidents		Struck by Train		Ran into Side of Train (Striking)	
	Number	% of Total	# Daylight	# Dark	# Daylight	# Dark
Clear	2,215	68.76	1,131	454	300	330
Cloudy, Rain, Fog, Snow, etc.	1,006	31.24	438	243	148	176

[1]Adapted from Rail-Highway Grade-Crossing Accidents, DOT, Federal Railroad Administration Office of Safety, for the year ending December 31, 1971.

Table 2-5, based on 1970 California data, extends the striking-struck distinction to types of traffic control devices at the crossing. Automatic gates, flashing lights, and signs are respectively associated with significantly ($p \leq .05$) larger proportions of vehicle struck accidents. It would thus appear that the physical restraints (gates) and visual stimuli (lights) are more effective in alerting the driver that a train is occupying the crossing. In particular, the flashing lights may direct sufficient attention to the crossing to enable the driver to detect the generally low reflectant railroad cars.

Table 2–5

Vehicles Struck by and Striking Trains as Related to Types of Traffic Control, 1970 California[1]

Traffic Control	% Vehicles Struck By Front End of Train	% Vehicles Striking Train
Automatic Gates	77[2]	17
Flashing Lights	70	26
Signs	62	34

[1]Adapted from Annual Report of Railroad Accidents reported under General Order No. 22-B for Year 1970, California Public Utility Commission, Transportation Division, 30 June 1971.

[2]Percentages represent percent of total rail-vehicle accidents and, as such, do not total to 100.

National statistics presented in Table 2-6 indicate that there are significantly fewer ($X^2 = 40.89$, df 1) nighttime accidents at passive crossings than might be expected. This finding may be attributable to lower vehicle and/or train usage of the passive crossings after dark. However,

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Table 2–2

Grade Crossing Accidents in Relation to Weather Conditions and Active/Passive Traffic Control

Weather	Traffic Control: Active	Traffic Control: Passive	
Clear	171	113	$x^2 = 0.19$
Rain or Fog	23	12	

Table 2-3 shows the relation between weather conditions and accident severity.* Based on this rather small sample, it does not appear that accident severity is dependent on prevailing weather conditions.

Table 2–3

Relation Between Weather Conditions and Railway-Highway Accident Severity

Accident Severity	Weather: Clear	Weather: Rain, Snow, etc.	
Fatal	21	2	
Injured	94	13	$x^2 = 1.19$
Property Damage	141	26	

On a national basis (see Table 2-4), 68.76 percent of all 1971 railway-highway accidents occurred in clear weather. It should be noted that the statistics on road conditions from 23 states indicate that 69.9 percent of all motor vehicle accidents in 1971 occurred on dry road surfaces. Table 2-4 also reveals that a significantly higher proportion (z = 3.33, df 2264) of nighttime vehicle accidents occur during poor weather conditions. If we now look at vehicles that ran into a train, we find that over 50 percent of these accidents occurred after dark (as opposed to approximately 33 percent of vehicle struck accidents). In addition, a significantly larger proportion of the vehicle striking accidents occur under other than clear weather conditions (54 percent versus 36 percent for striking and struck, respectively). The above differences may reflect the difficulty drivers have in detecting the unilluminated railroad cars at night and during periods of poor visibility,

*HSRI, Oakland County, Michigan (1968-1970), Bexar County, Texas, (1969-1970), Texas (1969-1970), Seattle, Washington (1969).

when compared to crossings at which there is active protection, a significantly greater proportion of the accidents at passive crossings represent the vehicle striking type of accident (46 percent versus 36 percent).

Table 2–6

Day/Night Railway-Highway Casualty Accidents Involving Motor Vehicles, by Type of Crossing Protection, 1971[1]

Type of crossing protection at time of accident	Number occurring		Struck by train		Ran into Side of Train (Striking)	
	Daylight	Dark	Daylight	Dark	Daylight	Dark
Lowered gates	45	93	39	64	6	29
Audible & Visible signal	391	282	281	179	110	103
Audible signal	19	5	16	5	3	-
Visible signal	289	192	214	117	75	75
Total Active	744	572	550	365	194	207
Signal or sign not of a type indicating approach of train	1,268	605	1,019	325	249	280
Grand total	2,012	1,117	1,569	690	443	487

[1] Adapted from Rail-Highway Grade-Crossing Accidents DOT, Federal Railroad Administration Office of Safety, for the year ending December 31, 1971.

Note: Where more than one type of protection was afforded at the time of accident, the accident was classified according to the type first shown above.

Based on the data available through the HSRI accident files, we could not detect any relation between day/night accident occurrence and accident severity* (see Table 2-7). There does, however, appear to be a relation between hour of the day and accident frequency. Figure 2-1 displays this relation for 1971 accident data. Three to 5 PM appears to be the peak accident period and, not surprisingly, also correspond to the hours of peak traffic volume. A review of seasonal and daily accident records did not, however, reveal a stable relation between accident frequency and these calendar type variables.

Table 2–7

Relation Between Time of Accident Occurrence and Accident Severity

Accident Severity	Time of Day: 0600–1759	Time of Day: 1800–0559	
Fatal	10	5	
Injured	54	22	$X^2 = 0.95$
Property Damage	51	29	

*HSRI, Oakland County, Michigan (1968-1970), Dade County, Florida (1970), Seattle, Washington (1969). Night is defined here as the hours between 6 PM and 6 AM.

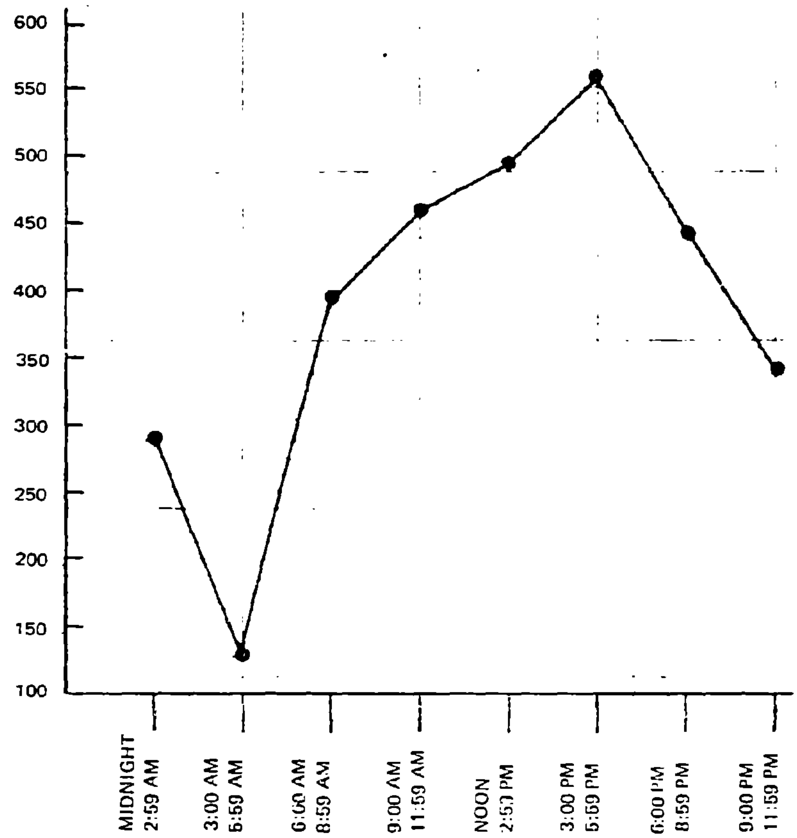

Figure 2–1. Relation between railway-highway casualty accidents and time of day, 1971.

We can further inquire into the extent to which the day/night railway-highway accident involvement differs from all traffic accidents. Table 2-8 displays this relation.

Table 2–8

Frequency of Railway Highway Casualty Accidents and All Traffic Accidents by Time of Occurrence, 1971

Accident Type	Time of Day (Hours) 0600–1759	1800–0559	
Rail-Highway	1967 (61%)	1257 (39%)	
			$X^2 = 14.09$
All Traffic	864, 645 (64.2%)	482, 154 (35.8%)	

Although the above table indicates a statistically ($p \leq .01$) higher proportion of railway-highway accidents occurring after 6 PM, the practical significance of a 3.2 percent difference (39.0 percent versus 35.8 percent) does not appear particularly noteworthy. In fact, the similarity of the percentages are somewhat surprising in light of the fact that the values were drawn from two different sources.[7, 9]

A comparison of fatal railway-highway accidents with all fatal accidents may provide a perspective for some of the previous discussion on time of occurrence.[8] In particular, six years of Michigan accident data indicate that a higher percentage of railway-highway fatalities (63.9 percent) occur during daytime hours than vehicle fatals in general (44 percent).

Several epiphenomena may be associated with the presumed higher daytime occurrence of fatal railway-highway accidents. For instance, the same Michigan study found twice as many cases of alcohol and drug use among the general vehicle fatal accidents (26.6 percent versus 12.6 percent). In addition, a significantly greater proportion of females were involved in railway-highway fatalities than in all fatal vehicle accidents (22.7 percent versus 16.7 percent). Both of the above findings are probably attributable to the higher incidence of drinking drivers and male drivers at night.

Finally, the great difference in mass between the train and the automobile contributes greatly to the severity of railway-highway accidents. A recent report to Congress states that of all transportation accidents, only aviation accidents exceed the severity of railway-highway accidents.[10] The report further indicates that the ratio of persons killed in railway-highway accidents to the total number of railway-highway accidents is over 40 times greater than the same ratio for all motor vehicle accidents. Thus, it is estimated that there will be one fatality for approximately every eight railway-highway accidents.

Before concluding this brief presentation and analysis of the accident data, it would be profitable to review some railway-highway accidents in far greater detail than that available through police and railroad records. The reports prepared by the multidisciplinary accident investigation teams (MDAI) provide a promising source of in-depth information. Table 2-9 presents the result of a content analysis of the 12 available MDAI reports.

It is interesting to note that in seven out of the eight cases where the drivers' familiarity with the crossing was noted, the involved driver was aware of the existence of the crossing. This finding is supported by the findings of several large data base studies.[6,11] These studies indicated that approximately 95 percent of the accident-involved drivers were residents of the states in which the accident occurred and 65 to 78 percent could be classified as either living in the city in which the accident occurred or being local residents.[6, 11]

Table 2-9

Summary of Multidisciplinary Railway-Highway Accident Reports

Case No.	Driver		Roadway				Crossing			Situation			Vehicle		Accident				Comments
	Age	Sex	Speed	Lanes	Pave	R/U	Cont.	Tracks	S-D	Time	Vis.	Fam.	Pas.	Type	Viol	T-S	V-S	Sev	
AA-133	63	M	35	2	D	R	G	2	P	N	C	Y	0	C	A	65	5	F	2nd track Gate often failed to work Drove around closed gate
AA-164	55	M	45	2	S	R	XW	1		N	S	Y	1	C	S	30-35		F	Skid onto train tracks
AA-132	24	M	35	2	D	R	F	2	G	D	PCL	Y	0	C	FL	60		SI	2nd track Thru activated flashers
441	19	F	65	2	D	R	XW	1	P	D	C	N	3	C	FL	65	40-45	F	Advanced warning sign turned around
198	23	M	25	2	D	R	XW		P	D	C	Y	1	TT	FL	35-40	10-15	F	Driver & passenger talking Proceeded across track without stopping
098	22	M		2	D	R	FB	2	P	N	C	Y	2	C	A	60	ST	F	Crossing in poor state of repair - stalled vehicle
511	16	F	50	2	D	U	XW	1	P	D	PCL	Y	2	C	MJ			F	Road parallels track Left turn into train
327	25	M		2	D		XW	1		D	C		0	C	S			SI	Skid 231' into train
046	23	M		4	D		F	1		N	F		0	C	A			I	Skid into side of parked train - tires in poor condition
632	34	M	40	2	D	R	FB	1	G	D	PCL	Y	0	C		25	40	SI	Signals not working
040	69	F	35	6	D	U	FB	1	P	D	C		1	C	FL	15		SI	Driver talking
222	70	M	35	2	D	U	XW	1	G	D	CL		0	C	FL			N	Broken hearing aid
	Sex M = Male F = Female		Pavement: D = Dry S = Snow W = Wet Location (R/U) R = Rural U = Urban				Controls: G = Gates X = Crossbucks W = Warning Signs F = Flashing Lts. B = Bells XW = Crossbucks and Warning Sign FB = Flashing Lts. and Bells Sight-Distance (S-D): G = Good P = Poor			Time: N = Night D = Day Visibility (VIS): S = Snow C = Clear CL = Cloudy PCL = Partly Cloudy F = Fair CL = Cloudy R = Rain Familiarity (FAM): Y = Yes N = No			Veh. Type: C = Car TT = Tractor Trailer B = Bus T = Truck PAS = Number of passengers in vehicle		Severity: F = Fatal I = Injury SI = Serious Inj. N = None Violation: A = Alcohol S = Speeding FL = Failure to Look MJ = Misjudged Speed T S = Train V S = Vehicle				

The "Comments" column indicates a variety of precipitating and predisposing factors associated with the accident occurrence. These factors include railroad crossing in poor state of repair, malfunction of an active signaling device, advance warning sign not maintained, poor sight distance, inattention on the part of the driver, driver physically disabled (hearing loss), and driver's disregard of gates resulting from a previous history of failure.

The precipitating factors can be subsumed under the two general rubrics of:

- maintenance or engineering problem, and
- driver attention and detection problems

Accident History At Local Project Sites

Virginia

Table 2-10 presents details on accidents occurring at selected Virginia grade crossings. The sites shown include all those within the city limits of Manassas with a grade crossing accident history during the period 1956–1972. All grade crossing accidents at these sites during this seven-year period are shown.

Of the three Virginia sites at which traffic behavior and driver questionnaire data were collected on this project, two are in the city limits of Manassas. These are the Fairview and Route 28 sites. As shown in Table 2-10, each has an accident history. The third Virginia site, Calverton, is in Fauquier County, outside the city limits of Manassas. Calverton and Manassas are separated by about ten miles. The same railroad passes through all locations.

As shown in Table 2-10, only one accident was on file at four of the grade crossing locations during the 1956–1972 period. Two of these had active protection and two had passive protection. In each case, the train struck the motor vehicle.

At the other five sites shown in Table 2-10, three or more accidents were on file. All but one of these sites, Calverton, had active protection. The site with the greatest number of accidents was South Grant Avenue with nine accidents recorded. Second and third in numbers of accidents recorded were Fairview Avenue (seven) and South Main Street (six).

Considering the table as a whole, there are 33 accidents, of which 30 or about four per year occurred within the Manassas city limits. The age of the drivers ranges from 17 to 84 years. All but four were male. The representation of females in Table 2-10 is not greatly different from their representation in the national sample data (23 percent). All but two of the drivers had in-state driver's licenses. Alcohol was cited as a factor in only three of the accidents.

Table 2–10

Accidents at Selected Virginia Sites, 1956–1972

Yr.	Location	Control	Driver Sex	Driver Age	Driver Lic	Driver Alc	Conditions D/N	Conditions W	Conditions Surf	Conditions SPD/S.L.	Fat/Inj	Comments
	Manassas											
'71	Cockrell Rd.	P	M	42	Va	No	N	F	W	25-30/?	1 / 3	T–C
'71	Stonewall Rd.	P	M	22	Va	No	D	C	D	2/25	1	T–C. Driver stopped and looked. Disregarded signal.
'70	Quarry St.	A–F	M	50	Va	DWI	N	Cy	D	0/25		T–C. Car was stopped on crossing.
'56	Battle St.	A–F	M	37	Va	No	N	C	D	10/5	1	T–C. Driver disregarded red signals.
	So. Main St.											
'71	1	A–F	F	39	Va	No	D	C	D	?/25	1 / –	T–C. Driver looking back at son.
'69	2	A–F	Irrelevant. Train pushed boxcar into vehicle parked parallel and too close to track.									
'65	3	A–F	M	25	Va	No	D	C	I	15-20/25	1	T–C. Driver did not look.
'61	4	A–F	Irrelevant. Vehicle parked too close to track. Totalled by train.									
'60	5	A–F	M	51	Va	Yes	N	C	D	?/25		C–T.
'59	6	A–F	M	23	Va	No	N	C	D	5/25		Car missed R turn. Hit RR station.
	So. Grant Ave.											
'72	1	A–G+F	M	17	Va	No	N	Cy	D	5/25		Driver backed into car behind.
'69	2	A–G+F	M	51	Va	No	N	C	D	20/25		C–T. Gates and signals not operating. Driver did not see flagman.
'68	3	A–G+F	F	46	Va	No	N	C	D	15/25	1	Driver did not control vehicle. Hit 2 cars ahead stopped for crossing.
'67	4	A–G+F	M	?	?	No	D	C	D	0/25	1	T–Plow. Tractor plow came loose on track. Driver tried to remove it.
'67	5	A–G+F	M	50	Va	DWI	N	C	D	25/25		Hit car ahead stopped for train.
'67	6	A–G+F	M	26	Va	No	DWN	M	W			Started up too fast and hit car ahead after train passed.
'65	7	A–G+F	M	23	Va	No	DSK	C	D	15/25		C–T. Driver fell asleep.
'67	8	A–G+F	M	18	Va	Yes	N	M	W	25/25	1	Hit car ahead which was stopped for train.
'61	9	A–G+F	M	36	Va	?	D	C	D	15/25		Same as above.
	Fairview Ave.											
'68	1	A–F	F	74	Va	No	D	C	D	5/25		T–C. Woman saw train but pulled out on track and car choked out on track.
'67	2	A–F	F	51	Va	No	D	C	D	8/25		T–C. Car stopped on track.
'67	3	A–F	M	20	Va	No	N	Cy	W/S	0/25		T–C. Car stalled on track.

Table 2–10 (Continued)

Accidents at Selected Virginia Sites, 1956–1972

Yr.	Location	Control	Driver Sex	Driver Age	Driver Lic	Driver Alc	Conditions D/N	Conditions W	Conditions Surf	Conditions SPD/S.L.	Fat	Inj	Comments
Fairview Ave. (Cont'd.)													
'64	4	A–F	M	84	Va	No	D	Cy	D	5/25			C–T. Car drifted into side of train.
'64	5	A–F	M	30	Va	No	N	M	W	25/25			T–C. Car swerved and became stuck between the tracks.
'62	6	A–F	M	35	Va	No	DSK	S	S	?			Skidded on snow and collided with another car on tracks. No train.
'60	7	A–F	M	39	Cal	No	D	?	D	0/25			T–C. Stalled on track.
Manassas PW 28													
'70	1	A–F	M	30	Pa	No	D	C	D	50-55/45	1		C–T.
'66	2	A–F	M	39	Va	No	D	C	D	45/45		1	C–T. Talking to wife. Tried to stop.
'56	3	A–F	M	30	Va	No	DWN	C	D	50/5		1	T–C. Saw train but thought it was stopped.
Fauquier Co. Calverton													
'68	1	P	M	38	Va	No	D	Cy	D	40/Slp		1	T–C.
'64	2	P	M	46	Va	No	D	Cy	D	55/55		1	C–T. Car tried to stop.
'57	3	P	M	65	Va	No	N	R	W	20/55			C–T. Lights of on-coming car not dimmed. Did not see or hear train. Visibility poor.
'57	4	P	M	33	Va	No	D	R	W	35/55		1	C–T. Engineer was blowing whistle and ringing bell.

Control
A = Active
P = Passive
G = Gate
F = Flasher

Sex
F = Female
M = Male

D/N
D = Day
DWN = Dawn
DSK = Dusk
N = Night

W (Weather)
C = Clear
Cy = Cloudy
M = Mist
R = Rain
F = Fog
S = Snow

S (Road Surface)
D = Dry
I = Icy
S = Snowy
W = Wet

SPD/S.L. = Vehicle speed/speed limit

C–T = Car struck train
T–C = Train struck car

With regard to the conditions surrounding the accidents, about half occurred at night or during dawn or dusk. This is about ten percent higher than the proportion of night accidents in the data reported on page 2-6. About two-thirds of the accidents occurred under clear or cloudy conditions with a dry road surface. In all but one case, the driver was proceeding at or below the speed limit.

Both "train struck car" and "car struck train" accidents occurred but the train struck car type were somewhat more frequent. At Calverton (passive), three of the four accidents were of the car struck train variety. At Fairview Avenue (active), all but one of the train-involved accidents were of the train struck car type. Unfortunately, the data set is too small to conclude that this distinction between accident type and type of protection is real as was suggested by the larger data data base. (Note that there are inversions in the relationship: e.g., Route 28.)

The most striking feature of Table 2-10 is the unique circumstances under which some of these accidents occurred and the diversity of these circumstances. Considering first the train-involved accidents, examples are: (1) disregarding the signals and/or the sight of the train: (2) sudden mechanical failures occurring *on* the tracks such as stalling, a plow coming loose, and an apparent loosening of rodends resulting in the car swerving and becoming stuck between the tracks; (3) falling asleep at the wheel; and (4) divided attention such as looking back at son or talking to wife. Two principles for development of countermeasures can be derived from these circumstances. The first of these is the need to increase the perceived hazard of railroad grade crossings, particularly when a signal is activated or a train is in sight. The second is the need to counteract distracting influences and increase driver awareness in the vicinity of the crossing. Rumble strips, for example, is a countermeasure deriving from this principle.

Another facet of Table 2-10 is the accidents which occur in the vicinity of grade crossings which do not involve a train. Two types of these accidents may be identified: (1) backing up into another vehicle; and (2) striking the end vehicle in a queue of vehicles stopped at the crossing. These accidents point to the need to inform/warn drivers of other than direct train-involved hazards at railroad crossings.

Maryland

Three of the nine project sites were located in the state of Maryland (Sunnyside, Linthicum, and New Midway). In comparison to Virginia, railroad grade crossing accidents in Maryland are poorly documented. A search for records resulted in the following:

- Sunnyside – no records of accidents at this high train frequency active crossing were found.

- Linthicum – at this passive crossing, between 1966 and 1971, only one accident was recorded. In late 1968, a car struck a pedestrian at the crossing. No train was involved. The weather was clear and dry.
- New Midway – between 1966 and 1971, one injury was recorded at this passive crossing. A car struck a train on a clear, dry day in 1966.

It is difficult to believe that so few accidents have occurred, particularly at the Sunnyside crossing. Consideration should be given to a standardized records-keeping system for use in all states so that a more comprehensive data base for use in elucidating the contributing factors for grade crossing accidents can be developed.

Crossing Inventories

Each Virginia county maintains an inventory of grade crossings, and duplicate files were found at the State level. For each crossing, a number had been calculated which was called the "Hazard Index." A major factor in this index is "Quadrant Visibility Factor," but no definition of this term was readily available. The "protection factor" is always 0.9 for passive crossings including those with only one of the two required crossbucks. The equation used for the Virginia hazard index is the product of all of the following terms:

Average daily traffic
Average daily trains
Protection factor
1.5 if multiple tracks
Accidents last 5 years plus 1
Quadrant visibility factor

Maryland also has a partial inventory of grade crossings compiled during a 1967 grade crossing study. This study also established their current method of calculating a hazard index. It is interesting to note that, since driver sight distances were not included in the study, this factor (a major multiplier in Virginia) is not included. As late as 1969, comprehensive grade crossing protection programs were not being pursued in Maryland, due in part to the 1968 fatality report which showed only seven-tenths of one percent of all motor vehicle fatalities were train related (compared to 2.6 percent for the nation).[1]

[1] Coffman, S.F., Reed, M.F., Morgan, D., & Spicher, R. Maryland's highway safety needs in highway design, construction and maintenance. Highway Engineering Division, Automotive Safety Foundation, Washington, D.C., 1969.

During the course of this study, an accident reduction program of the Union Pacific Railroad Company was noted. The program is described in Chapter 3. Of interest here is the frequency of accidents on a seasonal basis. The figure below shows their northern and southern accident history for reportable and nonreportable events in 1971. The striking increase of accidents in cold weather is clearly an issue to be addressed by countermeasure innovations.

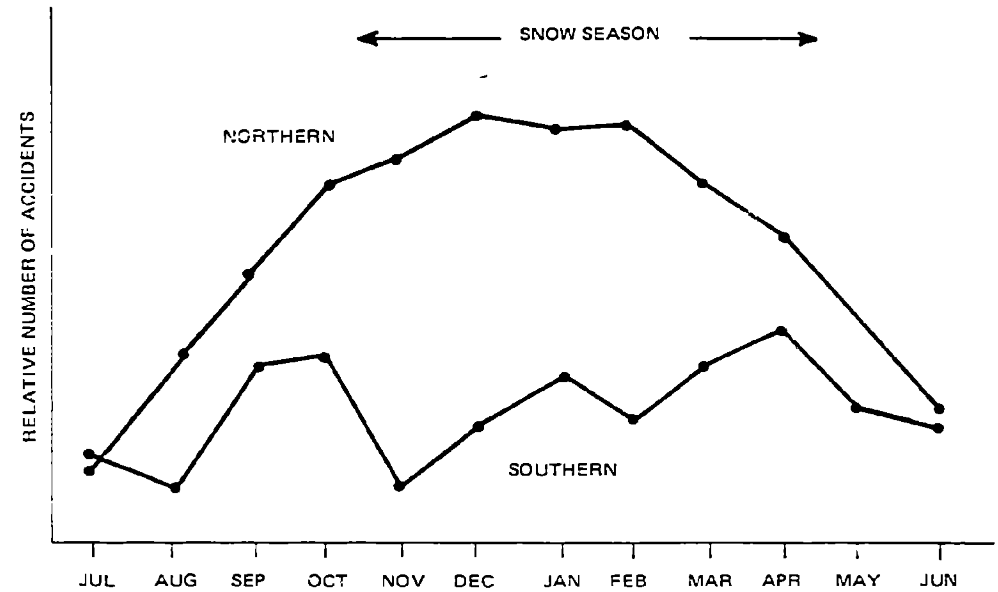

Figure 2–2. Vehicle-Train accident experienced by Union Pacific in 1971 for Northern and Southern State operations compared with cold weather factors.

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CHAPTER 3

APPRAISAL OF INHERENT DRIVER SAFETY POTENTIAL

The driver at the grade crossing represents a highly complex situation. His behavior is a product of a large number of interacting factors. Some of these are physical and objectively measurable (e.g., the characteristics of the site itself, the nature and status of signs and warning devices, the conditions of visibility and weather, the presence or absence of a train). Many others, however, are far less tangible. They include factors such as driver knowledge, driving experience, attitude, and perceptual-motor capabilities. Collectively, these intangibles may be designated as the human factors of grade crossing behavior. Figure 3-1 illustrates these factors.

An objective of this study was to describe general driver behavioral patterns and to develop an appraisal of the inherent safety potential which the driver brings to the grade crossing situation. The concept "inherent driver safety potential" means that conglomerate of educational, experiential, attitudinal, and psychophysiological characteristics which interact with situational and other environmental variables at any given moment. The result of this interaction, if it occurs in a potential accident situation, is either an accident or the avoidance of an accident.

The inherent driver safety potential, taken as a whole, is dynamic. Its "value" for any given driver fluctuates from moment to moment. However, this value results from components which are relatively constant (for example, factual knowledge of railroad grade crossing statistics) and components which fluctuate greatly (for example, attention to particular aspects of the driving task). Because of varying values for fluctuating components and their interaction with more static components, the inherent driver safety potential will also fluctuate.

A useful model is one deriving from work by Dimling and Miller (1969) which relates driver performance and system demands to accident occurrence. As shown in Figure 3-2, driver performance levels and system demands on the driver vary with time. An accident occurs when performance happens to fall below that required by system demands. Low performance levels do not necessarily result in accidents nor is a high performance level a guarantee against them. What is important is the relationship between performance level and demand level. In fact, it might be postulated that since performance levels and demand levels are usually not extreme, most accidents occur at intermediate values of each.

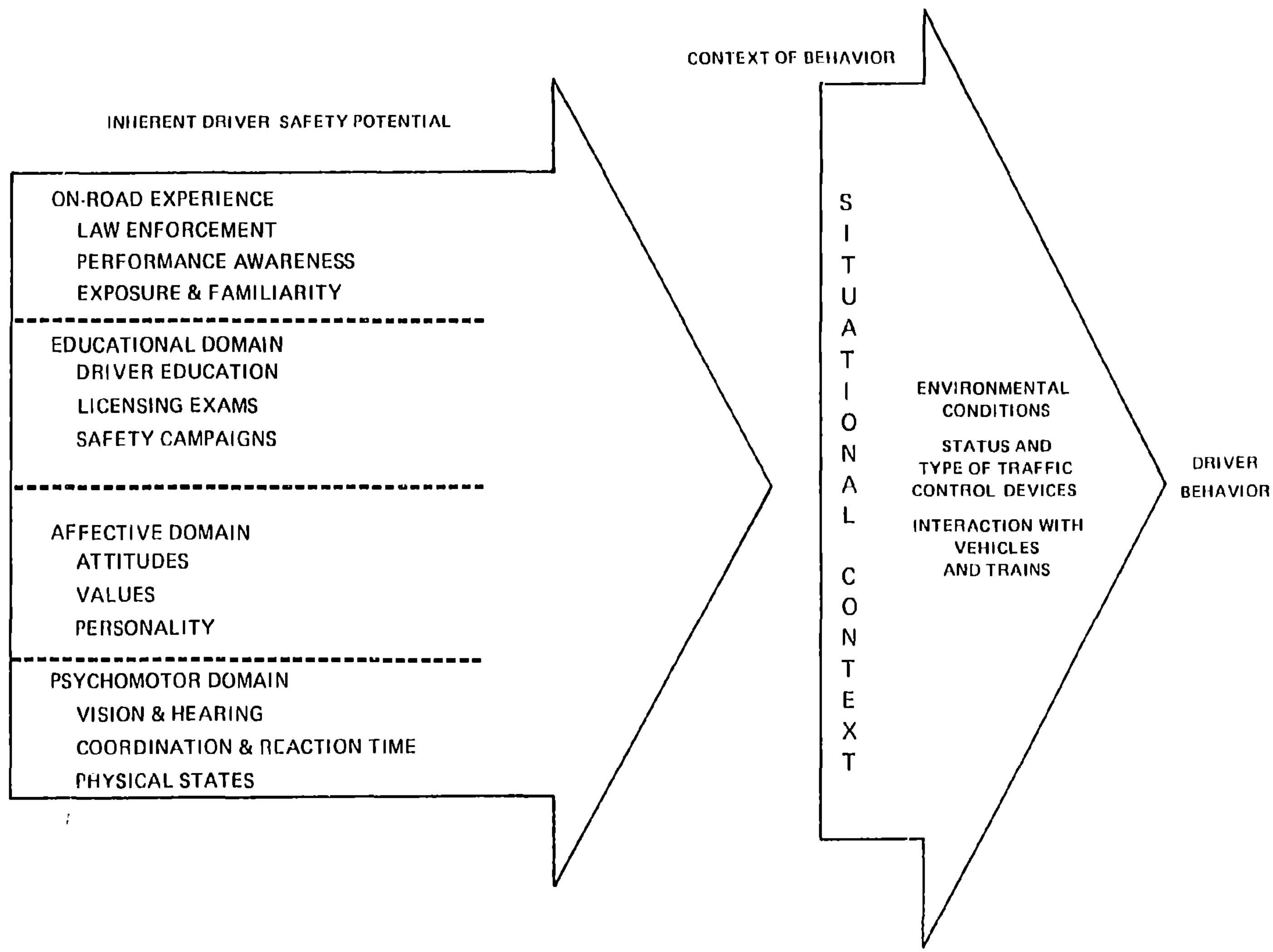

Figure 3-1. Components of driver response.

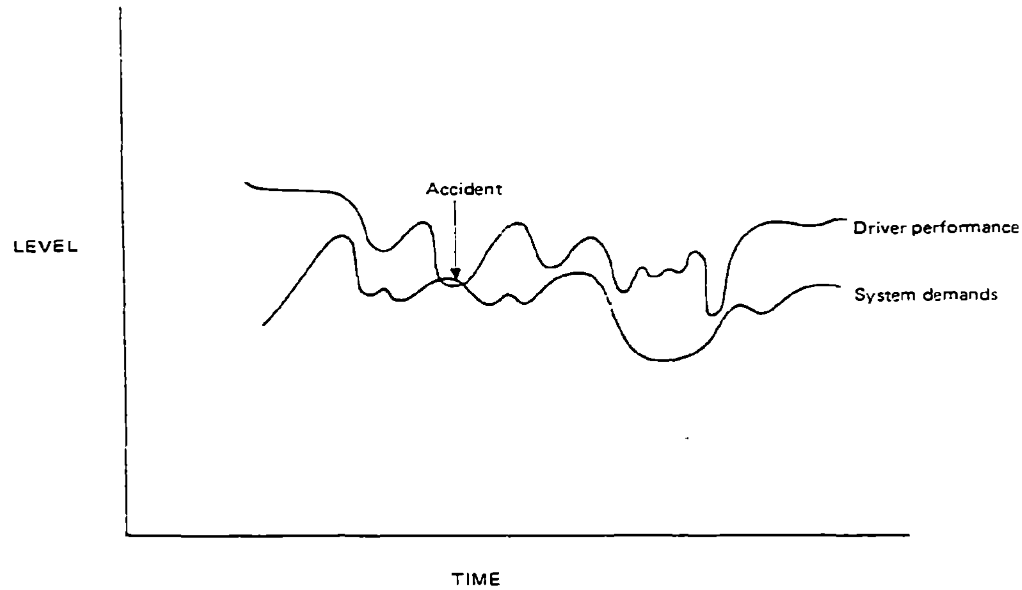

Figure 3–2. Hypothetical relationship between accidents, driver performance, and system demands (after Dimling & Miller, 1969).

Of particular interest to consider is the unpredictable manner in which system demands can change, which suggests a random factor in accident occurrence. As Dimling and Miller (1969) illustrate: "A driver may shift his eyes from the road in front of him to his rear-view mirror, speedometer, or a passenger with whom he is conversing, without having an accident. If, however, the car in front of his brakes suddenly, just as his eyes leave the road, he may crash into the car in front. Whether he is involved in an accident or not will depend, therefore, on whether the sudden stop by the car in front happens to coincide with his taking his eyes off the road; if he has no way to predict a sudden stop by the car in front, then his running into the car is essentially a random phenomenon."

In addition to illustrating the probablistic nature of accidents, the model in Figure 3-2 makes it clear that improving driver performance is only one way to reduce accidents. An alternate approach is to reduce system demands.

In Chapter 2, comments concerning the circumstances surrounding accident case histories at a number of accident locations were given. Especially noteworthy was the peculiar circumstances surrounding many of these accidents, circumstances quite compatible with a probablistic model of accident occurrence along the lines proposed by Dimling and Miller (1969). Although not developed for grade crossing accidents, their model appears very appropriate for this accident subset.

In the Dimling-Miller model, inherent driver safety potential may be meaningfully substituted for driver performance. Use of the term inherent driver safety potential emphasizes the fact that performance is a function of knowledge, experience, attitude, and inherent capabilities all of which will impact on the motorist's response to a particular driving situation.

In this Chapter, six major categories of factors which contribute to inherent driver safety potential are discussed. These are:

- Driver education
- State licensing procedures
- Safety programs
- Law enforcement
- Attitude and habit components of railway-highway safety
- Psychophysiological capabilities and limitations

Driver Education

One of the objectives of driver education is to impart the required knowledge, skills, habits, and attitudes to enable the driver to perform in a manner that will minimize the probability of his causing or being involved in a traffic accident. The National Education Association (1961) defines driver and traffic safety education as "learning experiences provided by the school for the purpose of helping students to become good traffic citizens and to use motor vehicles safely and efficiently."

Traditionally, driver training was accomplished by an experienced driver (usually a member of the family) teaching the novice the mechanics of driving and the rules of the road. In recent years, however, training has become institutionalized, and an increasing proportion of drivers receive all or most of their basic training through commercial driving schools or through the public school system. The latter has become of increasing importance and value since public school driver education programs typically include much more than guided practice in handling the vehicle and cover such topics as motor vehicle laws, safety measures, safe driving practices, and the like. For the younger generation of drivers, the exposure to such a broad course of driving and safety education has shown some payoff. For example, one possible interpretation which has been suggested for the decline in railway-highway accidents involving younger age groups in the Chicago area is the increasing prevalence and effectiveness of high school driver education in that city (Logan, 1969).

The Chicago experience has not been verified on any scientific basis. Although information regarding the railroad grade crossing is included in numerous high school driver education curricula, the time devoted is on the order of five minutes out of 30 class hours. A notable exception is the Waterloo school system in Iowa where each driver education student, as part of his behind the-wheel training, traverses a railroad grade crossing and is given a performance evaluation by the instructor. The Iowa Driver Education Curriculum contains a page devoted to the railroad grade crossing describing material for the instructor to cover as well as a series of specific proper and improper driver performances. The Iowa school system would appear to be a desirable location for a program to evaluate the potential of driver education upon grade crossing driver performance. In an examination of the high school driver training curricula in five school jurisdictions adjacent to Washington D.C. (Alexandria, Arlington County, Fairfax County, the District of Columbia, and Montgomery County), it was determined that railway-highway safety receives almost no attention. Apart from teaching recognition of the standard railway grade crossing signs and pointing out the legal requirement to stop at a flasher or barrier, the curricula in these five jurisdictions are almost devoid of instruction in grade crossing safety.

Some texts available to teachers contain sparse information on railroad grade crossings: typical of these are: "Tomorrow's Drivers," Pawlowski and Johnson (1971): "Mayday-Mayday," The Directorate of Aerospace Safety, U.S. Air Force (undated): "Sportsmanlike Driving," American Automobile Association (1970).

At this point in time, it must be surmised that the knowledge that the driver brings to the driving task based on his having completed the typical "30 and 6" secondary school driver education program is limited to the realization that the grade crossing presents a potential hazard but without a series of specific actions to be taken to minimize the frequency and severity of potential train-vehicle conflicts. The driver's inherent safety potential is presently not increased with respect to the grade crossing situation by driver education.

Researchers are developing materials to provide an accident countermeasure-oriented driver education curriculum. Specific action items on the part of the driver are described for varying conditions. Although these items are few in number, it provides a starting point. The Safe Performance Curriculum for Secondary School Driver Education Interim Specifications, HumRRO (1973) contains the following driver railroad grade crossing performance items:

> *The student will observe the highway well ahead for structures, such as railroad crossings, bridges, tunnels, and toll plazas.*
>
> He will:
>
> Watch and/or listen for physical indications that a railroad crossing is ahead, such as railroad tracks or the sound of the train or its whistle.
>
> Observe both directions of track.

Highway structures, such as toll plazas, railroad crossings, bridges and tunnels, provide cues to the student for the safe operation of the car. For appropriate speed control (when negotiating railroad crossings, the student will:

Reduce speed and prepare to stop at the crossing unless he has a clear view of the tracks.

If he is following a school bus, commercial passenger vehicle or tank truck, prepare to stop behind the vehicle.

When approaching a crossing with no signal, decelerate and:

If visibility is clear and no trains are in sight, maintain speed and cross immediately.

If train is approaching, stop the car within 50 feet but not less than 15 feet from the nearest rail.

When approaching a signalized crossing (flashing lights or gates), decelerate and prepare to stop in advance of the crossing if the signal is activated.

When encountering highway structures (railroad crossings, toll plazas, bridges, and tunnels, the student will respond by positioning the car in the appropriate manner. At railroad crossings, he will:

Proceed across the tracks:

When he has a clear view of all the tracks in both directions.

If no train is coming or if it is stopped or moving slowly at a distance.

If the flagman so directs.

Avoid stopping on the tracks or between tracks.

Enter the crossing only when there is sufficient space on the other side of the tracks to stop without projecting onto the tracks.

Wait for the train to complete the crossing before starting across, remaining stopped if other trains are approaching.

At signalized crossings:

Remain stopped until the signal indicates the track is clear.

Continue through the crossing as quickly as possible if the signal is activated while the car is crossing the tracks.

This group of specifications represents a portion of the curriculum that will be administered on a pilot basis to groups of secondary school students during the period July 1973–June 1974. Accident experience of students completing the total curriculum will be compared with that of (1) students receiving a driver education program not specifically designed, as this is, as an accident countermeasure, and (2) students receiving driving instruction outside of the formal school system. Students will be assigned to the three instructional groups on a stratified/random basis in order to eliminate any systematic differences in factors other than method of instruction.

This program has the potential to provide some data as to the effectiveness of driver education serving as an accident countermeasure in the grade crossing situation.

Public education is not the only means by which driving instruction is accomplished. Commercial driving schools account for a large proportion of driver training.

The general expectation with regard to commercial driving schools is that little or no emphasis is placed on railway-highway safety. This was borne out by sample inquiries of firms in the Washington, D.C. area. Of the six commercial driving schools contacted (two each in Virginia, Maryland, and the District of Columbia), none included any specific elements of railway-highway safety in their training syllabus, and none made any special effort to incorporate grade crossings in their practice driving tours for students.

State Licensing Procedures

Regardless of how the driver is trained, his qualifications to operate a motor vehicle are subject to examination by the state in which he resides. The licensing authority exercises two functions. It examines and certifies the applicant's driving ability and knowledge of motor vehicle laws, and it serves as an instrument of driver education and improvement.

The process of licensing drivers is geared toward exercising some form of control over inexperienced drivers. It has been previously pointed out that education and training prior to licensing can provide knowledge and skills and also encourage a change of attitude among novice drivers relating to vehicle operation and the driver's relationship to other motorists. If adequate course content in the public school systems relating to the railroad grade crossing situation were to be provided, it would be a significant period of time (over 15 years) before this training had been available to a large proportion of drivers.

In lieu of providing the required information in the classroom the states can: (1) provide relevant information in their drivers manuals, (2) have test questions for initial and renewal license applicants, and (3) utilize the driving test to verify operators' knowledge of proper performance at railroad grade crossings.

A national survey of state drivers manuals indicates that they normally contain a sketch of the Railroad Advance Warning sign (W10-1)[1] and may include a sketch of the Railroad Crossbuck sign (R15-1) and the auxiliary sign showing the number of tracks (R15-2). A

[1] Refers to symbols defined in the manual on Uniform Traffic Control Devices for Streets and Highways, AASHO.

statement is usually included that the railroad crossing is a hazardous location and that drivers are killed each year because they have been careless, not looked in both directions, or have passed other cars at the crossing. Table 3-1 provides a compendium of the number of state drivers manuals containing specific informational content while Table 3-2 indicates the same data on a state-by-state basis. Table 3-3 indicates those railroad grade crossings-related licensing examination questions developed by the Highway Safety Research Institutue of the University of Michigan (HSRI). These questions, compiled in a handbook, will be the basis for test items to be used in state Motor Vehicle Bureau examinations.

The increasing use of audio-visual testing systems to provide automated knowledge testing and a potential for remedial learning experience in areas where the applicant has demonstrated a lack of knowledge, would be particularly suitable for the development of a specific package on the railroad grade crossing situation, e.g., the state laws, emergency situations, safe practices, hazardous practices, etc.

In the area of performance testing, the objective is to determine whether or not the driver can operate his vehicle in a safe and proper manner. Test administrators could be trained and off-street testing facilities developed to evaluate the operators' performance of specific maneuvers under varying railroad grade crossing situations. Such facilities could be used for a teaching as well as a testing program in conjunction with the remedial teaching package mentioned previously. On-street testing in areas close to railroad grade crossings might make use of these physical test sites provided the test administrators are prepared to conduct an incremental form of test, each increment permitting the applicant to make an improper as well as a proper maneuver without creating a hazardous situation.

Although improved licensing techniques have the potential to provide the driver with particular safety oriented knowledge and attitudes to bring to the railroad grade crossing situation, at the present time it can be assumed that the driver licensing programs are not increasing the inherent driver safety potential at the physical crossing site.

Safety Programs

There is a considerable overlap among safety programs, driver education, licensing procedures, and law enforcement. Often, the program may take the form of instructional manuals or handbooks issued by private organizations or government agencies. For example, the American Trucking Association issues a truck drivers' handbook and monthly safety newsletters to its members. State motor vehicle bureaus often publish safe driving guides, posters, and such through their driver improvement programs. Frequently, too, law enforcement agencies sponsor safety campaigns. Thus, safety programs do not really represent a wholly separate avenue for influencing driver knowledge. Where safety programs do differ from these other sources is in their approach, which is usually broad and conducted through public media.

Table 3–1

Summary of State Driver Manual Information

#STATES	BEHAVIOR – GENERAL	
3	S	Stop
20	SD	Slow down
16	R-S	Is ready to stop
5	FSV	Follows stopping vehicles at a safe distance
2	CN	Exercises caution at night
27	L	Looks
1	RW	Rolls down window
9	LIS	Listens
1	C-R	Keeps right
8	R-P	Restricts passing
2	TT	Avoids being trapped on tracks
5	NSG	Avoids shifting gears on tracks
	BEHAVIOR IN PRESENCE OF TRAIN	
11	STC	Stops when train is close
2	STW	Stops when train whistles
10	STD	Stops a distance before tracks
17	C-ST	Checks for second train
	IDENTIFICATION OF CONTROL DEVICES	
26	CB	Picture of crossbucks
46	RR	Picture of advance sign
26	L-CB	Labeling of crossbucks
42	L-RR	Labeling of advance sign
8	C-CB	Color of crossbucks
18	C-RR	Color of advance sign
23	D-CB	Deployment of crossbucks
33	D-RR	Deployment of advance sign
2	PM	Picture of pavement markings
1	D-PM	Description of pavement markings
	REACTION TO CONTROL DEVICES	
15	S-F	Stop for flagman
21	S-FL	Stop for flashing lights
8	S-G	Stop for gong
5	S-SW	Stop for activated wigwag
14	S-GT	Stop for gate
7	NCG	Does not go around gate
15	NTI	Checks sign for number of tracks
4	R	Respects signs and signals
13	S-S	Stops for signal
6	S-SS	Stops for stop sign
2	OD	Obeys directions of officials
	SPECIAL REGULATIONS – STOPS REQUIRED	
16	S-SB	School busses
14	S-PS	Public service vehicles
14	S-EX	Vehicles carrying explosives or inflammable liquids

Table 3-2

Current Status -- Grade Crossing Information -- DMV Manuals

	S	SO	HS	FSV	CH	L	RW	LIS	CR	HP	IT	ASG	STC	STW	STD	CST	CU	HH	LCG	LHH	CCG	CHH	DCG	DHH	FM	DPM	SF	SFL	SG	SSW	SGT	SCG	NTI	II	SS	SSS	OD	SSN	[illegible]	[illegible]
ALABAMA	•					•		•									•	•	•	•							•	•	•	•										
ALASKA		•	•		•	•						•					•	•	•	•	•	•	•	•			•	•			•	•	•							
ARIZONA																		•		•															•			•	•	•
ARKANSAS		•	•			•		•		•								•							•															
CALIFORNIA													•		•	•		•				•						•			•	•								
COLORADO			•	•		•						•			•		•	•		•											•	•			•		•	•	•	•
CONNECTICUT		•		•		•			•									•		•				•				•										•	•	•
DELAWARE		•				•						•					•				•		•					•			•	•	•					•	•	•
FLORIDA		•				•		•								•	•	•	•	•			•	•													•	•	•	•
GEORGIA		•				•				•							•	•	•	•			•	•										•						
IDAHO						•										•	•	•																						
ILLINOIS			•			•	•	•					•		•	•		•				•		•	•	•	•	•			•		•							
INDIANA		•				•				•	•				•	•		•		•			•	•			•	•	•	•				•						
IOWA		•	•		•	•						•	•				•	•	•	•	•	•	•	•			•	•			•		•							
KANSAS			•													•	•	•	•	•		•	•	•										•						
KENTUCKY															•			•		•			•				•	•		•	•					•				
LOUISIANA													•	•	•			•		•	•						•				•	•			•			•	•	
MAINE						•				•					•	•											•	•										•		
MARYLAND																		•		•		•		•																
MASSACHUSETTS		•	•			•										•	•	•	•	•								•			•		•							
MICHIGAN		•				•		•								•	•	•	•	•		•	•	•				•			•		•							
MINNESOTA						•											•	•	•	•	•	•		•			•								•	•				
MISSISSIPPI	•					•		•									•	•	•	•		•		•																
MISSOURI						•												•		•		•		•																
MONTANA		•											•		•			•		•		•		•			•				•				•	•				
NEBRASKA																	•	•	•	•			•	•																
NEVADA						•									•		•	•	•	•			•	•									•							
NEW HAMPSHIRE		•				•		•		•							•	•	•	•			•	•					•						•					
NEW JERSEY				•									•	•	•			•	•	•	•	•					•						•					•	•	•
NEW MEXICO		•	•	•																								•										•	•	•
NEW YORK				•														•		•		•		•								•								
NORTH CAROLINA		•				•		•				•				•		•	•	•	•	•	•	•				•	•		•		•		•	•		•		•
NORTH DAKOTA		•	•														•	•	•	•		•	•	•																
OHIO																•		•		•											•				•	•				
OKLAHOMA										•								•		•		•		•														•	•	•
OREGON						•							•				•	•	•	•			•	•										•				•	•	•
PENNSYLVANIA		•	•							•			•			•	•	•	•	•			•	•				•					•					•	•	•
RHODE ISLAND	•					•		•									•	•	•	•			•	•																
SOUTH CAROLINA		•	•										•			•	•	•	•	•			•	•									•							
SOUTH DAKOTA											•					•	•	•	•	•			•	•			•	•	•	•			•					•	•	•
TENNESSEE		•	•										•			•	•	•	•	•			•	•				•					•					•	•	•
TEXAS		•	•										•					•		•				•			•	•	•						•					
UTAH																		•		•				•																
VERMONT			•			•										•	•	•	•	•			•	•									•							
VIRGINIA			•			•												•		•																				
WASHINGTON		•				•										•	•	•	•	•	•	•						•							•					
WEST VIRGINIA						•				•							•	•	•	•			•	•			•	•	•	•	•		•		•					
WISCONSIN			•															•	•	•		•	•	•								•			•					
WYOMING																		•		•				•											•	•		•	•	•
D C																											•	•	•						•					

Note: Abbreviations for information are based on code used in Table 3-1.

Table 3–3

Driver Licensing Questions From HSRI Handbook

I. Class C. Vehicles (Cars & Small Trucks) (p.62# 1-7)

1. If you come to a railroad crossing that does not have a signal on it:
   - a. Stop and look both ways before crossing.
   - b. Continue across at normal speed.
   - c. Blow the horn while driving over the tracks.
   - *d. Slow down and check for an approaching train.

2. If you come to a signalized railroad crossing:
   - a. Stop and look both ways.
   - *b. Slow down and be prepared to stop.
   - c. Continue at normal speed.
   - d. Speed up and cross quickly.

3. When you come to a railroad crossing with no signal, you should:
   - a. Speed up to clear the tracks quickly.
   - *b. Open the window and turn down the radio.
   - c. Look to the left and proceed if the way is clear.
   - d. Come to a stop and check both directions.

4. When coming to a railroad crossing where the signal is activated, you should:
   - a. Continue quickly across the tracks if the train has not yet arrived.
   - b. Slow down and cross the tracks slowly and carefully.
   - *c. Slow down and prepare to stop.
   - d. Turn around and try to find another route.

5. If you come to a railroad crossing where the signal is not activated, you should:
   - a. Speed up and cross the tracks quickly.
   - b. Continue at the same speed and check for a train before crossing.
   - *c. Slow down and check for a train before crossing.
   - d. Come to a complete stop before continuing across.

*Indicates proper answer.

Table 3–3 (Continued)

Driver Licensing Questions From HSRI Handbook

I. Class C Vehicles--(cont'd)

6. While stopped for trains at a multi-track crossing:
   *a. Wait until all trains have passed and you can see in both directions.
   b. Start across as soon as the near train has passed.
   c. Wait until flagman signals you to cross.
   d. Get out of your vehicle for a clear view.

7. When you are crossing railroad tracks at a slow speed, do <u>not</u>:
   a. Start across in low gear.
   b. Follow other vehicles at a distance.
   *c. Shift the gears while you are crossing.
   d. Drive at a smooth, even speed.

(P. 122, #4-6)

4. The message on this sign is (Railroad):
   a. Keep Right.
   *b. Railroad Crossing.
   c. Cross Walk.
   d. Do Not Enter.

5. You should expect this sign (Railroad Crossbuck R15-1) near a:
   a. School crossing.
   b. Fire station entrance.
   *c. Railroad crossing.
   d. Road construction area.

6. When you see this sign (Railroad Crossbuck R15-1), you should:
   a. Speed up to quickly cross the tracks.
   b. Stop until the flagman signals you to cross.
   *c. Slow down and be prepared to stop.
   d. Stop at the nearest rail and look in both directions.

(P. 128, #6-8)

6. The shape of this sign (Railroad Advanced Warning) indicates:
   a. Stop.
   b. School crossing.
   c. Yield.
   *d. Railroad crossing.

Table 3—3 (Continued)

Driver Licensing Questions From HSRI Handbook

I. Class C Vehicles--(cont'd.)

7. You should expect this sign (Railroad Advance Warning W10-1) before a:
   - a. School crossing.
   - b. Traffic circle.
   - *c. Railroad crossing.
   - d. Highway intersection.

8. This sign (Railroad Advance Warning W10-1) means:
   - *a. Slow down and look out for a train.
   - b. Railroad crossing ahead--always stop, look, and listen.
   - c. Railroad ahead is controlled; vehicles are not required to stop.
   - d. Stop at the nearest railroad tracks and wait for a signal before crossing.

(P. 138, #1)

1. These pavement markings (Railroad Crossing Approach 3-14) mean caution:
   - a. Stop signal ahead.
   - b. Road work ahead.
   - c. Detour; vehicles must turn right.
   - *d. Railroad crossing ahead.

Table 3–3 (Continued)

Driver Licensing Questions From HSRI Handbook

II. Class A & B Vehicles (Large Trucks & Articulated Vehicles) (p. 249, #1-10)

1. When coming to a railroad crossing, you should assume that:
   a. You have the right-of-way.
   *b. A train is coming.
   c. You will not need to stop.
   d. The signals would be on if there was a train nearby.

2. If you come to a railroad crossing where the signal is not on, you should:
   a. Speed up slightly and cross.
   b. Continue at normal speed and cross.
   *c. Slow down and check for trains before crossing.
   d. Come to a full stop and look both ways before crossing.

3. Before you cross an unsignalized railroad track, you should:
   a. Come to a full stop.
   *b. Be sure you have time to get all the way across.
   c. Speed up a bit so you will be sure not to stall.
   d. Keep one foot on the clutch in case you need to shift while on the track.

4. If you see a long train coming toward you at a railroad crossing, you should:
   a. Cross if you think you can do so quickly.
   b. Blow your horn and cross at a moderate speed.
   *c. Stop and wait unless you are sure you can cross in plenty of time.
   d. Turn around and continue by another route.

5. When you approach a railroad crossing in a long line of slow-moving traffic, you should:
   *a. Be sure you will not be trapped on the tracks before crossing.
   b. Attempt to pass when the vehicle ahead has slowed down to cross the tracks.
   c. Be prepared to shift gears while you are on the tracks.
   d. Stay close to the vehicle in front of you.

6. You may have to stop at a railroad crossing if:
   a. There is no gate at the crossing.
   *b. You are carrying certain cargo.
   c. There is more than 1 track.
   d. Your truck has more than 3 axles.

Table 3–3 (Continued)

Driver Licensing Questions From HSRI Handbook

II. Class A & B Vehicles--(cont'd.)

7. When you are the first to stop at a railroad crossing, you should <u>not</u>:
   a. Signal the drivers behind you.
   b. Pull over to the right.
   c. Downshift into neutral or your lowest gear.
   *d. Move as close to the tracks as possible.

8. When you are crossing railroad tracks, you should <u>not</u>:
   *a. Shift gears.
   b. Drive slowly.
   c. Look to the right and left.
   d. Maintain a constant speed.

9. If you come to a railroad crossing where there is a double set of tracks, you should:
   *a. Check to be sure you can get all the way across before crossing.
   b. Stop halfway across and check for trains from the other direction before continuing.
   c. Come to a full stop and check both ways before starting to cross.
   d. Look both ways and speed up to cross the tracks quickly.

10. Railroad crossings on streets in cities:
   *a. Are just as dangerous as rural grade crossings.
   b. Do not require that you slow down unless the signal is on.
   c. Require that you slow down unless the signal is on.
   d. Are all required to have gates and signals.

Table 3–3 (Continued)

Driver Licensing Questions From BSRI Handbook

III. Class M (Motorcycles) (p. 187, #1-6)

1. When driving, you should:
   a. Drive faster than the other vehicles around you.
   *b. Look for warning that railroad crossings are ahead.
   c. Stay 10 mph or more below the legal speed limit.
   d. Try not to lean when turning or changing directions.

2. When coming to a railroad crossing without warning signals, you should:
   a. Stop even if you don't see any trains coming.
   b. Look in both directions quickly.
   *c. Slow down and look before crossing the tracks.
   d. Press in the clutch before crossing the tracks.

3. The best way to cross railroad tracks is to:
   *a. Go slow and cross at an angle to the right.
   b. Reduce speed and cross at an angle to the left.
   c. Speed up slightly and lean forward for balance.
   d. Reduce speed and cross at a right angle.

4. When about to cross a railroad track when no trains are near, you should:
   a. Grasp handlebars loosely and instruct passenger (if any) to relax.
   b. Shift your weight back and forth as you cross the tracks.
   c. Accelerate sharply to gain momentum to get over tracks.
   *d. Keep your motorcycle as vertical as possible.

5. When crossing railroad tracks at a low speed, you should:
   a. Start across tracks in third gear.
   *b. Slip your clutch to avoid jerking the motorcycle.
   c. Shift into second or first gear when going over the tracks for more speed.
   d. Stop between the tracks to check again for trains.

6. If you drop something off your motorcycle while crossing railroad tracks, you should:
   a. Stop on the tracks and pick it up right away.
   b. Back up if it looks like no train is coming.
   *c. Keep going until you can pull off the road and walk back to tracks.
   d. Leave the object where it is, since it's illegal to pick things up from the track.

The National Safety Council, American Automobile Association, American Trucking Association, National Association of Motor Bus Owners, and Association of American Railroads all prepare and distribute literature regarding railroad grade crossing safety.

An example of an intensive, comprehensive safety campaign was that completed in October 1972 by the Union Pacific Railroad in Idaho.[1] The campaign lasted six weeks and included:

- newspaper ads in seven major daily papers;
- public service announcements over radio and television;
- talks by state policemen at schools and civic organizations (the police showed a special safety film and distributed "Lifesaver" candies with special wrappers emphasizing grade crossing safety);
- eyewitness accounts by engineers involved in fatal accidents (engineers appeared on television and films of near misses and crossing infractions by motorists were shown).

A major item in the campaign was increased enforcement. In addition to the cooperation of the police, traffic court judges were included in the campaign. This step prevented reduction of the enforcement impact by insignificant fines for infraction. Discussions with the Director of the Idaho State Police showed that a high level of enthusiasm was developed for the program among the various law enforcement agencies.

Unfortunately, the campaign did not end until October 1972. Thus, the benefits of the program will not be apparent for about a year when measured by the injury fatality rate and no evaluation of effectiveness can be included here.

Law Enforcement

Law enforcement, in the broadest sense of the term, has often been cited as an avenue to improve grade crossing safety. Law enforcement agencies and associations recognize their potential, and many have taken an active interest in promoting railway-highway safety. For example, the International Association of Chiefs of Police held a workshop on the topic at their 1969 convention. Several law enforcement agencies (the Kalamazoo Police Department, the Chicago Police Department, and the Arizona and California Highway Patrols to name a few) have active and forward looking programs related to grade crossing safety. However, the national pattern of law enforcement in this area is mixed, ranging from the excellent programs just cited to virtual inattention.

[1] N.D. Nelson, Manager Safety and Courtesy, Union Pacific Railroad, Omaha, Nebraska was in charge of this program. Mr. Nelson is currently preparing a film describing the Union Pacific campaign.

To obtain insights into local programs, traffic police officials in some nearby jurisdictions were consulted. The few examples of local law enforcement practices given below are illustrative of both the range of measures which are applied and the variation which exists among contiguous jurisdictions.

The Alexandria Police have no grade crossing safety program and no special or standing instructions are issued to traffic patrolmen in this regard. A few years ago, when a prominent citizen was killed in a grade crossing accident, a number of concerned community organizations instituted a safety campaign, which was fully supported by the Alexandria Police. In time, however, public interest dwindled, and the program lapsed. It is hard to say what lasting effect such a one-time effort has had.

In response to citizen's complaints about failure of motorists to heed flashers, the Alexandria Police have on occasion stationed a patrol car at the South Van Dorn Street crossing. As a result of summonses issued and the simple presence of officers, disregard of the warning signals drops off sharply and remains low even after the patrol car is withdrawn. After a few months, however, the pattern of crossing violations reemerges. From time to time, the monitoring of the crossing is reinstituted temporarily, but the police do not consider it feasible to adopt such an intensive countermeasure on a permanent basis.

The Arlington County Police have a program in cooperation with the high schools whereby an officer is assigned to each school to serve as a liaison between school and police officials. Primary attention is devoted to preventing juvenile offenses and to counteracting drug usage, but some effort is also devoted to traffic safety and to working with the driver training program. While no special emphasis is placed on railway-highway safety, it is felt that the participation of the police liaison officers does help to foster a greater safety consciousness.

Prince Georges County has a number of grade crossings which are considered dangerous. Recently, two which posed severe hazards were eliminated by closing the roads to the crossings and rerouting traffic. In this case, it was felt that a certain amount of public inconvenience and disruption of traffic flow was an acceptable price to pay for greater railway-highway safety.

These examples are not meant to reflect upon the quality of local law enforcement in relation to railway-highway safety. Rather, they are intended to indicate how perceived needs and commitments of resources can vary among law enforcement agencies in the same area and with the same general problems.

Accident data has shown that a majority of those involved in grade crossing accidents are familiar with the crossing, it being relatively close to their prevalent origin-destination points.

It would seem that in spite of the driver's perception of a potential hazard at the grade crossing, a habit is formed after repeated crossings without the presence of a train.

It is interesting to note that data taken in 1972 on 339 commercial and school buses at railroad grade crossings showed that 53 percent of the school buses and 88 percent of the commercial buses did not stop at the crossing as required by law (Sanders, 1972). These drivers are subjected to extensive education, licensing, and safety programs; they operate large and very easily detectable vehicles; and yet the average speed of the 53 percent of the school buses that did not stop was 25.1 miles per hour at the crossing. It is apparent that these drivers had no intention of stopping. The question must be asked, if education and training programs, rigorous license testing, and extensive safety campaigns cannot get more than half of the school bus drivers to stop at the crossing, as required by law, are there any inherent driver safety potential-oriented countermeasures that promise a greater safety payoff?

Based on grade crossing observations at a number of sites, it was found that drivers' compliance with safe performance practices substantially increased after a period of police patrol at a grade crossing site (Linthicum, Maryland). In one instance, a policeman was positioned out of the line of sight on the opposite side of the crossing from approaching traffic. On the first day of observation, 100 percent of one company's gasoline trucks, that had to cross the tracks to get to their fuel depot, did not stop prior to crossing the tracks. After crossing the tracks the drivers were able to see the uniformed officer. On the second day, although they could not see the officer prior to crossing the tracks, 80 percent of the company's gasoline trucks came to a full stop prior to crossing the tracks. Apparently implied police patrol has the potential to modify drivers' behavior.

It would seem that: (1) if the drivers' behavior can be modified to increase safety, and (2) if most of the drivers are not already driving with the concept of avoiding a traffic citation in mind at railroad grade crossings, then (3) increased police patrol can result in some measureable increase in safe driver performance.

In order to check out the second premise (that regarding the drivers presently performing in such a manner as to avoid a citation), approximately 650 persons in Michigan, Maryland, Texas, and California were asked the following question after crossing over a railroad track:

> Have you ever known anyone who got a traffic ticket for crossing a railroad track when the signal was on or the gate was down?

Approximately 90 percent answered negatively: approximately six percent indicated affirmatively that they had heard of such a ticket; and four percent did not answer. Fifteen police officers performing traffic enforcement duties who were given unstructured interviews in California, Maryland, Michigan, and Texas indicated that they have never written any tickets nor had knowledge of any being issued for law violations at railroad grade crossings.

Thus, although no quantitative measure has been made of the level of effectiveness, police enforcement would seem to have a positive effect. The expense of such increased patrols, especially at high accident locations, might be cost-effective particularly since the accident data shows the frequency of collisions to peak at the times of the greatest commuter traffic (the same times as the increase in passenger train service). Thus, police patrols could effectively cover a number of high accident incidence locations at the peak commuter periods.

Law enforcement can positively affect inherent driver safety potential. The analysis that must be performed is to determine whether the benefits that accrue justify the costs.

Attitude and Habit Components of Railway-Highway Safety

Of all the characteristics that the driver brings to the grade crossing, attitudes, personality, and habits are the most ill-defined and least understood. The existence of a relation between selected attitudinal, personality, and driving behavior variables have been explored in several studies (Adams, 1970; Case & Stewart, 1955; Fine, 1963; and Heath, 1959). Several significant relations have been found. For example, Heath (1959) examined the relationship between driving records, personality characteristics and biographical data of traffic offenders and nonoffenders. The offenders had three or more traffic accidents and/or moving violations while the records of nonoffenders were accident/violation free in the same period. Compared to nonoffenders, offenders rated significantly higher on impulsive and sociable scales and lower on the reflective scales (Thurstone Temperament Schedule). Significant differences were also found indicating that they were younger, more often single, less educated, had smaller earnings, and higher job turnover.

The interest in relating attitude and habit to driver performance and accident risk lies in the fact that the theory and practice of attitude measurement and change is well developed. Thus, if attitude and habit modification can be shown to be a potential countermeasure, the broad base of communication and social-psychological research can be brought to bear on presenting the appropriate message to target populations in the most effective setting. Table 3-4 presents a simplified view of the stages and psychological states involved in the process of attitude change.

Table 3–4

Components of Attitude Change Accompanying Each Stage in Making a Decision to Adhere to a Recommended Railway-Highway Safety Procedure

Components of Attitude Change (New Beliefs, Value Judgments, and Dispositions Toward Recommendation, R)	Initial Attitude of Complacency	Stage 1 Positive Appraisal of Challenge	Stage 2 Postive Appraisal of Recommendation (R)	Stage 3 Selection of R as the Best Alternative	Stage 4 Commitment to Decision to Adopt R
Verbal evaluation of threat					
1. Selectively responds and attends to communications about the threat? (Accepts assertions that the threat is serious)	No	Yes	Yes	Yes	Yes
2. Believes the threat is serious?	No	Yes	Yes	Yes	Yes
Verbal evaluation of R					
3. Selectively responds and attends to communications about R? (Accepts assertions that R is an effective means)	No	No	Yes	Yes	Yes
4. Believes R is a satisfactory means worth considering?	No	No	Yes	Yes	Yes
5. Believes R is best available means?	No	No	No	Yes	Yes
6. Feels willing to act in accordance with R?	No	No	No	No	Yes

Adapted from Janis, Irving. Stages in the decision making process. In R.P. Abelson et al., (Eds), Theories of Consistino: A Sourcebook. Chicago: Rand McNally, 1968.

Psychophysiological Capabilities and Limitations

In the course of this project, attempts were made to identify a particular subpopulation of grade crossing, accident-prone motorists which could be related to psychophysiological characteristics which were in turn suggestive of countermeasures. Unfortunately, this effort met with little success. A suggested disproportionate involvement of females in rail-highway fatalities (compared to their involvement in all fatal motor vehicle accidents) was found in accident records (see Chapter 2). However, possible confounding through higher exposure of the female population cannot be eliminated from these data. The motorist grade crossing safety measures developed in the course of this study did not discriminate particular groups of drivers as hazardous which might be characterized on psychophysiological dimensions (see Chapter 7). The only significant finding was an indication that males were more likely to be involved in grade crossing accidents than females at some sites; a finding which does not confirm the results of the accident data analysis. With regard to age, definitive evidence for disproportionate involvement of particular age groups in railway-highway accidents is lacking. Additionally, the percent of alcohol involvement seems to be significantly less than that experienced for accidents in general. Likewise, the predominance of daytime railway-highway accidents seems to decrease the likelihood of fatigue as a predisposing factor.

Lacking major evidence for a particular target group of motorists with a high probability of grade crossing accidents, no characterization of such drivers on psychophysiological dimensions (with consequent countermeasure recommendations) can be attempted. Instead, this section will provide data useful for two general approaches to countermeasures development.

The first is human psychophysiological capabilities and limitations which should be considered in constructing countermeasures along traditional lines: that is, warning devices which are external to the motor vehicle. Examples are signs and auditory warning devices located in advance or in the immediate vicinity of the grade crossing.

The second is human capabilities and limitations as related to hypothetical futuristic countermeasures. These are assumed to be in-vehicle auditory and/or visual devices. The critical point in the design of such devices is that they must be adequate to serve the needs of the worst case driver. This is the driver whose capabilities are degraded compared to the normal – either because of advanced age, genetic disability (e.g., color blindness), or for some other reason. The discussion is organized under the following topical headings:

- information processing and related topics (e.g., reaction time, attention),
- vision,
- audition,
- vibration, and
- summary.

The term "older driver" as used in this section, indicates a driver who is 60 years or older. This age group currently constitutes about 14 percent of the driving population and is increasing (Forbes, 1972).

Information Processing and Related Topics

Visual Modality. Significant periods of time are required to recognize and respond to visual messages. Thus, about one second is required to recognize four familiar related words and 0.40 seconds to recognize two out of four familiar words (Hurd, 1947).

On the other hand, the formula presented by King and Lunenfeld (1969) in a discussion of warning and regulatory signing results in a somewhat more conservative estimate. This formula is:

$$RT = \frac{2N}{3}$$

where RT = reading time in seconds
N = number of short familiar words or symbols

For four familiar words, this formula indicates a reading time of 2-2/3 seconds would be required.

About one second is probably a realistic estimate for a glance by a motorist at a roadway sign (Forbes, 1972). *Averaging* the recommendations by Hurd (1947) and King and Lunenfeld (1969), visual messages should not exceed three short familiar words if they are to be understood by the motorist in a one-second glance.

In general, significant savings in time and increased accuracy can be obtained using symbols rather than words (Brainard, Campbell, & Elkin, 1961; Janda & Volk, 1934; King & George, 1971; and Walker, Nicolay, & Steams, 1965). Hurd (1947) found that only 0.046 seconds is required to recognize one symbol representing three familiar words. Thus, a symbol corresponding in meaning to three familiar words can be recognized six times faster than two familiar words and almost 20 times faster than four familiar words. It is important, however, that any symbols used have commonly accepted meaning or that the motorist be taught their meaning or that new symbolic signs be accompanied by verbal messages when initially introduced. The necessity for thorough pilot testing in a laboratory setting of any alternate new signing configurations in terms of accuracy of interpretation and speed of recognition cannot be overstated.

Simple visual reaction time from stimulus awareness through recognition ranges from about 0.4 to 1.9 seconds (Eberhard, 1969). Of interest is the reaction time to a visual stimulus when a driving task, such as braking, is the required response. Johansson (1965) found brake reaction time in a roadway setting when the driver did not expect a signal to be as great as 2.0 seconds. The more complex the decision, the longer will be the time required for perception and initiation of a response. Thus, about four seconds appears to be required for the decision to overtake and pass on a two-lane road with on-coming traffic (Matson et al., 1955; Platt, 1958).

The above discussion is useful in considering new signs. An example of a railroad crossing advance warning sign is shown in Figure 3-3. As can be seen, this sign consists primarily of several separate symbolic elements. Although each alone has a commonly accepted meaning, understanding the message of the sign requires integrating the components. Repeated exposure to the sign would probably result in its being viewed as a whole. However, it would be expected that for the naive driver, this sign has too many components (more than three) to be understood in a single one-second glance and the response time from initial awareness of the sign to the beginning of a response would be in the order of several seconds.

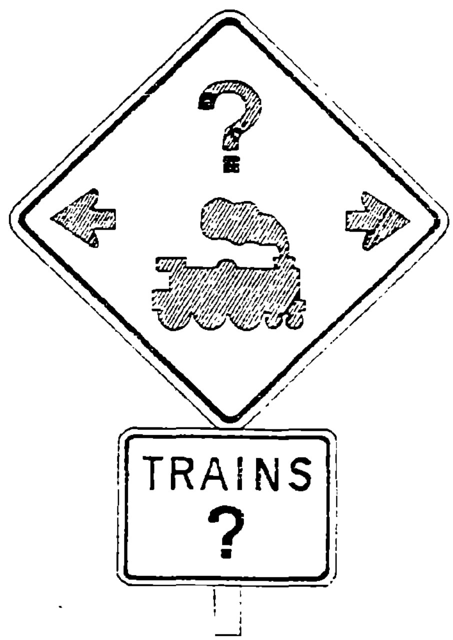

Figure 3–3. A proposed advance warning sign for unprotected crossings (Hulbert &Vanstrum, 1972).

Auditory Modality. Simple auditory reaction time is very slightly faster than visual. However, if the sound comes from another location than directly opposite the ear, reaction time increases (Eberhard, 1969). The masking effect of background noise is an important consideration in providing warning of an impending grade crossing via the auditory modality.

Also important to consider are adaptation effects arising from prior auditory stimulation. Anyone who has used earphones to listen to music for extended periods of time is well aware of the increase in tolerance for high intensity sound which occurs. This is accompanied by an increased threshold for sound. The increase in threshold is a function of the amplitude, frequency, and duration of exposure of the adapting sound as well as on the preexposure hearing level and the frequency of the test stimulus (Parker & West, 1973). Figure 3-4 shows this phenomenon.

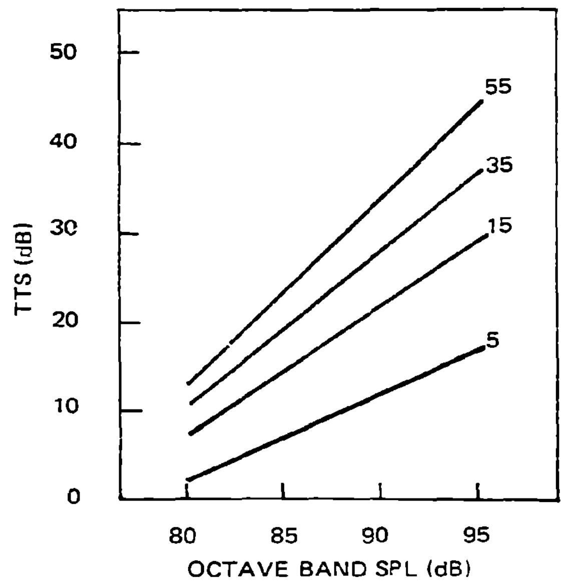

Figure 3—4. Increase in threshold (TTS) at 4 kHz as a function of sound pressure level (SPL) for exposure to octave band sound of 2-4 kHz. The length of exposure to the adapting sound in minutes is shown for each curve (from Shoji, et al., 1966 cited by Hodge in Parker and West, 1973).

The use of in-vehicle radio and tape deck equipment makes consideration of this phenomenon important for both external and in-vehicle auditory grade crossing warning devices. Also important is the simple "tuning out" of the driver who primarily uses his radio to provide background noise. As far as we know, there is a dearth of information on the prevalence and level of degradation of the auditory modality for the driving population and the impact of this degradation on the effectiveness of auditory warning devices in the "real world" situation.

Driver Expectancy. Expectancy or set plays an important role in motorist performance. As the driver can anticipate upcoming requirements, decisionmaking becomes more efficient and perception response time decreases. If there is inadequate information on which to base expectancy, the driver may develop an expectancy which is at odds with the real world situation. Where expectancy and the real world situation are not congruent, a conflict results and the driver may react in accord with his expectancy rather than the requirements of the situation. In extreme cases, he may react in a fashion which is not compatible with either his expectancy or the actual situation or he may not react at all.

An important implication of the above is the importance of developing advance warning signs for railroad grade crossings which distinguish between crossings protected by active devices (gates, train-activated flashing lights) and those not so protected (Shoppert & Hoyt, 1968, cited by Hulbert in Forbes, 1972). At passive crossings, responsibility for detecting the approach of a train rests with the driver. He should be made fully aware that the upcoming crossing is passive at the location of the advance sign so that his attempts to detect the presence or absence of the train begin early in his approach to the track.

At a lower level of analysis, it is important to attract the driver's attention to the existence of the crossing, regardless of whether it is active or passive. Review of railroad grade crossing accidents is provocative (see Chapter 2). Especially interesting is the frequent occurrence of accidents which can be characterized as related to inadequate attention, the motorist attending to other items than the grade crossing. The implication is that warning devices, whether active or passive, should be of high attention value relative to other stimuli in the environment.

Effect of Age. Age has a relatively small effect on simple reaction time, but a considerably greater impact on tasks involving judgment and choice. Response time in complex tasks increases significantly. In addition, psychomotor tasks involving several motions (such as moving from accelerator to brake pedal and turning a curve) which are performed in an integrated overlapping fashion by the young driver tend to be performed sequentially by the older driver. Learning is impaired and memory is degraded.

For these reasons, new countermeasures should be tested on older drivers and, preferably, little learning should be required.

Vision

A sign located at a grade crossing should be legible at a sufficient distance in advance of the crossing so that the motorist has time to perceive the sign, process its information, and perform any required maneuver. A rule of thumb for legibility distance is:

$$LD = H \times 50$$

where LD = legibility distance in feet
H = height of letters on the sign

The above is based on work by Forbes (1939) and is considered applicable to symbol signing using H to represent the height of the symbol in inches (King & Lunenfeld, 1969).

This rule of thumb is useful for estimating whether the distance at which a sign can be read given its letter (symbol) height is sufficient for safe motorist performance. First, the time necessary to read the sign and react to it is estimated (see Information Processing and Related Topics) and converted to distance traveled given vehicle speed. To this must be added the distance required to brake the vehicle at the range of speeds found for vehicles approaching the crossing (see Baerwald, *Traffic Engineering Handbook*, 1965). The computed distance is then compared to the estimated legibility distance.

The fact that the above is an approximation should be thoroughly understood. Sign legibility is a function not only of letter height but also of letter width, letter height-width ratio, the space between letters (or symbols) in the horizontal and vertical dimensions, and contrast between message elements and the background. Even more important perhaps, are the differences in visual capability between drivers and the variability in visual capability for any particular driver as a function of fatigue, drugs, alcohol, sickness, and similar factors. External factors such as day versus night and weather will also affect legibility. An example of this variability is shown in the fact that the 50 feet/inch rule for legibility distance was established for black-on-white Series D (medium wide) letters. Series B letters (which are narrower) resulted in legibility distances of 33 feet/inch of letter height (Forbes & Holmes, 1939, cited by Forbes in Forbes, 1972).

Despite these caveats, the above is useful for estimating whether the legibility characteristics of a proposed visual countermeasure are likely to be "in the ballpark" to meet motorist needs. For detailed treatment of particular aspects, human engineering texts should be consulted (e.g., Forbes, 1972; Woodson & Conover, 1964; Van Cott & Kinkade, 1972).

Driver age has a large effect on many aspects of vision. Some examples are given below:

- There is a drop in visual acuity of about 20 percent by age 60.
- Accommodation (or the ability to shift focus between far and near fields of vision) is generally reduced in the older driver. At the age of 20, the average minimum focusing distance is about nine inches whereas at the age of 60, it is 40 inches (Woodson & Conover, 1964). This means that some drivers cannot focus without aid on the instrument panel. Figure 3-5 illustrates the decrement in acuity and accommodation with age. In addition to the great increase in minimal focusing distance, the time required to accommodate is increased for the older driver. These two factors make shifting between near and far fields of view increasingly difficult and time-consuming with advancing age. The result is either that the older driver uses bi- or tri-focals (with attendant head movement requirements) or he simply does not refer to the instrument panel. These factors argue strongly that any visual in-vehicle display designed for critical information needs should be of the head-up variety. The head-up display appears at optical infinity (any object 20 feet or further away is at optical infinity as far as the eye is concerned) which is compatible with the focus used in general driving. Such a display requires no accommodation when shifting attention from the view of the road to the display.
- Capability for dark adaptation is sharply reduced in the older driver. A rule of thumb is that double the illumination is required to see an object for every 13 years of age (McFarland, 1956).
- Ability to see against glare is reduced with age. One researcher found that when five to 15-year-olds were compared to 75 to 85-year-olds, the increased brightness necessary to see against glare was 50 to 70 times (Wolf, 1968).

One final aspect of vision should be mentioned; namely, color deficiencies. Color deficiencies mainly occur in males, some eight percent being affected. The most frequent types are red blindness (protanopia) and green blindness (deuteranopia). With regard to the design of displays, it should be noted that green blind persons can see the full visual spectrum (though not in the same colors as the normal). However, red blind individuals cannot. For such persons, some of the red end of the spectrum cannot be seen at all (Woodson & Conover, 1964).

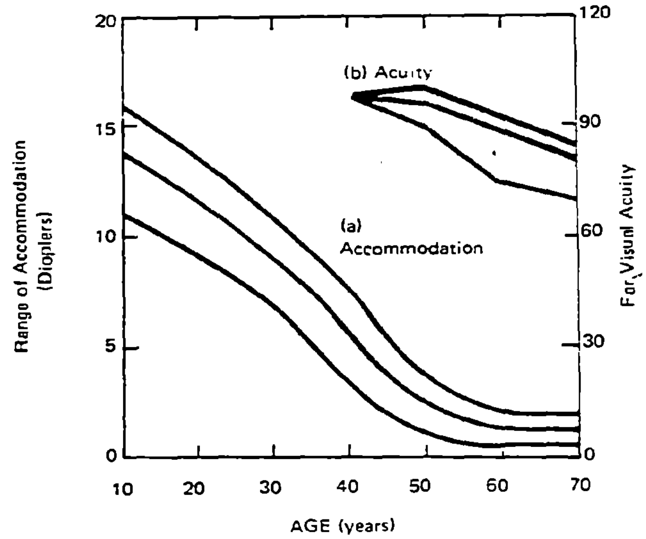

Figure 3–5. Maximal, minimal and average values for acuity and accommodation as a function of age (data of Duane & Friedenwald in McFarland, 1953).

Audition

The range of human hearing is about 20 to 20,000 Hz with greatest sensitivity from 2,000 to 3,000 Hz (Woodson & Conover, 1964). The effect of age on hearing is shown in Figure 3-6. It is important to note that low frequencies are least affected by aging.

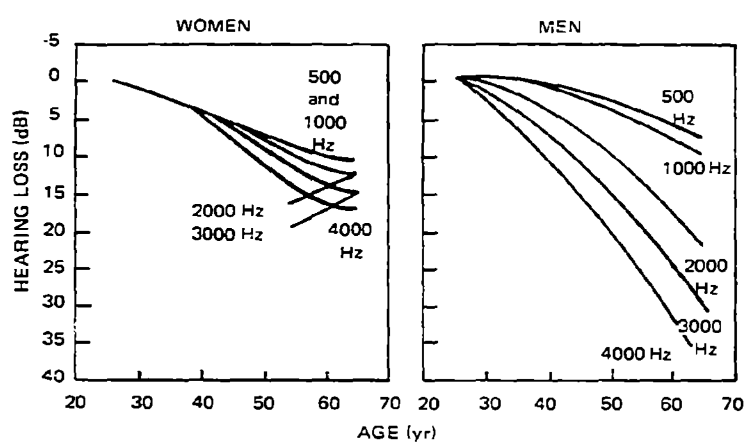

Figure 3–6. Relation between age and hearing loss for men and women (ASA, 1954 reproduced from Deatherage in Van Cott & Kinkade, 1972).

In considering the use of the auditory channel for warning of an impending grade crossing, auditory adaptation (already discussed) and masking are the main limitations to be considered. The most important source of masking noise in the automobile is the background noise arising from the engine, passage of the vehicle through air, and options such as radios/tape decks. Interestingly, masking noise has its greatest effect on those with most acute hearing (Gladwell, 1964). In view of the very high levels of background noise which may be found in an automobile (reading 90 dB), thorough testing of auditory warning devices on a representative population is clearly vital. It is also important to note that the levels of sound necessary to insure that any warning signal is perceived may reach the discomfort level (110 to 120 dB) or the level of sound associated with pain (140 dB and up).

Vibration

This sensory channel has been relatively little explored. Frequencies of ten cycles per second or less are generally considered "pulsation." Above about 20 Hz, individual pulses are not discriminated and, at these levels, the sensation is referred to as vibration. Figure 3-7 shows threshold values for perception, discomfort, and pain to sinusoidal vibratory stimuli.

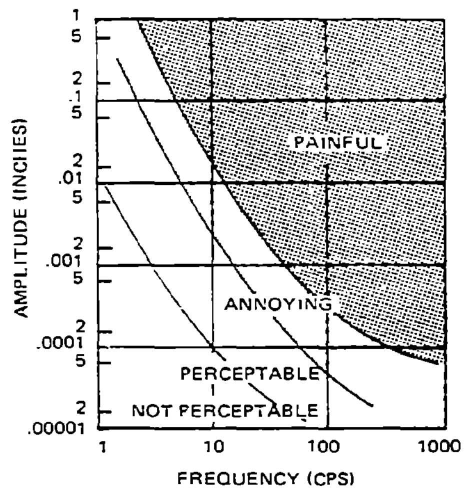

Figure 3–7. Relationship between frequency amplitude of sinusoidal vibration and human perception (drawn from Woodson & Conover, 1964).

Of interest is the fact that the resonant frequency of the human body is about 5 Hz. Thus, vibration at this frequency is particularly unpleasant (Woodson & Conover, 1964).

Summary

Evidence for a particular subgroup of high-risk grade crossing accident drivers characterizeable on psychophysiological dimensions was not found in the course of this study. Accordingly, general capabilities and limitations of drivers along the dimensions of information processing and related topics, vision, audition, and vibration have been briefly discussed. The discussion should be useful in obtaining ballpark estimates of the adequacy of existing and new countermeasures. Of particular importance in this section is the demonstrated degradation of driver psychophysiological capabilities with age. Because the 60-year-old and above driver constitutes 14 percent of the driving population and is increasing, the importance of considering this group in the development of new countermeasures concepts cannot be overemphasized. Representative sampling by age as well as across educational and geographic lines is clearly essential in the testing of new countermeasures concepts. Consideration should also be given to the handicapped, especially the color-blind (eight percent of the male population) and those with hearing deficiencies.

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CHAPTER 4

DESIGN OF THE FIELD DATA COLLECTION STUDY

Study Objectives

The primary objective of the project is to provide a sound, factual base for planning a large-scale field experiment in which the full range of prospective countermeasures can be evaluated. This experiment, Phase IV of the current effort, will be concerned with the following five categories of countermeasures experimental variables:

- Site engineering, Type 1 – improved caution signs, active warning devices, etc.
- Site engineering, Type 2 – increased visibility, reduction of physical hazards, etc.
- Procedure intervention – modification of railroad operating practices or equipment usage.
- Driver training – safety campaigns, modification to training curricula, etc.
- Enforcement – publication of increased enforcement, changes in state law, etc.

To develop the base for planning such a study, the current effort was directed toward assessment of the efficiency, reliability, and usability of test instrumentation; observation and recording methods; and the analysis, interpretation, and presentation of data. The central objective of the present study was to develop a research methodology suitable for use in the large-scale field experiment. In essence, this study attempted to determine the feasibility and efficacy of using various experimental procedures in the design and evaluation of countermeasures.

Experimental Design

The basic design was a before/after study. The design thus included collection of baseline data under existing conditions, implementation of countermeasures, and then collection of data after countermeasures intervention. Because the project is primarily a feasibility study, the design was intended to accomplish objectives beyond simple preliminary countermeasures evaluation. Thus, the data served as a basis for selecting the particular countermeasures concepts to be implemented. Details of the design were as follows:

- Inclusion of both active and passive crossings.
- Inclusion of both rural, urban, and sub-urban crossings.
- Inclusion of a set of four geographically separated crossings matched as closely as possible on other variables (e.g., all of these were active crossings).

- Use of several different data collection techniques. These permitted collection of both driver behavioral data (e.g., speed at defined locations and looking behavior) and data on driver knowledge, attitudes, and various demographic and experiential characteristics.
- Selection of sites which were limited in sight distance (so that driver looking would be an expected behavior on the approach to the site).
- Selection of sites where track roughness was approximately equal so that this would not be a confounding variable affecting driver behavior.

Although the above has described the basic dimensions of the design, other variables naturally intervened as a consequence of the impossibility of finding sites which were matched on all other dimensions. Examples include variation in the frequency and scheduling of trains, variation in the number of tracks at the grade crossing, and variation in traffic volume between the study sites.

Site Selection

Selection Rationale

The alternative strategies considered in selecting test sites were as follows:

1. a fully representative sample based on random (i.e., unbiased) selection,
2. a fully representative sample based on stratification by type and hazard level,
3. a categorical sample based on economic (i.e., payoff) and engineering criteria, and
4. an undifferentiated sample based on convenience criteria.

If the present project were intended to provide definitive, substantive answers leading to the selection of optimum countermeasures for grade crossing hazards, either of the first two alternatives would be preferred strategy; but such strategies in the present instance are unjustifiably expensive and of low feasibility. A complete compendium of grade crossing sites in the United States would be needed. While partial catalogs by states exist, a complete national listing is not available. It is estimated that some 220,000 grade crossings exist. This means that observations of about 220 sites would be required to attain a sample size of one-tenth of one percent. The logistic costs associated with the instrumentation of such a large number of test sites, in and of themselves, made such an approach impractical.

The fourth strategy was discarded because of lack of rigor. While costs might be minimized, the payoff with respect to the value of the findings of research planning is not predictable.

The third and preferred approach rests upon the proposition that the objective is to learn something about how a definitive field experiment should be structured. The decisions to be made are those having to do with the identification of critical variables, choice of driver behavior indicators, selection of instrumentation, data processing operations, and modes of data presentation and interpretation. This approach was used in selection of the study sites.

Each site was selected to conform as nearly as possible to the following requirements:

1. two-lane, two-way roadway,
2. ADT above 2,000,
3. no significant grade change in approach,
4. no traffic signals, speed zones, or major intersections within 1,000 feet of the crossing,
5. no parking within 500 feet of the crossing,
6. suitable interview area,
7. anticipation of two or more train movements,
8. restriction to motorist seeing trains in at least one quadrant, and
9. for active crossings, flashing lights, and bell (no gates, wigwags, etc.); for passive crossings, standard crossbuck symbols.

In all, nine sites were selected. They were characterized along the dimensions of the experimental design as follows:

- six were active, three were passive;
- four were urban, four were sub-urban, and one was rural*;
- the four geographically separated sites were located in Virginia (Route 28), Michigan, Texas, and California (all were active, sub-urban, single-track, similar in speed limit on the approach to the crossing, and had similar traffic characteristics in terms of vehicle type); and
- at seven sites, there was one track while at two crossings there were two tracks.

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*A comment is required concerning the urban versus sub-urban versus rural classification. Such a classification was felt necessary despite the inherent problems and difficulties associated with such attempts. The procedure was to classify the sites as urban, sub-urban, or rural based upon the immediate impression generated by the surroundings of each crossing. The reader is urged to examine the site descriptions in Appendix A to obtain a more detailed impression of the site characteristics along this dimension.

The sites and the above characteristics by site are summarized below:

Site	Active = A Passive = P	Urban = U Sub-urban = SU Rural = R	Geographic Set	Number of Tracks
Linthicum	P	U		1
New Midway	P	U		1
Calverton	P	R		1
Sunnyside	A	U		2
Fairview Avenue	A	U		2
Route 28	A	SU	x	1
Michigan	A	SU	x	1
Texas	A	SU	x	1
California	A	SU	x	1

In the selection of the remote sites (in Michigan, Texas, and California), the experience of three individuals who were familiar with most of the crossings in their vicinity were drawn upon. Mr. Clarence McGoon of the Michigan Public Service Commission, Mr. Hoy Richards of Texas Transportation Institute, and Mr. Ken Baldwin of BioTechnology, Inc. in San Jose, California, were given the general requirements desired and asked to select as many sites as could be located. The data collection crew then made the final selection after visiting each of the preselected sites. In this manner, it was possible to locate four sites which had similar physical characteristics in a short time at relatively low cost.

Experimental Measures

Two categories of measurement were used in the empirical demonstration study: (a) driver behavior and (b) driver reports. Essentially, driver behavior involves measuring the performance of drivers as they approach the grade crossing under varying circumstances. Objective indicators of driver behavior were obtained by covert observation techniques on the site.

Driver reports consisted of self-descriptions, indicators of knowledge and atitudes related to grade crossing situations and hazards, and drivers' recollections of their perceptions in the specific instance of approaching the grade crossing. These data were obtained by an interview-questionnaire administered to drivers at the sites immediately after they passed through a grade crossing.

Pretest of Data Collection Protocol

On 8 June 1972, data was collected for one day at the selected evaluation location, Sunnyside Avenue, near Beltsville, Maryland. This crossing was chosen as it had been used in a previous study and therefore we were familiar with its characteristics. Several items were examined or evaluated during this pretest, and a summary of the results is presented below.

Unfamiliar Driver. It had been planned to code into the Traffic Evaluator System (q.v.) the familiarity shown by the license plate of all vehicles. This would have yielded a much larger population of unfamiliar drivers and their behavior approaching the crossing than the population identified through the questionnaire.

It had been found during the collection of interview data concerning signing on interstate highways[1] that drivers who had license plates issued by a state other than that where the data was collected were generally not familiar with the road on which they were identified. To verify this, a sample of thirty drivers was selected who had license plates from a state other than Maryland, Virginia, D.C., or the Federal Government. They were stopped and asked if they frequently traveled over the railway-highway grade crossing on Sunnyside Avenue. Most of the drivers were found to cross it more than once per day, while only two stated that this was the first time they had traveled the route in question, although all thirty were residents of the general suburban area of Washington, D.C.

While these results might not be consistent with populations in areas not confounded by the highly transient D.C. area, the selection of unfamiliar drivers on the basis of out-of-state license plates was rejected.

Driver Looking Behavior. The driver approaching a railway-highway grade crossing was expected to look at the signal (where active protection existed), and was also expected to look up and down the tracks to confirm the absence of a train. Observation of drivers failed to reveal any covert method of determining the observation of the signal standard, but head movements in advance of the grade crossing corresponded to the road segment near the crossing on which the track could be scanned. It was observed that at sites with no major obstruction to train visibility, the incidence of large or obvious head movements was greatly reduced apparently due to the driver looking for trains much farther from the crossing than the observers could be located. A major constraint to the selection of sites was therefore developed: that visibility should be restricted (by buildings or natural obstructions) in at least one

[1] Kolsrud, G. S. Diagrammatic guide signs for use on controlled access highways. Vol. III. Traffic engineering evaluation of diagrammatic guide signs. Prepared for Federal Highway Administration, Washington, D.C., December 1972.

quadrant and that this obstruction should be located close enough to the crossing that the useful looking zone was well defined. Further, the zone should be such that an obvious head movement would be required of a driver who did, in fact, look to see if a train was present.

The useful looking zone at Sunnyside was limited to the last 200 feet in both quadrants. The points within this zone were carefully noted for all traffic for an hour, at which time it was concluded that the looking behavior fell into two sections. Some drivers looked for trains as soon as there was a clear area (100 to 200 feet), while others made a last second token effort (ten to 50 feet). Coding was then initiated to record into the Traffic Evaluator System the looking behavior of all drivers in the zones bounded by the 50- and 200-foot road switches, and by the 10- to 50-foot switches. It was noted that the driver's head movement could not be seen well from the right side of the approach, therefore coding was done from the left side of the road. Further, coding personnel were not able to observe both zones without missing some vehicles. Two people were therefore used, one for each zone. The codes represented the four possible actions in each zone: looked left, looked right, looked both ways, and did not look. Examination of the results, shown in Figure 4-1, revealed that few drivers looked only one direction (13 percent), and that they subsequently looked the other direction in the next zone, or during the transition area between zones and were therefore not coded for the second look. The coding scheme was modified to omit the left and right looking data, and only two codes were used (looked or did not look). This reduction in choices also eliminated the incidence of missing data due to workload and virtually all drivers received codes in both zones.

An attempt to film driver looking behavior was made, but the results were unsatisfactory. The camera had to be tripod-mounted to insure smooth tracking at a high magnification, and the area to be panned had to be reasonably clear of obstructions. This latter constraint placed the camera and operator in a rather obvious location which necessarily revealed the presence of a data collection effort to the driver.

A sample of the drivers who were stopped for interviews were asked if they had noticed anything unusual during their approach to the crossing, in an attempt to determine the efficiency of the camouflage being used for people and equipment. The only positive response was during a period when the film was being changed and the driver had seen that operation in progress. The film changing involved climbing a 20-foot ladder to reach the camera located on a telephone pole. The ladder was normally hidden in some high grass over a fence near the camera. A driver who saw the ladder being restored to its hiding place returned later and attempted to steal it, not having seen the six observers who were taking data nearby.

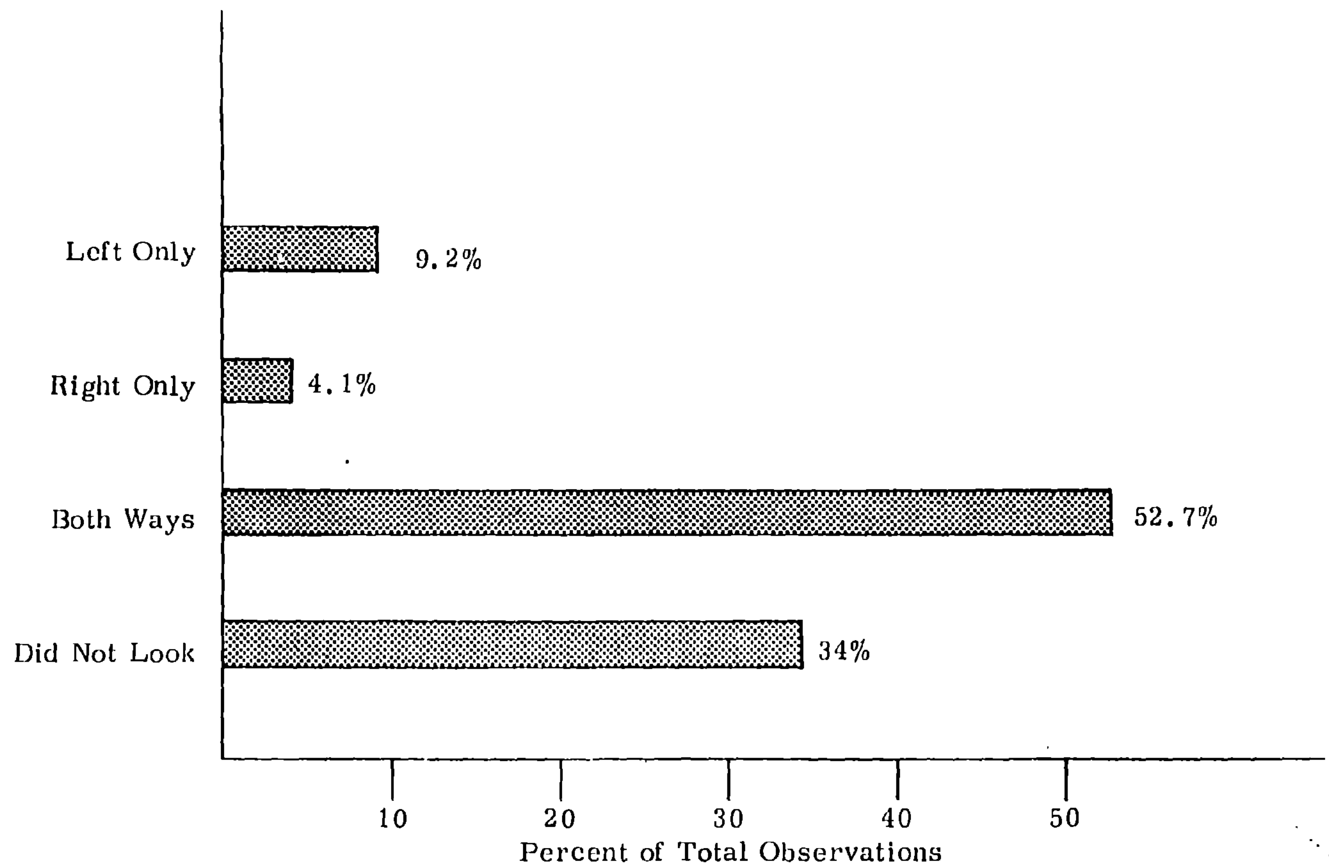


Figure 4–1 Looking behavior for 664 vehicles observed between –10 and –150 feet. (Sunnyside Avenue grade crossing, June 1972)

During the pretest, time-lapse film of the driver's approach to the crossing was taken for the first 30 minutes of each hour. The quantity of film thus generated was felt to be excessive, particularly since no useful information was identified beyond that discussed under the section on photography. It was decided to reduce this effort to the first half-hour of each odd hour, but to supplement it with a special events record of driver behavior whenever a signal was activated or a train was approaching.

The procedure noted in the section on obtaining driver interviews was verified, and reduced to a step-by-step plan which resulted in a high degree of success in stopping the selected driver. The major factor which determined if the driver would complete the questionnaire form was found to be the action of the police officer who stopped traffic for us. During the pretest, three policemen were assigned to us in shifts. One insisted on talking to each driver before directing him to the waiting interviewer. He stated that we were conducting a survey on how railroad crossings could be made safer, and then said "if you have a few minutes to spare..." which prompted most drivers to ask if the interview was mandatory. When the officer stated that is was not, most drivers would not stop for the interview. Police who did not address the driver but simply pulled him into the interview site yielded a much higher proportion of drivers who completed the form. As a result, during the rest of the study, all police were carefully briefed on the prefacing remarks which the interviewer was to make to the driver and requested to restrict their activities to directing traffic.

The reduction and analysis of the pretest data revealed the need for a number of changes in the format or wording of certain questions, and verified that the anticipated procedures were appropriate. Comparisons of the pretest data and the subsequent data collected on 10 and 11 July showed no significant changes in driver behavior. For example, Figure 4-2 shows the mean speeds for the pretest and for the actual data collection periods. The maximum speed change was less than one mile per hour.

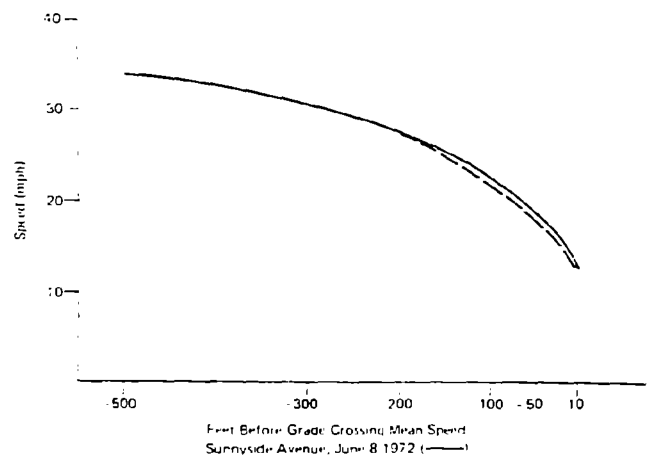


Figure 4–2. Mean speed profile for Sunnyside Avenue taken on consecutive months.

Verification and Validation of Measures

Overview

In consultation with the Contract Technical Manager, a test program was initiated to verify the concept of *countermeasure* evaluation as developed during this study. This program consisted of the collection of data at a passive crossing under three conditions: with existing crossing protection, and with the addition of high and low intensity flashing amber lights mounted on the advance warning sign.

Countermeasure Development

It must be emphasized that the selection of flashing lights as the countermeasure does not imply an endorsement of that countermeasure: it was selected because it had a high probability of being effective, and it was inexpensive to develop for this test. The requirements which the countermeasure was required to meet were::

1. availability
2. rapid installation
3. easily changed in effectiveness
4. have a high probability of changing motorist behavior

The installation of flashing lights on the left and right sides of the existing advance warning sign was selected as a countermeasure which met all of the above requirements.

Two sealed beam, yellow lamps, six inches in diameter, which operated from a 12-volt power source, were mounted on an aluminum arm and supported by a strap over the top of the existing 4- x 4-inch sign support resulting in a device as shown in Figure 4-3. When attached, the lamp face was flush with the plane of the 30-inch standard advance sign. A timing circuit was built which alternately lit the two lamps at a 60-cycle per minute rate. Two levels of brightness were achieved by operating the lamps from a six-volt automobile battery for low, and a 12-volt battery for high intensity.

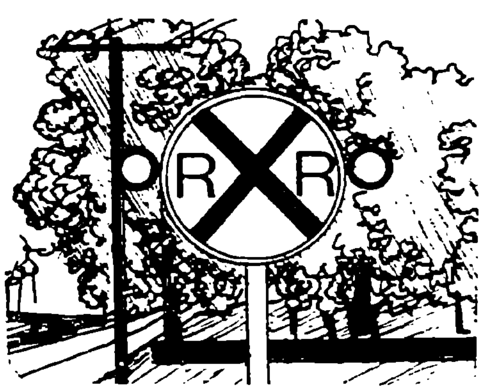


Figure 4–3. Modified advance warning sign.

The brightness of the test installation was measured using an SEI Photometer. The study was conducted on a fully overcast day to maximize the attention getting qualities of the flashing lights. The important measurements were:

Sky Brightness	500 foot-Lamberts
Sign Background	53 foot-Lamberts
Low Intensity Lamp	174 foot-Lamberts
High Intensity Lamp	2291 foot-Lamberts

Thus, the low intensity lamp, against a background of trees, had a contrast ratio of about 3.5:1. The high intensity lamp contrast ratio was 43:1.

Experimental Plan

Measures. Two primary measures were obtained for three segments of the population using the crossing: speed decrease and looking behavior. The number of drivers who stopped in the absence of a train was also noted for both directions of travel.

Site Selection. The location selected for study was a passive crossing referred to in this report as Calverton, Virginia. This crossing has extremely limited track visibility (left and right sight distance), but a relatively straight, unrestricted approach to the crossing. The restriction to visibility was important, so that the looking behavior of the approaching driver was restricted for practical results to the last 100 feet before the crossing. Since this was a passive crossing, the approaching motorist could not determine whether or not a train was present in either direction until he was within 50 feet of the intersection.

Finally, the site had provision for covert observation of the approaching motorist from the parking lot of a country store 90 feet downstream from the rail-highway intersection.

The advance sign which was modified was located 433 feet upstream from the crossing.

Data Collection. A spot radar was used to obtain two measurements of speed on all approaching vehicles which did not have another vehicle in either lane during the approach from 500 feet to the crossing. No train influence was involved on the day selected for data collection. (The restriction against a vehicle in either lane was required because the beam width of the radar was such that interference was caused by vehicles moving away from the data collection site, and by the desire to eliminate the influence of a lead vehicle.) Special use vehicles such as school buses and fuel trucks were omitted from the study due to the atypical behavior of that group.

The radar was hidden from the view of the approaching driver. The sensitivity was adjusted to "lock on" to target vehicles at about 500 feet upstream from the crossing. A reading was taken when the subject reached the downstream edge of the advance pavement markings, (430 feet) and a second reading was taken when the subject reached the double stop lines (ten feet). If the driver looked to see if a train was approaching when he was within 100 feet of the crossing, he was said to have looked. By selecting a site with such limited sight distance, the driver who looked for trains was required to make an obvious head movement, making the determination of looking behavior relatively easy.

Three observers were used. One observed the driver with binoculars for looking behavior, one noted the speed meter readings and recorded observations, and the third selected and observed the subject vehicles, calling out the two times when a speed reading was to be taken.

Results

Considerable detail has been included above to allow interested agencies to essentially duplicate the study for appropriate countermeasures. It is most likely that techniques and devices which have potential application would not produce changes of the magnitude shown in this evaluation project, particularly after the acclimation effects had been eliminated; therefore, a much larger sample of the population would be required. The techniques for determining the required population is shown in the section of this report titled "Validation by Accident Reduction." Of particular importance is the size of the baseline or "before" sample. An insufficient data base obtained before the modification program is begun will result in an inability to evaluate the effect of a weak but appropriate change.

The baseline data obtained at the crossing under study consisted of two hours of driver behavior samples, a total of 54 subjects. The baseline period was taken in two parts, before and after the with-countermeasure data collection periods, to insure against time-of-day variations.

Comparison of the short baseline data obtained during this study and the data obtained at Calverton, Virginia, when interviews were being conducted, indicates that no significant difference was obtained between looking behavior and speed decrease. Table 4–1 compares the means and standard deviations of looking and speed decrease for the two samples of the population at Calverton.

The null hypothesis to be evaluated is "no significant difference exists between population behavior under the influence of either dim or bright flashing lights located at the advance warning sign compared to the existing rail-highway grade crossing protection."

Table 4–1

Comparisons of Data Items for the Same Crossing Obtained at Two Different Times

• LOOKING BEHAVIOR NEAR THE CROSSING

Data Collection Period	N	Mean	Std. Dev.
Countermeasure Data	54	0.36	0.48
Interview Data	284	0.44	0.46

t = 1.218: Not significantly different

• SPEED REDUCTION PERCENT CHANGE

Data Collection Period	N	Mean	Std. Dev
Countermeasure Data	54	33%	20
Interview Data	286	35%	22

t = 0.703: Not significantly different

To evaluate this hypothesis, Table 4-2 shows the means, standard deviations, and "t" values for the three conditions under which data were obtained.

Table 4–2

Results of the Data Collection Effort for Measures Evaluation

• LOOKING BEHAVIOR
(Look = 1, Not Look = 0)

Crossing Condition	N	Mean	Std. Dev.
Existing Protection	54	0.36	0.48
Dim Flashing Lights	77	0.52	0.50
Bright Flashing Lights	75	0.84	0.36

• SPEED REDUCTION
$(V_1 - V_6) \div V_1$

Crossing Condition	N	Mean	Std. Dev.
Existing Protection	54	0.33	0.20
Dim Flashing Lights	77	0.47	0.23
Bright Flashing Lights	75	0.69	0.29

• T–VALUES

Comparison	Looking Behavior	Speed Reduction
Existing vs. Dim	1.84	3.71
Existing vs. Bright	6.16	8.34
Dim vs. Bright	4.54	5.10

The above differences are all significant at the .05 level: and, in fact, all except existing protection versus dim flashing lights for looking behavior are significant at the greater than .001 confidence level.

To reject the null hypothesis, it is necessary that both speed reduction and looking behavior change in the appropriate direction by a significant amount. For example, a candidate countermeasure which implied a high degree of grade crossing roughness might result in an increased speed reduction without a corresponding increase in looking behavior. A countermeasure which was located too close to the crossing or was of insufficient size for the population to note the message in time, could result in an increased looking behavior at the crossing without a corresponding speed reduction. In this case, both looking behavior and speed reduction were shown to be significant in the predicted direction and, therefore, the hypothesis was rejected.

In summary, the change in behavior of the driver population was, for their first exposure to the countermeasure, exactly as had been predicted. The driver slowed down upon noticing the countermeasure, made a diligent effort to detect a possible train hazard and, in fact, the potential for a train-vehicle collision was materially reduced. The countermeasure was also found to be increasingly effective in proportion to the brightness of the lamps as is seen in Figure 4-4.

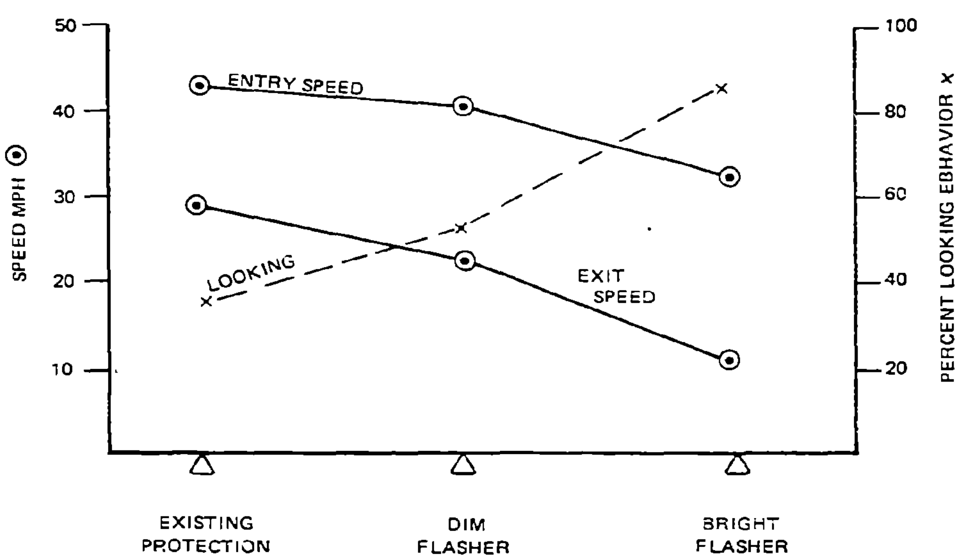


Figure 4—4. Comparisons of measures for entry speeds (430') and exit speeds (10') and looking behavior for three conditions of protection.

Of note are the number of drivers who came to a full stop at the painted stop lines before proceeding on their trip. The number of drivers who came to a full stop in both directions was noted, and the noninstrumented direction used as a control. Under the three protection levels, the percent of drivers who stopped is shown in Figure 4-5.

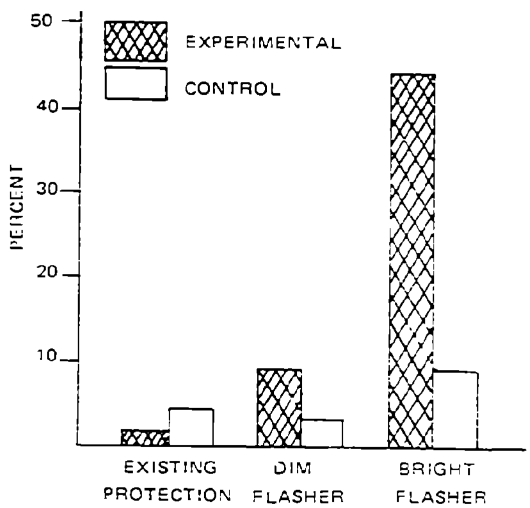


Figure 4-5. Percent of drivers who stopped at the crossing for both directions under three experimental conditions.

Conclusions

The purpose of this study was to validate the measures suggested for countermeasures evaluation. In fact, the hypothesis to be tested was, "Given a modification of the Calverton grade crossing, which caused a short term modification of behavior in a safe direction, are the measures sufficiently sensitive to that change to indicate a significant result?" It must be concluded that the measures proposed and used are, in fact, sensitive to a change in grade crossing safety behavior, and are valid measures which may be used in the evaluation of candidate countermeasures.

CHAPTER 5

FIELD DATA COLLECTION TECHNIQUES

The data obtained under this contract at the nine locations investigated during Phase II is a massive base containing information on the behavior, attitudes, knowledge, and biography of over a thousand drivers. Additional information regarding the physical surroundings at the collection locations, the operation of railroad equipment, and trains was collected. All of the above was examined in the light of findings of other researchers through a review of the pertinent literature, and with an understanding of the types of accidents which have occurred at grade crossings. Table 5-1 may be useful in pointing out the measures gathered in the second phase of this contract. In the sections which follow, each of the data collection techniques used in obtaining these measures, viz., the Traffic Evaluator, photography, and motorist interviews, are discussed.

The Traffic Evaluator System

The Traffic Evaluator System was developed in 1969 by the Federal Highway Administration to allow large-scale collection of data pertaining to the operating characteristics of highway traffic. The system records discrete events on magnetic tape. It is a rugged, portable, battery-operated system which can continuously monitor 60 switch contacts. Upon activation of any contact, the time of initial closure and the address of the active switch is written on seven-track computer tape.

The complete Evaluator System consists of an array of vehicle sensors, the evaluator recorder, and electronics unit (hereafter referred to as the "evaluator"), power supplies, manual code boxes, associated cabling, and a set of computer programs for reconstruction of the original vehicle characteristics.

Vehicle Sensors

Two primary methods of sensing vehicle position are available. These are tapeswitches and pneumatic tubes. Pneumatic tubes are traditionally used in traffic counting devices and could be used with the Traffic Evaluator System. They have a low initial cost and a long life. However, we have not used them in any of the studies we have conducted using the Traffic Evaluator System and there are several reasons for this. First, they are highly visible to motorists and suggestive of a speed trap, causing motorists to alter their driving pattern as they enter an area where pneumatic tubes are deployed. The operation of long tubes is undependable unless very sensitive pressure sensors are used with some electronic amplification and pulse shaping. Double pulses are common in mechanical detector combinations. The most serious fault is in the sensor equipment. A large enclosure must be attached to the end of the hose, so measures of traffic in a single lane of multiple lane roads requires an unwieldy geometry of tubes and logic to determine which lane the vehicle was in by counting the number of tubes hit. Wheel bounce and adjacent lane vehicles make this technique unreliable.

Table 5—1

Data Categories

DATA CATEGORIES AND ITEMS	SOURCES OF INFORMATION						
	QUESTION-NAIRE	INTER-VIEWER	OBSERVER	TRAFFIC EVALUATOR	PHOTOG-RAPHY	SITE SURVEY	
Crossing Characteristics							
Location		√					
Weather		√					
Roadway conditions		√					
Advance sign; what kind?	√				√	√	
How many sets of tracks?	√				√	√	
Train visibility						√	
Signal visibility						√	
Speed limit						√	
Crossing roughness						√	
Driver Biographical Data							
Sex		√					
Age?	√						
Occupation?	√						
Glasses?		√					
Sunglasses?		√					
Obvious handicaps		√					
How many miles a year do you drive?	√						
State you got first license?	√						
Where do you live?	√						
How long have you lived there?	√						
Reason for drive	√						
Driver Vehicle Characteristics							
Type	√		√				
Lead vehicle	√		√				
Color	√		√				
Window position	√		√				
Radio on	√						
Air conditioner	√						
Seat belt	√						
Shoulder harness	√						
Make and model	√		√				
Year	√						
State licensed	√						
Number of occupants	√		√				
Other windows open	√						
Window condition	√						
Obvious defects	√						
How fast at tracks?	√						
Driver's Crossing Behavior							
Roll down window?	√						
Listen for train?	√						
Did you look?	√		√				
Stop at crossing?	√		√				
Did you slow down?	√						
Did you come to complete stop?	√						
Why did you stop?		√					
Why did you continue ahead of train?		√					
How fast did you cross tracks?	√						

Table 5–1 (Continued)

Data Categories

DATA CATEGORIES AND ITEMS	SOURCES OF INFORMATION: QUESTION-NAIRE	INTER-VIEWER	OBSERVER	TRAFFIC EVALUATOR	PHOTOG-RAPHY	SITE SURVEY	
Driver Awareness of Safety							
Law says you should have done what here?	√						
Do all crossings have signal or gate?	√						
Do all crossings have a sign way up road?	√						
Most accidents occur with-without gates or lights?	√						
Most accidents occur day/dark?	√						
Most accidents occur good/bad weather?	√						
Most accidents at crossings with signals due to carelessness or nonworking signals?	√						
How many motorists killed in U.S. at crossings last year?	√						
How many of above drunk?	√						
How many killed in all traffic accidents in U.S. last year?	√						
If no signal; only few trains/only slow trains?	√						
Signals at crossings always tell when train is coming; warn in plenty of time to stop.	√						
Have ever known anyone to get ticket for crossing when signal on?	√						
Driver Knowledge and Experience with Crossings							
How often do you cross these tracks?	√						
How far do you live from crossing?	√						
What first indication of crossing?	√					√	
Advance sign; what kind?	√					√	
Did you know number of tracks?	√						
How many tracks?	√					√	
Markings on road? what do you remember?	√					√	
Anything making it hard to tell if train?	√					√	
Receive specific instruction on crossing?	√						
Train and Countermeasure Data							
How improve advance warning sign?	√						
Is train scheduled now?	√						
How often do you see trains at crossings?	√						
Ever cross when signal on? Why?	√				√		
Average delay at crossings?	√						
How long after signal is train?	√						
What are most effective countermeasures?	√						
How fast was train going?		√	√				
All Vehicles Data							
Type				√			
Wheel base				√			
Number axles				√			
Platoon				√			
Type previous vehicle (for each trap in array)				√			
Speed in mph				√			
Headway in seconds				√			
Headway in feet				√			
Tailway in feet				√			
Time of day				√			

The practical procedure is the use of tapeswitch sensors manufactured by Tapeswitch Corporation of America. These sensors consist of two metal strips separated by plastic spacers and enclosed in an extruded plastic jacket. A leadwire runs from one end of each tapeswitch to a terminal box located off the shoulder of the road. When the wheel of a vehicle rolls onto the switch at any point along its length, the metal strips are pressed together and an electrical circuit is completed. The switches are obtainable in any length desired. The input connections from the switches to the data recorder are such that each switch is uniquely identified. By limiting the length of the switch to the width of a highway lane, the specific lane in which each vehicle is located is automatically identified.

Four models of tapeswitch are useful in sensing wheel crossing. These are the models 131, RB, RBS, and 170-IS. Each of these switches has different characteristics. For most applications, the model of choice is the 170-IS which designates a BioTechnology, Inc. modification which is particularly appropriate for traffic research. This switch is lightweight, about 1/2" wide by 1/8" high, and causes almost undetectable vibration and noise when crossed by motorists.

Tapeswitch sensors are attached to the road with adhesive tape. A double-faced tape the width of the switch is placed beneath each switch. Tape with adhesive on one surface only is placed on top of the switch. This tape is about six inches wide and contacts both the switch and the roadway. The combination of two adhesive tapes permits switch deployments to last for a week or more under high-speed, high-density traffic conditions. The single-faced tape on top of the switch provides protection while the double-faced tape between the switch and the highway prevents "creep" of the switch in the downstream direction.

Evaluator (Data Recorder)

The evaluator consists of an electronics unit which codes incoming data, and a digital tape recorder for mass storage. A pair of shielded wires are run from each switch in the array of vehicle sensors to a central position where they are connected to the evaluator. An individual 12-volt line is run to each normally open switch. The closing of the switch charges a capacitor which is sensed by a level converter and the resulting pulse is converted to a +5-volt logic level. After inversion, the pulse is routed through a diode matrix and the six-bit coded output is applied to the first stage of a six word silo memory. The appearance of a coded switch closure at the memory triggers a cutoff line and is "and gated" with the original pulse from the switch to fire a 40-millisecond, one-shot multivibrator. This disables the input from the vehicle sensor that initiated the signal. A 10 k Hz clock is the primary time-of-day mechanism. Twelve bits of time data are loaded into the silo memory with the switch closure code, and the resulting 18-bit word is read out of memory in its turn to the recorder.

The clock is reset every 2016 milliseconds. This event is transmitted through the diode matrix just like a road switch and is recorded, giving a continuous record on the tape of time since initial device activation.

The mass storage device is a Precision Instruments PI-1387 incremental digital tape recorder. Completely passive unless commanded to record, this instrument writes six bits of data plus parity at each step. The three steps required to write the 18 bits of data generated by each switch closure require 18 milliseconds. The maximum writing speed at 200 characters per inch is 200 steps per second. Six 100-foot tapes are used, representing a maximum capacity per reel of 480,000 switch closures.

Certain limitations of the evaluator regarding accuracy should be noted. The 0.5 millisecond uncertainty due to the clock rate will result in an uncertainty of 0.0184 percent per mile per hour. The vehicle may not be moving along a line perpendicular to the sensors. A five-degree angle will cause an erorr of 0.38 percent. A placement error of 1/4 inch from the desired four-foot separation causes a 0.52 percent error. Other factors which may result in small errors are axle misalignment on the subject vehicle, unevenly worn tires, etc.

The magnitude of the errors can be greatly reduced by averaging the reading for all axles, placing the switches at points of low lane changing probability, and taking great care in positioning the switches exactly four feet apart and perpendicular to the flow.

The evaluator in its present configuration contains only a six-word memory. Up to ten microseconds are required to process data for each switch closure. The hardware may fail to recognize a second closure within the processing period of the first. If six switch closures are queued for the recorder, data generated will not be stored until there is room in the memory. The data written on the tape must be formatted into records and files for further processing. During the 0.75 seconds required to write an end of record code on the tape, no data can be recorded. This problem is minimized by using extremely long record lengths, but at the cost of requiring a great deal of core memory to read the tapes.

Manual Code Inputs

Since the evaluator recognizes all switch closures in the same way, some of the 60 codes available may be used by observers to record discrete events manually. Three 8-button boxes, four 1-button boxes, and associated wiring are available. The meaning of the codes may be defined in any way desired.

Power Supplies

The evaluator system is designed to operate on three voltage sources, a 12-volt automobile storage battery for the road sensors and recorder, a six-volt storage battery for the electronics unit, and a 12-volt dry cell for negative bias of the level converters. The recorder draws 40 watts when writing data and virtually no power in the standby mode. Two ampere-hours is about average depending on the characteristics of the vehicle array and traffic volume. The electronics package draws a steady 25 watts from the six-volt battery. The drain on the bias supply is negligible.

Cables

The system is connected together by 60 interchangeable cables. These are each 330 feet long and may be hooked together like household extension cords to obtain the necessary length. Amphenol connectors terminate the cables at the evaluator on one end and to either a manual code box or road switch terminal strip box on the other.

Data Processing

Two utility computer programs and one analytical program are used to prepare data obtained in the field with the Traffic Evaluator System. These programs translate time and switch codes into vehicle and traffic flow histories, reproducing the conditions actually experienced on the roadway.

The utility programs serve only to edit data stored on magnetic tape in the field and to translate these data into a form more readily reviewed by a research engineer. Originally, the data are stored as large blocks of continuous binary bits. These are scanned one bit at a time to locate the first valid time pulse, stored as 0000 followed by an 01 switch code. This operation is used to synchronize the edit program with the data base. Data in each record are then translated from continuous binary bits into elements of three words of six bits each. The first two words, or twelve bits, represent the time, and the third word represents the switch code.

The edit program also provides the user with a means for selecting specific blocks of field data to be processed by the analytical program. Input controls are provided to specify the beginning and ending file and record numbers of field data which are to be stored for further analysis. Options are also given to print the data processed in octal or decimal and to write the data on magnetic tape.

The primary function of the analysis program is to reproduce the field situation that was originally stored on magnetic tape. This is accomplished by taking axle time pulses and the associated switch codes and producing vehicles at each pair of switches in each lane of roadway.

An important feature of the analysis program is its capability to determine when failures of road switches occurred. Original data which are missing from the input file of times and switch numbers can frequently be reconstructed and used by the program without causing the vehicle to be lost from the output data file. Many internal checks are performed before permitting the reconstruction of missing data, and the output can be used with great confidence.

The program is designed to assign a unique identification number to each vehicle that is recognized entering the array and to track this vehicle through the entire array of switches on the roadway. As vehicles are determined by the program, the interrelationship of each vehicle with adjacent vehicles in the lane is computed in terms of time and space headway. These vehicle relationships and other space and time measures are output both on magnetic tape and in printed tables.

A number of user generated input items are provided to permit maximum user control of the data to be processed. Among these are parameters that define analysis periods, locate and identify valid switch codes by lane, and establish ranges and intervals for tabulation of the data. Time and space factors are included for fitting the analysis program to the traffic conditions that prevailed when the data was recorded.

The output of the analysis program is stored on magnetic tape and provides the researcher with the greatest flexibility for conducting many different statistical analyses and tests on the traffic measures. By sorting the data on file with a standard computer utility sort program, any of the fields in a record can be selected as the major control field and any other data in the record as minor control fields, creating any desired set of data for subsequent analysis.

Two different kinds of output record may be obtained. The first is a cumulative record of a given measured event by switch pair, or lane, or both. Among the events which may be so described are:

1. number of vehicles (by type and grouped in platoons if desired),
2. lane change,
3. lane straddles,
4. speed (absolute and relative),
5. headway (time or space),
6. acceleration,
7. manual inputs (e.g., local versus nonlocal), and
8. vehicle characteristics (number of axles and wheelbase).

The second kind of record is a track of a specific vehicle as it passes through the tapeswitch array. Included in this track history are a unique identification for each vehicle detected, the vehicle type (auto or nonauto), the lane traversed, and switch pair crossed within the lane. The analysis period, platoon number, and number of axles on the vehicle are also recorded. Associated with this information, each record presents the front axle speed, the rear axle speed, the time each axle reached the switch, average vehicle speed, the distance between the first two axles, time and space headway between the current vehicle and the preceding one, the manual observer code (if any), and the clock time in hours, minutes, and seconds. The beginning clock time is established by the user through an input parameter.

Road Switch Placements

The Traffic Evaluator System was used in a grade crossing study for the Federal Highway Administration (Speed Profiles and Time Delay at Rail-Highway Grade Crossings[1]). Speed data was collected at the one thousand-foot and one hundred-foot points on both sides of the crossing and at the crossing. The resulting profiles showed that the crossing does not influence traffic behavior significantly beyond 500 feet. To generate smooth curves the switches were spaced as shown in Figure 5-1 below. This gave measures of vehicle parameters at six points within 500 feet of the crossing at approximately regular time intervals as the vehicles decelerated.

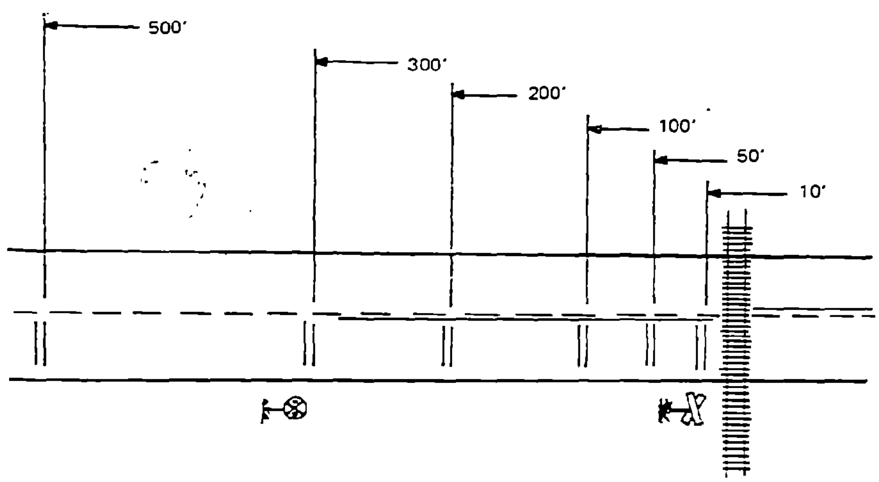


Figure 5–1. Placement of vehicle sensors in advance of grade crossings.

The speed measures obtained represent the speed of the motorist under study under conditions both with and without the influence of the grade crossing environment.

Manual Coding

For each vehicle passing through the array of vehicle sensors during the period of observation, the looking behavior of the driver was coded by hidden observers. The approach to the crossing was divided into two zones and the obvious head movements of the driver were coded by four categories: (1) did not look, (2) looked to the left, (3) looked to the right, and (4) looked both ways.

[1] Sanders, J.H. Speed profiles and time delay at rail-highway grade crossings. Final Report. Prepared by BioTechnology, Inc. for Federal Highway Administration. May 1972.

All sites were selected with obstructions in at least one of the two quadrants so that the driver would not benefit from looking for a train before reaching a point less than 200 feet before the crossing. The two zones selected for observation were from 150 feet to 50 feet, and from 50 feet to 10 feet. The pre-test of the data collection methodology showed that virtually all drivers fell into the "not look" or "both ways" category, and that the coding task was slightly more reliable when only these two categories were used. It was further shown that two observers were required, one for each zone.

The software developed for the Traffic Evaluator System permits vehicle specific coding to be entered on the magnetic tape. Small boxes were constructed with two buttons on each labeled "yes" and "no". These were connected to the Traffic Evaluator System. In order for these codes to be associated with the correct vehicle, they had to be entered onto the tape when the observed vehicle would be the next one to pass over the vehicle sensors at the end of the zone.

Additional codes were used by the site leader. A third pushbutton box was provided for entry into the Traffic Evaluator System of codes representing the start and end of crossing signal activation, the arrival and departure of trains, and whenever a train whistle was heard. These five codes were not vehicle-related, and were retrieved by a search of the magnetic tape for these particular five codes. A sixth code was used for the designation of vehicles selected to receive interviews. This code was entered so that the selected vehicle would be the next one to cross the last pair of sensors. It was not always possible to enter this code at the correct time, however, since some vehicles which were interviewed were chosen because they stopped when the signal was not activated, and it was not recognized that they were going to stop until after they had already reached the last pair. In these cases, the interview code was associated with the next vehicle, and a notation was made to allow correction of the data base.

A similar problem was discovered with the looking codes. That is, some vehicles were found in the data with three codes instead of two. This was caused by the design of the study requiring coding of behavior within a zone before the subject reached the end of the zone. However, analysis of the data showed that late codes which were assigned to the following vehicle (along with the actual codes for that vehicle) were in all cases "did not look" codes. This discovery allowed correction of the data without loss of information. The apparent reason for this phenomena is that drivers who did look for trains were coded as soon as the action was observed. The observers, anxious to give the driver every opportunity to look, sometimes waited 0.3 to 0.5 seconds too long before signaling a "did not look" code.

A second problem was with the coding of the signals and trains. At crossings without bells, it was frequently difficult to know when the signal came on, and the additional task of selecting and coding vehicles which drove through an activated signal sometimes preempted the task of coding these other items. When this was recognized, a small photoelectric device was constructed which could be taped in the corner of the signal. The relay closure output from this device was connected directly to the Evaluator System so that signal activation periods were automatically coded. Unfortunately, the need for this device was not recognized before some signal activations had been missed.

Photography

There were three types of photography used extensively during the project: 35mm still photography, super-eight movies, and super-eight time-lapse photography.

Site Documentation

The black and white 35mm photographs were used to draw descriptions of the physical characteristics of each site, in conjunction with measurements of the location of driveways and intersecting streets, signs, and other items which could attract the interest of the driver approaching the crossing. These pictures were made from the driver's eye level with a wide angle lens from around 1000 feet from the crossing at 100-foot intervals. Additional measures in support of the site documentation included signal visibility zones and sight distance down the track from various driver distances.

Train Events

Upon activation of the signal at the six active crossings or the approach of a train at the three passive crossings, a special events camera operated by the site leader at the observer location was used to film the immediate approach zone. A film speed of eight frames per second was used to permit maximum filming time (about seven minutes) while being fast enough to eliminate jerky movement of vehicles when projected. These films were used for two important purposes, to give a striking visual record of driver behavior when warned of an approaching train, and to allow manual vehicle reconstruction of the Traffic Evaluator System data on vehicles which stop (see section on the Traffic Evaluator System).

Vehicle Tracks

Each day during the collection of data, a super-eight camera was mounted about 500 feet before the crossing. This camera was generally located on a telephone pole, carefully orientated so that it could not be seen by the drivers going in the direction of interest. The cameras filmed all activity from about −300 feet to beyond the crossing for the first half-hour of each odd hour. A filming speed of two frames per second was used. This film, in color, was primarily intended as a back up to the Traffic Evaluator System. It was also used to verify the matching of Traffic Evaluator System records with specific driver interviews.

An effort was made to develop some cross-site comparisons by counting the incidence of brake lights at the −100-foot and −10-foot points. This project was terminated after two sites had been "scored." The difficulty of detecting brake lights at the angle and distance of filming required about two hours per half-hour of filming to tabulate, and the vehicles with brake lights on were consistently found to be going about 15 percent faster than the cars without brake lights on (from the Traffic Evaluator System record). These vehicles were also found to show a much greater deceleration value than the nonbraking vehicles. As no new information was obtained, the brake light project was terminated.

In summary, since the Traffic Evaluator System produced data for all of the sites, the cost of attempting to develop duplicated data from the time-lapse film was not warranted and no further reduction of this filmed data was performed.

Questionnaire Construction and Administration

The investigation of driver response to the grade crossing environment would not be complete without an extensive knowledge of the individual driver. This information was obtained through the use of a structured interview-questionnaire, designed for administration following the covert observation of drivers traversing the selected grade crossings.

The instrument for the collection of this data provided for driver attributes in the following domains:

- Actual knowledge of regulations governing motor vehicle operations at grade crossings
- Actual knowledge of hazards at grade crossings
- Attitudes toward grade crossing safety including level of concern about the problem
- Differences between driver concepts of grade crossing situations and other hazards
- Demographic and related background information about drivers.

The questionnaire used in this project was constructed and submitted with the proposal. Some minor changes were made after the pre-test of the data collection protocol. The resulting instrument contained 40 items covering five general categories, as follows:

Section	Number of Items	Page Length
1. Behavior at crossing	6	1
2. Approach to crossing	7	1
3. Safety facts	10	1+
4. Previous experience	6	1-1/2
5. Biographical	11	1
Totals	40	5-1/2

Due to the length of the completed package, we did not feel that the cooperation of the motorist would be maintained throughout the entire questionnaire. Therefore, four different questionnaire forms were developed from the five sections and administered in a regular order.

In addition to the five sections noted above, a sixth section was filled out by the interviewer. This section provided information on the type and condition of the driver's vehicle, record keeping data, use and presence of safety and comfort equipment, etc. This section was also used to note the driver's answer to situational questions as appropriate, such as his reason for driving through an activated signal.

The resulting package on each driver selected for interview therefore always had Section 6, while Sections 3 and 5 were completed by three-fourths of the population. These two, knowledge of safety facts and biographical information on the driver, were felt to be more relevant to driver performance. The remaining sections were completed by half the population. Each item could be paired with every other item in some subset of the total population ranging from one-half to three-quarters. Thus, while minimizing the time required for the driver to complete the forms, we were able to generate a complete data base permitting bivariate distributions of all item pairs.

Questionnaire Forms were made up from the five sections as diagramed in Table 5-2.

Table 5–2

Administration Strategy

		Sections Included in Form					Number of Items
		1	2	3	4	5	
Form	1	x		x		x	27
	2	x	x		x		19
	3		x	x		x	28
	4			x	x	x	27

A copy of each of the forms used in this project is shown in Table 5-3.

Table 5–3

Questionnaire Forms

CODE #1________________ CODE #2________________

#________________

INTERVIEWER FILL IN THIS PAGE

Information in Advance of the Motorist

Location:________________ Date:________________

Weather: clear, cloudy, foggy, other________________

Roadway conditions: dry, wet, ice, snow, other________________

Information to be Completed by Interviewer

Time:________________

Type of Vehicle:

- 1.1 Passenger
- 1.2 Small truck
- 1.3 Large truck
- 1.4 Tractor-trailor
- 1.5 School bus
- 1.6 Commercial bus
- 1.7 Motorcycle
- 1.8 Other (specify)________

Color (specify)________________

Reason for Selection:

- 2.1 Stopped when signal was off
- 2.2 First to stop for signal or train
- 2.3 Crossed against signal
- 2.4 Nth vehicle
- 2.5 Other (specify)________

Did Lead Vehicle Stop?

- 3.1 Yes
- 3.2 No

Type of Lead Vehicle:

- 4.1 Passenger
- 4.2 Small truck
- 4.3 Large truck
- 4.4 Tractor-trailor
- 4.5 School bus
- 4.6 Commercial bus
- 4.7 Motorcycle
- 4.8 Other (specify)________

Driver Window Position:

- 5.1 Closed
- 5.2 Part opened
- 5.3 Fully opened

Head Movement:

- 6.1 None
- 6.2 Left
- 6.3 Right
- 6.4 Both

(Section VI)

Table 5-3 (Continued)

Questionnaire Forms

Radio on? ____ Yes ____ No

Air conditioner: ____ On ____ Off ____ None

Seat belt: ____ Yes ____ No ____ N/A

Shoulder harness: ____ Yes ____ No ____ N/A

Vehicle Make and Model:____________________ Year:__________________

State Licensed:____

Driver's sex: ____ Male ____ Female # Occupants including driver____

Glasses: ____ Yes ____ No Sunglasses: ____ Yes ____ No

Obvious driver handicaps:____

Others windows opened:__L-V __R-V __L-R __ R-R __R-F __ T-G

Window condition (e.g., foggy, cracked):______________________________

Obvious vehicle defects:____

Amplifying information:____

____

____

(Section VI)

Table 5–3 (Continued)

Questionnaire Forms

INTERVIEWER QUESTION TO MOTORISTS WHO STOPPED

(After introductory remarks)

What first prompted you to stop?

______ saw the train

______ heard the train's ____ whistle ____ bell ____ rumble

______ heard the bell at the crossing

______ saw the crossing signal lights

______ saw the gates coming down

______ saw the other motorist stopping ____ in front of me

____ in the other lane

______ usually stop

______ always stop

INTERVIEWER QUESTION TO MOTORIST WHO CROSSED THE CROSSING AFTER TRAIN IS OBVIOUSLY APPROACHING

What was the basis for your continuing across the grade crossing ahead of the train?

______ train was stopped

______ train was moving slowly

______ train was far away

______ no train in sight

______ other cars were crossing the tracks

______ vehicles behind me wanted to cross

______ police or railroad officials signaled me to cross

______ did not see the signal

______ other (specify)________________________________

INTERVIEW QUESTION TO BOTH OF THE ABOVE

How fast would you say the train was moving when you first noticed it?

____ 0-10 mph	____ 20-30 mph	____ 40-50 mph	____ 60-70 mph
____ 10-20 mph	____ 30-40 mph	____ 50-60 mph	____ Over 70 mph

(Section VI)

Table 5-3 (Continued)

Questionnaire Forms

#____________________________

MOTORIST QUESTIONNAIRE

First, please tell us what you did at this crossing.

1. When you first realized you were approaching a crossing, did you slow down?

   ______ No   Yes (indicate below):

   ______ in order to match the speed of the vehicle in front of you

   ______ so you could check for signals and trains

   ______ because tracks are usually bumpy

   ______ other (specify)______________________

2. Did you listen for a train? _____ Yes _____ No

3. Did you roll down your window? _____ Yes _____ No _____ It was down

4. Did you look down the tracks before crossing?

   ______ No

   ______ Left only

   ______ Right only

   ______ Both ways

5. Did you come to a complete stop before crossing the tracks?

   ______ Yes ______ No

6. How fast do you think you were going when you crossed the tracks?

   ______ 0-5 mph   ______ 30-40 mph

   ______ 5-10 mph   ______ 40-50 mph

   ______ 10-20 mph   ______ Over 50 mph

   ______ 20-30 mph

(Section I)

Table 5–3 (Continued)

Questionnaire Forms

Next, would you tell us something about what you remember of your approach to this crossing.

1. What was your <u>first</u> indication you were approaching a railroad grade crossing?

   ________ an advance sign way up the road

   ________ markings painted on the road

   ________ saw the sign at the crossing

   ________ knew it was there

   ________ saw a train

   ________ saw the lights flashing at the crossing

   ________ saw the tracks

2. If you saw an advance sign way up the road, what do you remember about the sign?

   ________ did not see an advance sign

   ________ the color (circle one) : white yellow red

   ________ the shape (circle one): ○ □ △ ▽

   ________ the symbol (circle one): X  RR R✕R

3. Did you know how many sets of tracks there were before you reached the crossing?

   ________ No Yes (indicate below):

   ________ remembered from when I was here before

   ________ could see the tracks

   ________ saw sign showing the number of tracks

4. How many sets of tracks were there at this crossing:

   ________ 1 ________ 2 ________ 3 ________ 4

   ________ 5 ________ don't know

5. If you saw markings painted on the road, what do you remember about them?

   ________ did not see any markings

   ________ the symbol (circle one): RR X = R✕R

(Section II)

Table 5–3 (Continued)

Questionnaire Forms

6. Was there anything that might have made it hard to tell if a train was coming?

_______ No   Yes (indicate below):

_______ could not see very far down the tracks

_______ had to watch the vehicle ahead

_______ people near the crossing were distracting

_______ other (specify)_______________________

7. What additions to the warning sign way up the road would have improved your confidence in approaching this crossing?

_______ an indication of the number of tracks

_______ an indication of the type of device at the crossing

_______ an indication of distance to the crossing

_______ a suggested approach speed

_______ flashing lights on the sign that are turned on by the train

_______ adequate as is

_______ other improvement suggestions_______________________

____

8. Is a train scheduled to come by about now?

_______ Yes, I think so

_______ No, I don't think so

_______ I don't know

(Section II)

Table 5–3 (Continued)

Questionnaire Forms

Please tell us what you remember about highway-railway crossing safety.

1. According to state and local law, what should you have done at this railroad crossing just now?

   ______ stopped

   ______ slowed down and been ready to stop, if necessary

   ______ maintained speed unless you saw or heard a train

   ______ no state law about speed at these crossings

2. Do all railroad crossings have a signal or gate that warns you when a train is coming?

   ______ Yes ____ No

3. Do all railroad crossings have a sign way up the road warning you that there is a crossing ahead?

   ______ Yes ____ No

4. Most accidents occur at crossings:

   ______ having gates or lights ______ without gates or lights

5. Most railroad crossing accidents occur:

   ______ after dark ______ during the day

6. Most railroad crossing accidents occur during:

   ______ bad weather (fog, rain, snow) ____ clear weather

7. Most accidents at crossings having signals are due to:

   ______ driver carelessness ______ signals that fail to work

(Section III)

Table 5–3 (Continued)

Questionnaire Forms

8. How many motorists do you think were killed in accidents at railroad crossings last year in the United States?

______ less than 100	______ 1000-1500
______ 100 - 500	______ 1500-2000
______ 500-1000	______ more than 2000

9. How many of the above accidents involved a driver who would be considered drunk under the law?

______ about 10%	______ about 75%
______ about 25%	______ about 90%
______ about 50%	

10. How many people do you think were killed in <u>all traffic accidents</u> on the streets and highways of the United States last year?

______ less than 1,000	______ 20,000 - 30,000
______ 1,000-5,000	______ 30,000 - 40,000
______ 5,000-10,000	______ 40,000 - 50,000
______ 10,000 - 20,000	______ 50,000 - 60,000
	______ 60,000 or more

11. If a crossing does <u>not</u> have a signal, it usually means that:

Only a few trains use the crossing	______ Yes	______ No
Only slow trains use the crossing	______ Yes	______ No

12. Signals at crossings:

Always tell you when a train is coming	______ Yes	______ No
Warn you in plenty of time to stop	______ Yes	______ No

(Section III)

Table 5–3 (Continued)

Questionnaire Forms

We would like to ask you about your previous experience at railroad crossings.

1. Do you recall receiving specific instruction or advice on railroad crossing safety?

   ________ No   Yes (indicate below):

   ________ in driver education classes in school
   ________ in other driver training
   ________ through safety campaigns (radio, TV, etc.)
   ________ in a driving license applicant's manual
   ________ other (specify)____________________

2. What is the average delay that you have experienced when stopped at a railway crossing?

   ________ 0-30 seconds   ________ 5 minutes
   ________ 30-60 seconds   ________ 10 minutes
   ________ 2 minutes   ________ Over 10 minutes

3. How long does it generally take a train to reach the crossing after the warning signal goes on?

   ________ 0-10 seconds   ________ 1-2 minutes
   ________ 10-20 seconds   ________ 2-4 minutes
   ________ 20-60 seconds   ________ Over 4 minutes

4. Have you ever crossed a track when the signal was on?

   _____ No   Yes (Check those conditions that existed the last time you crossed the tracks when the signal was on):

   _____ train was stopped
   _____ train was moving slowly
   _____ train was far away
   _____ no train in sight
   _____ other cars were crossing the tracks
   _____ vehicles behind me wanted to cross
   _____ police or railroad officials signaled me to cross
   _____ did not see the signal
   _____ other (specify____________________

(Section IV)

Table 5–3 (Continued)

Questionnaire Forms

5. How often do you see trains at railroad crossings?

_______ 1 time out of every 2 times you cross a track

_______ 1 time out of every 10 times you cross a track

_______ 1 time out of every 25 times you cross a track

_______ 1 time out of every 50 times you cross a track

_______ 1 time out of every 100 times or more

6. Have you ever known anyone who got a traffic ticket for crossing a track when the signal was on or the gate was down?

_______ Yes _______ No

7. Which of the following are the two most effective measures to reduce crossing accidents?

_______ more gates at crossings

_______ better warning signals at crossings

_______ better warning signs way before the crossing

_______ improved driver education

_______ public safety campaigns

_______ stricter law enforcement

_______ require trains to whistle before crossing the road

_______ require trains to have more lights

_______ lower speed limits for vehicles

_______ require trains to slow down before crossing the road

_______ all vehicles should stop at crossings

_______ signal in your vehicle that is turned on by an approaching train

(Make sure you have checked 2 of the measures above.)

(Section IV)

Table 5–3 (Continued)

Questionnaire Forms

We would like some information about the kind of motorists who are helping us. Please tell us ...

1. Your occupation ________________

2. How old are you?

____ 16-20	____ 31-35	____ 46-50
____ 21-25	____ 36-40	____ 51-55
____ 26-30	____ 41-45	____ 56 or over

3. About how many miles a year do you drive?

____ less than 5,000	____ 10,000-15,000
____ 5,000-10,000	____ Over 15,000

4. In what state did you get your first drivers' license? ________

5. Where do you live? City ________ State ________

6. How long have you lived there? ________

7. What is the reason for your drive (vacation, going to work, going shopping, etc.)? ________

8. How often do you drive across these tracks?

   ____ this is the first time
   ____ once or twice before
   ____ about once or twice a month
   ____ about once or twice a week
   ____ about once a day
   ____ more than once a day

9. How far do you live from this railroad crossing?

____ 0-1/2 mile (up to 10 blocks)	____ 2-5 miles
____ 1/2-1 mile (10-20 blocks)	____ 5 miles or more
____ 1-2 miles	

(Section V)

The resulting forms generally required about five minutes to complete. The questionnaire sections were presented to 1556 drivers during the data collection effort at nine sites. Each section was administered according to the tabular matter which follows.

Section	Number of Times Answered
1	646
2	632
3	936
4	647
5	931

About 20 percent of the attempts at interviewing drivers were unsuccessful.

In addition to these five sections, a sixth, as noted above, was filled out by the interviewer.

Administration

There were two primary restrictions placed upon the questionnaire administration: (1) the driver should not become aware of any activity which might modify his behavior until after he had crossed the tracks, and (2) there should be a reliable method for obtaining the cooperation of specific motorists selected before they reached the grade crossing.

Covert Observation. The first of the above restrictions was met by insuring that, as far as possible, the approach to the crossing was not modified in any way which was detectable by the motorist. With the exception of the vehicle sensors taped to the road using camouflage tape, all equipment and personnel were hidden taking advantage of existing cover. Where no trees or buildings were available, the observers were located in a 1962 Plymouth station wagon which was carefully situated to appear to be in a normal location off the road.

Interview Site Location. The location of the interview site presented somewhat greater problems than did the observer location. The safe operation of the study was always the primary consideration. The task of stopping selected vehicles and parking them where they did not pose a hazard to passing traffic, required a parking area large enough for at least three cars, with room to maneuver a large truck, and a safe return path to the original route. An additional constraint imposed by the law enforcement officers hired to direct selected motorists to the interview site was that they have jurisdiction over the roadway at the interview site. Since most of the crossings were located near the city limits, several cases involving two or more authorities had to be negotiated. In Milpitas, California, for example, the interview site was located at the city limits to San Jose. We would have liked to have moved it further than the resulting 300 feet from the crossing but a cooperative agreement could not be arranged between the police in the two cities in the time available.

At another site, Virginia Route 28 near Calverton, the state police were required and they insisted on erecting a "Prepare to Stop" sign and a "Survey in Progress" sign at 100 feet and 50 feet, respectively in advance of the interview site. This required us to move the interview site farther from the crossing than was desired in order to keep the first sign out of the sight of traffic until after crossing the tracks.

In some cases, the desired location was on private property. In every instance, arrangements were made with the apparent responsible parties for the use of their property. Aside from some unpredicted expenses, this created no problems. Arrangements were also made for sanitary facilities at a nearby commercial establishment.

Summary of the Interview Operation

Personnel. To conduct the interviews it was necessary to coordinate the activities of several people: a crew leader, located at the observer position just before the crossing, who selected drivers for interview; a crew leader located at the interview site, three or more interviewers, and the police officer.

Personnel used as interviewers were research assistants from BioTechnology. The same people were used at all six sites. The remote data were collected by temporary personnel arranged for in advance from employment agencies in Michigan and California. Brian, Texas had no temporary agency but Mr. Richards, who did the preliminary site selection for us, was also able to provide interviewers.

Training and Instructions. The acceptance of the delay imposed on the selected driver was enhanced to some extent by using attractive female interviewers, although this practice was not followed exclusively. The interviewers were carefully briefed on tactful approaches and on the overall procedure. A reasonably standard introductory statement was given to each motorist as follows:

INTERVIEWER APPROACH TO MOTORIST

Auto Beyond the Crossing

"We are trying to get information that will help to improve certain features of railway-highway crossings, and we think that motorists know the answers to these problems better than anyone else. We are working under contract to the Department of Transportation, the Federal Government agency responsible for railway-highway intersection safety research. This study is concerned with information the motorist needs and uses, and we would like to ask you a few questions. The questionnaire is short. We would very much appreciate your assistance if you can spare a few minutes of your time."

For training purposes, task sheets were prepared for each type of operation. Each interviewer was given a package containing all five sections which he filled in as would a driver, while another administered the questionnaire. They then reversed positions. Each of the questions was discussed to permit them to help the driver as required, and to familiarize them with areas where the motorist might not properly complete the form.

Task Sheet

Interviewer

1. Administer interview/questionnaire to drivers
2. Fill out required spaces on interview information sheet (IIS)

Task Description

Driver Interview. Upon the approach of a selected vehicle, receive from the coordinator a completed cover sheet. Obtain a questionnaire and copy the interview number from the cover sheet.

Brief the driver as rehearsed. Give him the questionnaire on a clipboard with a pencil. Assist him as required but do not influence his answers.

As the questionnaire is being filled out, complete the IIS. Check the cover sheet for correct information.

Remain near driver just behind his window.

When driver has completed questionnaire, ask if radio or tape player was on.

Ask special case questions.

Quickly look for errors in questionnaire, and ask driver to correct any found.

Thank driver for his cooperation.

Other Duties. Relieve coordinator if he is interviewing another driver.

Interview Procedure. Interviews were taken for the first 45 minutes of each hour. The interview coordinator was in contact with the site leader located at the observer site via two way radio operating on the Citizen's Band frequencys. The coordinator called for a driver to be interviewed on the basis of a table of random numbers provided. Table 5-4 was used in the order shown. The next number was radioed to the site leader who began counting at that time, selecting the n^{th} vehicle for interview. A code was entered into the Traffic Evaluator System just before the selected vehicle reached the −50-foot trap thus permitting the Evaluator data to be associated with the questionnaire. The site leader called a description of the selected vehicle: color, make, and model; position of driver's window at the track; and the time of day. This information was noted on the interview cover sheet, and the police officer was told the make, model, and color of the selected vehicle. He proceeded to stop the driver and direct him to the interviewer who indicated where he should stop.

In addition to the vehicles selected at random, special cases were interviewed whenever they occurred. These consisted of drivers who stopped short of the crossing without signal activation, drivers who crossed the tracks when the signal was operating, the first vehicle to stop for a train, and other cases of interest such as driver's education cars. The use of random number selection procedures resulted in selection of several cases which were not appropriate, such as a Brink's Armored Car, but also gave us data on drivers which we might have otherwise elected to pass, such as city bus drivers and police officers.

Table 5–4

Vehicle Identification and Selection Sheet

X = missed

Location: [illegible] **Date:** July 11 1972

Weather: (clear), cloudy, foggy, other______

Roadway Conditions: (dry), wet, ice, snow, other______

10	0	1	2	3	4	5	6	7	8	9
11	0	1	2	3	4	5	6	7	8	9
12	0	1	2	3	4	5	6	7	8	9
13	0	1	2	3	4	5	6	7	8	9
14	0	1	2	3	4	5	6	7	8	9
15	0	1	2	3	4	5	6	7	8	9

#137 - MISSED - PREVIOUS INTERVAL

#156 - MISSED PREVIOUS INTERVAL

TOTAL -
1300 - 96% [illegible]
1430 - 94%
1600 - 99%
1730 - 93%

Table of Random Numbers for Vehicle Selection

~~2~~	~~3~~	~~4~~	~~4~~	3	2	4	4	1
~~3~~	~~2~~	~~4~~	~~1~~	2	1	3	1	3
~~1~~	~~2~~	~~3~~	~~4~~	1	4	3	4	1
~~4~~	~~2~~	~~4~~	~~2~~	2	4	1	2	1
~~4~~	~~1~~	~~4~~	~~4~~	1	4	1	4	2
~~4~~	~~1~~	~~2~~	~~4~~	2	1	2	3	3
~~1~~	~~1~~	~~2~~	~~4~~	2	3	4	1	3
~~2~~	~~4~~	~~3~~	~~1~~	4	3	1	1	1
~~2~~	~~4~~	~~3~~	~~3~~	2	4	1	3	1

SUMMARY OF MISSED: 2.1 = 4 ; 2.4 = 3

GOOD INT. SUMMARY: 2.1 = 13 ; 2.2 = 3 ; 2.3 = 4 ; 2.4 = 32

CHAPTER 6

FIELD STUDY DATA

During the Phase II data collection effort, information was obtained to develop an understanding of the safety problems at railway-highway grade crossings and to provide a factual base of driver behavior and attitudes. The reduction of the data collected was directed toward identification of methods which would redirect the drivers toward safer conduct in a safer environment.

The information obtained consisted of four parts: questionnaire responses, driver performance records collected with the Traffic Evaluator System, physical measurements and descriptions of sites and railroad equipment, and accident histories at the instrumented sites. The following sections illustrate the methods of reduction and analysis directions.

Summary

In summary, not including the pretest data collection period, nine sites were involved in the Phase II data collection effort for two days at each site. A total period of 112 hours, 17 minutes of data were recorded with the Traffic Evaluator System which yielded complete tracks on 18,552 vehicles. Fifty-seven trains were observed during data collection periods. Of the 1,556 drivers selected for interview, 1,267 completed the questionnaire. The tabular matter that follows summarizes the effort at each site.

Questionnaire Responses

Procedure

The various questionnaire forms (discussed in Chapter 5) were coded and keypunched to yield one punched card for each section answered by each subject. A program was written to examine the file for missing data (blanks) and for codes which were not appropriate. The program output was a list of card numbers which contained defective information. These cards were recoded after review of the original questionnaire, and the defective cards were replaced with valid data cards.

The primary reason for the defective cards was found to be the omission of an item during the coding process which resulted in a one- or two-column shift to the left of the codes which followed.

Summary of Field Data Collection

Site	Date (1972)	Complete Vehicle Tracks	Trains Observed	Hours of Data Collection	Total Hours	Completed Questionnaires
Sunnyside Avenue Beltsville, Maryland	July 10 July 11	1388 882	13 6	1021 – 1858 1345 – 1846	13 hr. 38 min.	129
Route 170 Linthicum, Maryland	July 17 July 18	2281 1021	0 0	1030 – 1745 1030 – 1430	11 hr. 15 min.	92
Route 190 New Midway, Maryland	July 19 July 20	488 190	2 0	1225 – 1930 1305 – 1605	10 hr. 5 min.	90
Grange Hall Road Holly, Michigan	July 25 July 26	998 793	2 4	0943 – 1600 1155 – 1717	11 hr. 39 min.	146
Route 28 Calverton, Virginia	July 26 July 27	414 383	0 0	0835 – 1601 0830 – 1746	16 hr. 42 min.	154
Carson Avenue Bryan, Texas	July 31 August 1	870 795	4 1	1338 – 1800 1000 – 1544	10 hr. 6 min.	163
Route 28 Manassas, Virginia	August 2 August 3	1769 770	3 1	0910 – 1800 0900 – 1329	13 hr. 19 min.	168
Central Avenue Milpitas, California	August 9 August 10	1930 1681	2 1	1000 – 1645 1015 – 1555	12 hr. 25 min.	162
Fairview Avenue Manassas, Virginia	August 9 August 10	1177 722	10 8	0950 – 1800 0900 – 1358	13 hr. 8 min.	164

A second program was written which examined the file for logical errors. This inspection was for items such as "Have you ever crossed a track when the signal was on?" which were answered both "no" and "yes. . . ." The short list discovered by this program revealed some actual inconsistent responses which were changed to the "no response" code for that item, and some coding and keypunch errors which were corrected.

Response to Selected Items

Several items on the questionnaire were not intended to be compared with driver performance measures, but were included to develop an understanding of the attitude of the public on certain issues. Most of the other questionnaire items are discussed in support of the hypotheses testing in Chapter 7. Items which are felt to be of general interest or which clearly have countermeasures implications are listed below.

- Two-hundred and seventy-five drivers (46 percent) indicated that they slowed down at the crossing because tracks are usually bumpy.
- Most drivers indicated that they detected the crossing by remembering it was there. The remaining 246 drivers selected:

Saw advance warning sign	–	38.2%
Saw pavement markings	–	10.6%
Saw the crossing protection	–	37.4%
Saw the tracks	–	13.8%

- Two-hundred and sixty-six drivers indicated that there was something that made it hard to detect trains. Significantly more drivers at passive crossings so indicated than at active crossings. Generally the response was concerned with restrictions to visibility down the tracks.
- In general, there is no demand for signing indicating the number of tracks at the crossing. This is probably due to a lack of understanding of the use of the information.
- Sixty-eight percent of the drivers at passive crossings and 46.5 percent of the respondents at active crossings indicated a desire for active advance warning displays. Only 22 percent indicated satisfaction with present advance warning signing.
- At *passive* crossings, 15.4 percent of drivers thought there was an active device at *all* crossings. This increased to 22.8 percent at *active* crossings. Over 35 percent of the California drivers believed *all* crossings had active warning systems.
- Ninety-one percent of the respondents (825 drivers) felt that most accidents occur at passive crossings. They were split about evenly between day and night. Sixty-four percent believed most accidents occur in bad weather and over 90 percent attributed accidents to driver carelessness.

- Drivers felt that drinking was a major contributer to accidents. Responses to "How many (rail-highway fatal) accidents involved a driver who would be considered drunk under the law?"

About 10%	was selected by	28.9%
About 25%		25.9%
About 50%		28.4%
About 75%		12.2%
About 90%		4.6%

- Sixty-five percent of the drivers felt that passive crossings were characterized by low train volumes. Nearly 80 percent of the respondents *at* passive crossings selected this statement. Half of the drivers felt only slow trains use passive crossings.
- Affirmitive response to "Signals at crossings always tell you when a train is coming" was smaller than expected. Three-hundred and eleven subjects (37.6 percent) said "No." However, the next question "(Do) signals. . . .warn you in plenty of time to stop?" had only 19.6 percent stating "no."
- Asked to recall any specific instruction or advice on railroad crossing safety, most stated they remembered information in a driver's license manual or in driver's education classes. Thirty-five percent could not recall any instructions.
- Fifty-four percent of the drivers (338) stated that they experienced an average delay in excess of 5 minutes when stopped at a crossing.
- An extended view of time between signal activation and train arrival is held, as seen by the responses:

0-10 seconds	was selected by	5.0%
10-20 seconds		21.7%
20-60 seconds		32.3%
1-2 minutes		25.5%
2-4 minutes		10.4%
Over 4 minutes		5.1%

- Drivers were asked to suggest measures to reduce crossing accidents. The percent of drivers responding to each measure suggested were:

more gates at crossings	39.1%
better warning signals at crossings	27.6%
better warning signs way before the crossing	10.9%
improved driver education	8.6%
stricter law enforcement	5.5%
public safety campaigns	1.9%
require trains to whistle before crossing the road	1.5%
lower speed limits for vehicles	1.5%
require trains to slow down before crossing the road	1.4%
all vehicles should stop at crossing	1.0%
require trains to have more lights	0.5%
signal in your vehicle that is turned on by an approaching train	0.5%

- As was expected, virtually all of the drivers lived in the community where the crossing under study was located. Even in the vicinity of Washington, D.C., the driver's license was obtained in the same state as the crossing.

- The population had a mean of 12,800 miles per year driving experience, divided as follows for four classifications:

Less than 5,000 miles per year	15.7%
5,000 – 10,000	22.5%
10,000 – 15,000	21.3%
Over 15,000	40.5%

- The population using crossings generally had lived in the community for over ten years.

Less than 5 years	29.6%
5-10 years	20.2%
11-20 years	24.3%
Over 21 years	25.7%

- Nearly all (96.9 percent) of the vehicles had a radio installed although only 28.2 percent had the radio on. Thirty-eight point five percent had air conditioners, and of those who did have them, 58.6 percent were in use (observations were made in July and August.)

- Seat belts were installed in 90.6 percent of the vehicles observed, since most cars were newer than 1965. Of the cars with seat belts installed, 11.2 percent were in use. Forty-two percent of the cars did not have shoulder harnesses installed, and in those which did have them, only 24 drivers (3.3 percent) were using them. The list below shows the proportions of availability and use for each of the sites at which data was taken.

Site	Shoulder Harness		Seat Belts	
	% Having	% Use	% Having	% Use
Linthicum	41.0	9.7	91.1	19.6
New Midway	58.2	3.5	84.7	15.7
Calverton	58.1	4.7	93.8	21.0
Sunnyside	55.5	3.6	90.7	30.9
Fairview	63.1	2.4	93.1	16.4
Route 28	54.0	2.5	93.4	12.8
Michigan	85.3	1.6	85.0	10.6
Texas	41.2	1.5	89.2	5.7
California	66.2	3.5	89.6	16.7

- Drivers were asked what the purpose of their trip was. The responses were:

Working or going to work	47.3%
Shopping	22.5%
Miscellaneous	9.2%
Returning home	5.9%
Visiting friends	5.7%
Pleasure drive	3.8%
On vacation	3.1%
Going to doctor's office	1.5%
Getting car repairs	1.0%

- Female drivers represented 31.4 percent of the sample.
- An average of 1.72 people including the driver occupied the cars in the sample. The distribution was:

Occupants	Percent Cases
1	60.2
2	22.1
3	9.2
4	5.1
5	1.9
over 5	1.4

- Twenty-seven point nine percent of the drivers wore corrective glasses. Twenty-seven point one percent had on sunglasses.

Driver Performance

Traffic Evaluator System

The magnetic tapes generated by the Traffic Evaluator were processed in several steps. The first requirement was to copy the field tapes onto reels compatible with the computer system used to further process these data. The copied tapes with any parity errors eliminated were edited to convert the raw data stream into a form acceptable to the program which reconstructed the original vehicles. The corrected tapes were then processed by the vehicle reconstruction programs resulting in a set of files of reconstructed behavior of drivers as they passed through the instrumented section of roadway.

System Software Products

Summary statistics were available from the output of this program. These were used to develop preliminary behavioral comparisons among sites. Information which is descriptive of sites is included in Appendix A. A brief summary of the information developed by this series of computer runs is shown in the tables below.

For each site, the absolute speed distribution shows the number of vehicles identified by the program at each trap and the first four moments of speed. Table 6-1 is typical of all sites. Note the large kurtosis figures indicating a very pointed distribution. As an aid to interpretation of the moments, the actual distribution of speeds for passenger cars, which were tracked by the system through all six traps is shown in Figure 6-1. For clarity, only the first, fourth, and sixth traps are shown.

Table 6–1

Absolute Speed Distributions (mph)

PAIR	SIZE	MEAN	STD_DEVIATION	SKEWNESS	KURTOSIS
1	950	33.88	5.97	.27	6.3671
2	953	31.31	5.93	.27	7.6115
3	959	28.24	6.20	.40	9.0307
4	956	22.70	6.32	-.18	5.1836
5	926	17.63	5.96	.37	4.3339
6	929	12.37	6.11	1.56	6.2192

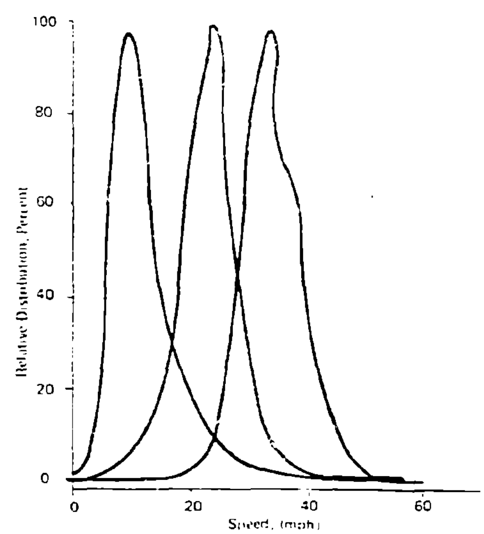


Figure 6–1. Distribution of speeds, Sunnyside Avenue, at (left to right), -10,000, and 500 feet before the grade crossing.

Additional summaries for relative speed (Table 6-2), time headways (Table 6-3), and space headways (Table 6-4) are available. Examples of each are shown below. These data are from Sunnyside Avenue. The relative speed table (speed of Nth vehicle compared with that of N-1) shows a very pointed bell-shaped distribution about a mean of zero. The essentially constant (not significantly different) second moments as the driver approaches the crossing were consistent for all crossings.

Table 6–2

Relative Speed Distributions (mph)

PAIR	SIZE	MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
1	949	.00	6.80	.10	7.1544
2	952	-.00	6.40	-.42	9.2087
3	958	-.00	6.34	-.17	11.0364
4	955	-.01	6.26	-.07	9.6095
5	925	-.01	6.44	-.34	4.6240
6	928	.00	7.50	.05	5.1081

Table 6–3

Relative Speed Distributions (mph)

PAIR	SIZE	MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
1	949	18.40	22.04	2.34	10.4459
2	952	18.30	21.87	2.35	10.5975
3	958	18.12	21.54	2.37	10.8683
4	955	18.01	21.54	2.35	10.7973
5	925	18.25	22.21	2.36	10.5150
6	928	17.76	23.25	2.57	11.6147

Table 6–4

Relative Speed Distributions (mph)

PAIR	SIZE	MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
1	949	942.37	1168.16	2.47	11.5152
2	952	868.87	1078.92	2.44	11.1931
3	958	782.39	979.69	2.49	11.6448
4	955	634.88	820.19	2.63	13.2435
5	925	503.12	689.96	3.07	18.0594
6	928	350.71	564.58	3.59	28.1101

The headway data presented in Tables 6-3 and 6-4 reflect typical moderate to low volume sites with random separation between vehicles. The time headway distribution is proportional to the traffic volumes observed, but not linear, as shown in Figure 6-2. This relationship is not true for sites characterized by definite platooning as when traffic is controlled by a nearby signalized intersection.

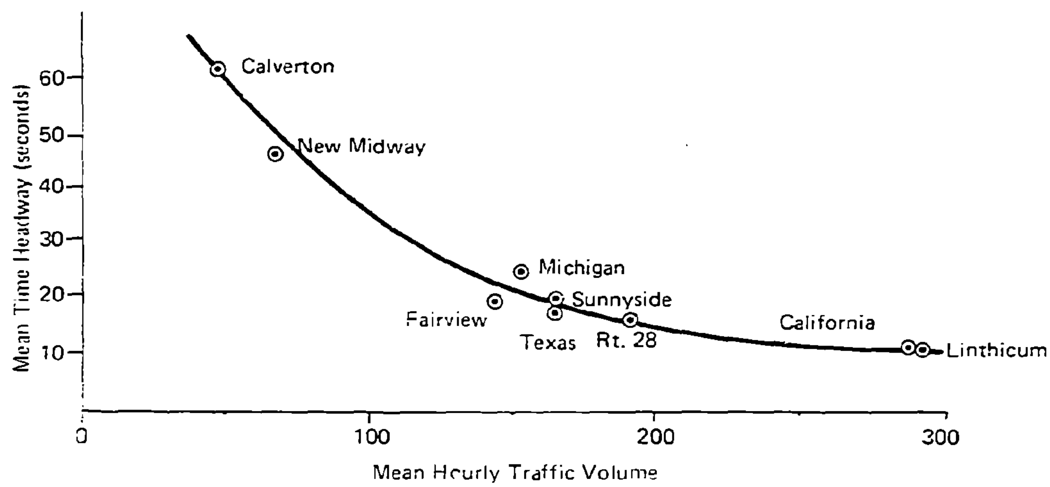


Figure 6-2. Time headway distribution for observed traffic volumes.

Cars entering the instrumented segment at low speeds accelerate until the crossing influence predominates. In general, this point is at approximately 200 to 300 feet, which also corresponds to the location of the advance warning signs, but also is the range at which most drivers scan the road ahead and might be expected to observe the actual crossing. Since a majority of drivers stated that they knew from past experience that the crossing was there, and the change from acceleration to deceleration is at about the same distance for the crossings with advance warning much further from the tracks, the latter is taken as the correct conclusion. For the population entering the array at the higher speeds, the figures generally show a continuous and increasing deceleration. The majority of the drivers exhibit a distributed point of maximum deceleration which appears to be related to other factors which are specific to the subject driver. The use of this point as a measure will be discussed in Chapter 7.

Individual Vehicle Reconstruction

The vehicle reconstruction program also presented the physical characteristics for each vehicle detected. Table 6-5 is a key for interpretation of the vehicle reconstruction tables.

An example of the printout generated is shown in Table 6-6. As an aid to interpretation of the vehicle reconstruction, the following translation for the third vehicle shown, number 776, is presented:

EXAMPLE OF VEHICLE 776

Data from Holly, Michigan, 25 July 1972

Vehicle 776 was a standard passenger car, in lane one, recorded at pairs one through six. He was following a large truck. He was in platoon 449 and had two axles separated by 9.9 feet.

As he approached the crossing, his speed changed from 47.8 mph to 40.4 mph. He was about 23 seconds behind the truck and closing from 1263 feet to 336.4 feet. The car behind him (number 777) was about 296 feet away.

This vehicle did not look for a train between −150 and −50 feet (code 44), nor did he look between −50 feet and −10 feet (code 42). He was stopped and interviewed (code 38). He entered the array of sensors at 1501:51 and crossed the track at 1501:58.

The flag codes (***2***) point out that his speed at traps 4, 5, and 6 was greater than the mean speed plus one standard deviation.

The interpretation of the vehicle reconstruction tables is only straightforward for those vehicles which did not either stop or slow down greatly. The limit of the capability of the software to track the vehicle from trap to trap is reached at a speed of about eight miles per hour. Many of the most interesting drivers were those who either stopped at the crossing or slowed greatly. The computer printout for these vehicles is frequently useless and their behavior must be determined by hand. The procedure for this will not be discussed other than to note that the reconstruction is highly reliable but time consuming. It is done by obtaining a printout of the original time and switch codes as recorded in the field, then calculating the final parameters as would have the vehicle reconstruction program if the speeds had been within its capability.

The behavioral information from the Traffic Evaluator System was matched with the interview-questionnaire form filled out by the subject driver, and was processed by a computer program which outputs a punched card containing the information shown in Table 6-7. This card is then included in the deck of cards for each driver which had been generated by the questionnaire reduction, making a total of five cards for each respondent.

Table 6–5

Key to Vehicle Reconstruction Tables

ITEM	DESCRIPTION
1. Flag Code	1 = Vehicle Accelerated 2 = Speed Greater Than Mean +1 S.D. 3 = Time Headway Less Than 2 Seconds
2. Sequential Vehicle Number	
3. Vehicle Type	0 Compact Car 1 Standard Car 2 Small Truck 3 Large Truck 4 Bus 5 Truck Combine
4. Lane	
5. Pair	
6. Type of Previous Vehicle	
7. Platoon Number	
8. Number of Axles	
9. Wheelbase, Feet	
10. Speed, M.P.H.	
11. Headway, Seconds	
12. Headway, Feet	
13. Distance Ahead of Next Vehicle	
14. Observer Codes	37 - Signal 38 - Questionnaire 39 - Train Arrival 40 - Near Look, Yes 41 - Whistle 42 - Near Look, No 43 - Advance Look, Yes 44 - Advance Look, No
15. Time of Day	

Table 6-6

Traffic Evaluator System Vehicle Reconstruction Example

	774	1	11	1	447	2	10.1	47.8	29.2	1879.2	3975.0	4442	15	0	30.491
	774	1	12	1	447	2	10.2	45.0	29.0	1813.1	3866.8	4442	15	0	33.387
	774	1	13	1	447	2	10.2	44.0	28.9	1698.1	3745.8	4442	15	0	34.907
	774	1	14	1	447	2	10.2	36.9	28.6	1360.6	3175.5	4442	15	0	36.572
	774	1	15	1	447	2	10.1	29.7	28.4	1155.3	2579.4	4442	15	0	37.578
	774	1	16	1	447	2	10.1	26.4	20.3	1097.2	2315.2	4442	15	0	38.558
	775	3	11	1	448	3	10.1	36.8	56.6	3975.0	1263.0	4440	15	1	27.421
	775	3	12	1	448	3	10.1	34.4	57.5	3866.8	1134.9	4440	15	1	31.206
	775	3	13	1	448	3	10.2	30.9	58.1	3745.0	992.3	4440	15	1	33.280
	775	3	14	1	448	3	10.0	24.7	58.7	3175.5	760.1	4440	15	1	35.693
	775	3	15	1	448	3	9.7	18.9	59.2	2579.4	555.0	4440	15	1	37.206
	775	3	16	1	448	3	10.0	13.3	59.8	2315.2	366.4	4440	15	1	38.838
	776	1	11	3	449	2	9.9	47.8	23.4	1263.0	296.2	444238	15	1	51.288
	776	1	12	3	449	2	9.9	45.3	22.5	1134.9	290.9	444238	15	1	54.195
	776	1	13	3	449	2	10.0	43.6	21.9	992.3	283.6	444238	15	1	55.732
••• 2 •••	776	1	14	3	449	2	10.0	42.1	21.0	760.1	275.0	444238	15	1	57.332
••• 2 •••	776	1	15	3	449	2	9.9	40.7	20.1	555.0	265.4	444238	15	1	58.157
••• 2 •••	776	1	16	3	449	2	10.0	40.4	18.7	366.4	262.9	444238	15	1	58.830
	777	1	11	1	449	2	10.1	45.1	4.2	296.2	1096.7	4442	15	1	55.794
	777	1	12	1	449	2	10.0	42.6	4.4	290.9	1074.1	4442	15	1	58.878
	777	1	13	1	449	2	10.0	41.6	4.4	283.6	1071.0	4442	15	2	.476
••• 12•••	777	1	14	1	449	2	10.2	41.6	4.5	275.0	1098.1	4402	15	2	2.107
••• 2 •••	777	1	15	1	449	2	10.1	40.7	4.4	265.4	1090.0	4442	15	2	2.935
••• 2 •••	777	1	16	1	449	2	10.2	40.6	4.4	262.9	1100.5	4442	15	2	3.605
	778	1	11	1	450	2	10.1	37.4	16.6	1096.7	63.4	4442	15	2	12.685
	778	1	12	1	450	2	10.2	35.9	17.2	1074.1	72.7	4442	15	2	16.384
	778	1	13	1	450	2	10.0	33.7	17.5	1071.0	71.9	4442	15	2	18.341
	778	1	14	1	450	2	10.2	31.3	18.0	1098.1	72.4	4442	15	2	20.420
	778	1	15	1	450	2	10.0	29.0	18.3	1090.0	72.8	4442	15	2	21.529
	778	1	16	1	450	2	10.1	29.2	18.5	1100.5	74.2	4442	15	2	22.445
••• 3 •••	779	1	11	1	450	2	10.3	36.6	1.2	63.4	2851.9	4342	15	2	14.209
••• 3 •••	779	1	12	1	450	2	10.2	33.1	1.4	72.7	2595.4	4342	15	2	18.149
••• 3 •••	779	1	13	1	450	2	10.4	32.7	1.5	71.9	2569.7	4342	15	2	20.202
••• 3 •••	779	1	14	1	450	2	10.4	28.7	1.6	72.4	2254.6	4342	15	2	22.434
••• 3 •••	779	1	15	1	450	2	10.2	27.2	1.7	72.8	2131.6	4342	15	2	23.653
••• 13•••	779	1	16	1	450	2	10.4	27.5	1.7	74.2	2150.9	4342	15	2	24.645

Table 6–7

Behavioral Items Available for Each Questionnaire Respondent

Item	Item
Subject Identification Number	Subject Vehicle Speeds Measured
Site Number	Followed Distance (Tailway) Trap 1
Card Number	Tailway Reduction Percent Trap 1 to 6
Time Entering Array	Trap Before Maximum Deceleration
Vehicle Sequence Number	Headway Reduction Percent Trap 1 to 6
Vehicle Type	Headway at Trap 1
Is There a Lead Vehicle Before Crossing?	Minimum Time Headway
Lead Vehicle Type	Did Subject Vehicle Stop?
Lead Vehicle Speed at Crossing	Date
Did Subject Look in Advance Area?	Is Subject Under Signal or Train Influence?

Some of the variables included in Table 6-7 were used to refine the driver population. For example, it is known that drivers who are behind vehicles which stop for the crossing (for any reason) are strongly influenced by the lead vehicle's behavior. Figure 6-3, taken from data at all active sites, graphically shows this behavior influence. The special events film shows several cases where a driver stopped for an activated signal and was passed by several less patient drivers before deciding to continue his trip. Therefore, a subset of the driver population being examined for particular characteristics included those drivers who were not being influenced by a signal or train, slow leader, tailgater, or other highly influential outside variable.

Format of the Data on Subjects

The 1,236 subjects remaining after elimination of respondents who made gross errors on the questionnaire and those who had a behavioral data base which could not be recovered constituted the sample on which the conclusions of the next chapter are based. This is felt to be a fair distribution of the population which uses the nine rail-highway grade crossings that were studied. The three passive crossings are represented by 322 subjects. Six active crossings are described by 914 sets of behavioral and questionnaire responses. The four geographically separate crossings have a total of 630 subjects divided into 174 from the Milpitas, California, crossing, 155 from Bryan, Texas, 149 from Holly, Michigan, and 152 subjects from Route 28, Manassas, Virginia.

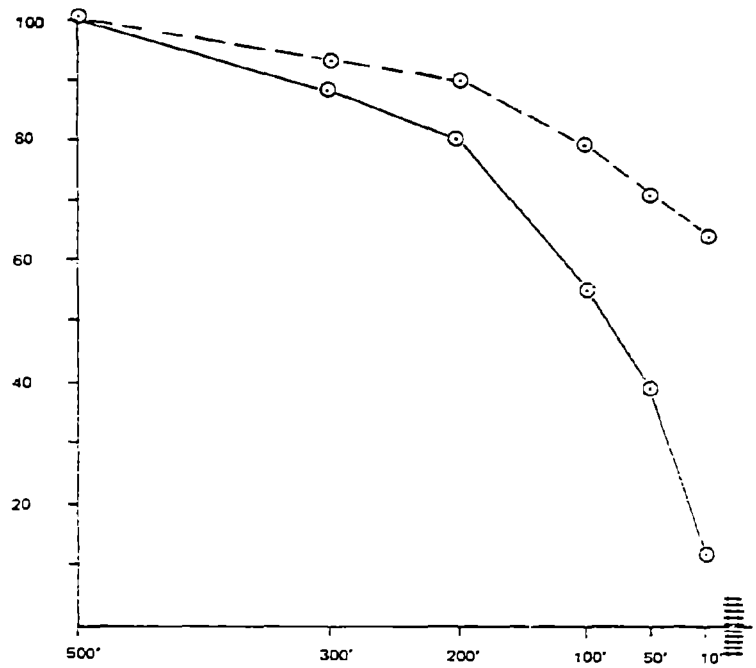


Figure 6–3. Percent of initial headway for vehicles following cars who stop without activated signals (solid), average headway reduction for all vehicles (dashed).

A file was created for each subject containing 176 entries. The definition of each entry is given in Appendix B of this report.

Each location has a characteristic distribution of speeds due to the physical surroundings, speed limit, road width, traffic volume, etc. The distribution of speeds 500 feet in advance of the crossing for passenger cars without vehicles between them and the crossing are shown for the active crossings in the Maryland-Virginia area (Figure 6-4), for the three "local" passive crossings (Figure 6-5), and for the intentionally "matched" set of geographically displaced sites (Figure 6-6). That there are differences among sites is readily apparent, but the striking similarity among the matched set shows that if crossings are selected to have similar physical surroundings, the behavior of the subject population, even though widely separated, may have substantially the same performance characteristics.

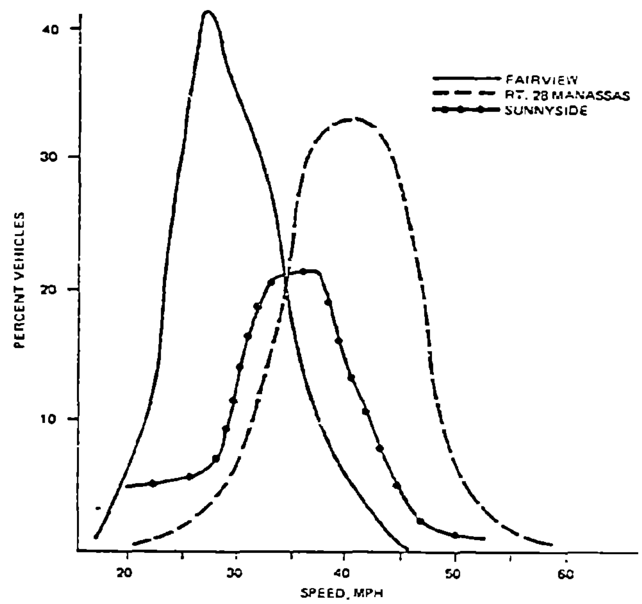


Figure 6-4. Speed distribution for passenger cars, no lead vehicle, local active crossings.

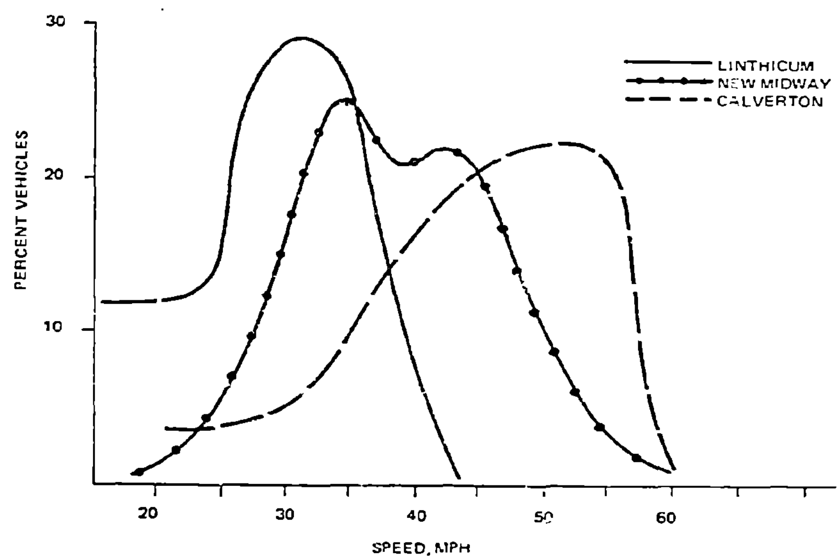


Figure 6–5. Speed distribution of passenger cars, no lead vehicle, passive crossings.

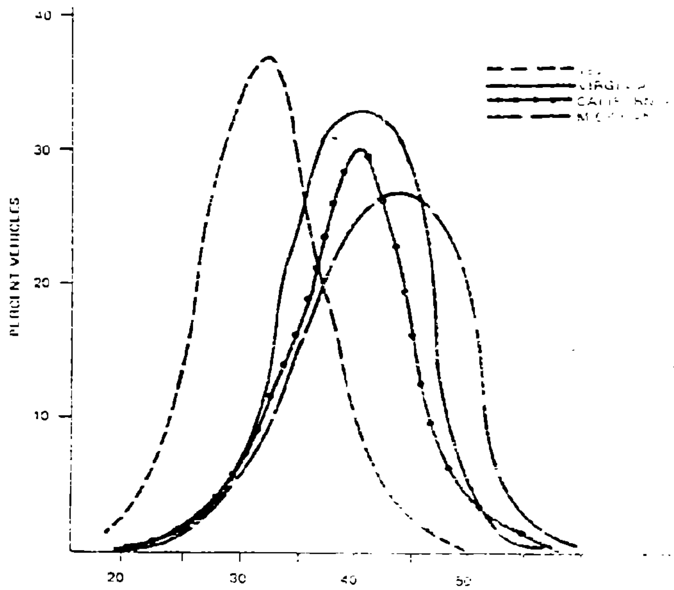


Figure 6–6. Speed distribution of passenger cars, [illegible]

Physical Site Characteristics

To preserve a record of the sites at which data were [illegible] using a surveyor's measuring wheel from the crossing to all prominent landmarks such as buildings, signs, obstructing trees, etc. Photographs were taken [illegible] 100 feet for over 1,500 feet in advance and for a reasonable distance [illegible] crossing. The plan views of each crossing shown in Appendix A were drawn using this information.

The visibility distances available to the driver were made for each site as follows. [illegible] observer was stationed at intervals from 500 feet to ten feet before the crossing at the approximate level and position of a subject driver. A second observer measured along the track from the center of the intersecting street until told to stop by the first observer. Communication was maintained by two-way radio. The stopping point was that at which the measurer could no longer be seen or, when appropriate, when a flag on the [illegible] antenna could not be seen. This flag was used in the case of low brush and extended the visibility measurements to a point some 15 feet above the track level. After measuring a set of maximum visibility points at several locations before the crossing, the measurements were repeated on the other side of the track. Distances in excess of 1,000 feet were estimated. The results are shown in Appendix A.

During a period of signal activation, an observer drove from beyond 2,000 feet toward the crossing noting landmarks at which each of the signal heads became visible. Measurements were then made to these landmarks.

Interactions With Railroad Equipment

Simultaneous Arrivals

As a vehicle approaches the grade crossing along the mean speed profile, there is a point at which he cannot stop his car short of the tracks. If he is not aware of the approach of a train by this point, he has no possibility of avoiding collision unless the train is moving slowly enough that the driver can pass ahead of the train.

The point where stopping distance equals distance to go was calculated for each of the nine crossings studied using Figure 6-7. Only four of these calculations resulted in a distance greater than 50 feet, but two of these four sites had passive protection. All of the sites were selected in part because of restricted sight distance to an approaching train. If a situation is constructed such that an approaching train reaches the available sight distance when the driver reaches his critical point, the train speeds for simultaneous arrival can be calculated. Two train speeds are shown: if the driver does not try to stop, the time to reach the crossing is readily calculated; if he makes a maximum effort to stop, the time to reach the crossing varies but is not less than twice the time calculated above.

If the detection of trains is limited to the driver actually seeing it, and some level of effort is made to stop, the probability of a collision is extremely high for train speeds above the lower speed shown in Table 6-8. Several reasons exist which explain why the accident rate is as low as it was found to be for these crossings. First, the train speeds observed were near the lower figure, typically 10 to 15 mph. Second, the requirement to actually see the train is eliminated at the two signalized crossings. Upon activation of the signal, the speed profile changes dramatically which permits the safe driver to always stop before reaching the tracks. Mean vehicle speeds with and without signal activation are shown in Figure 6-8. Third, the train whistle announces the approach.

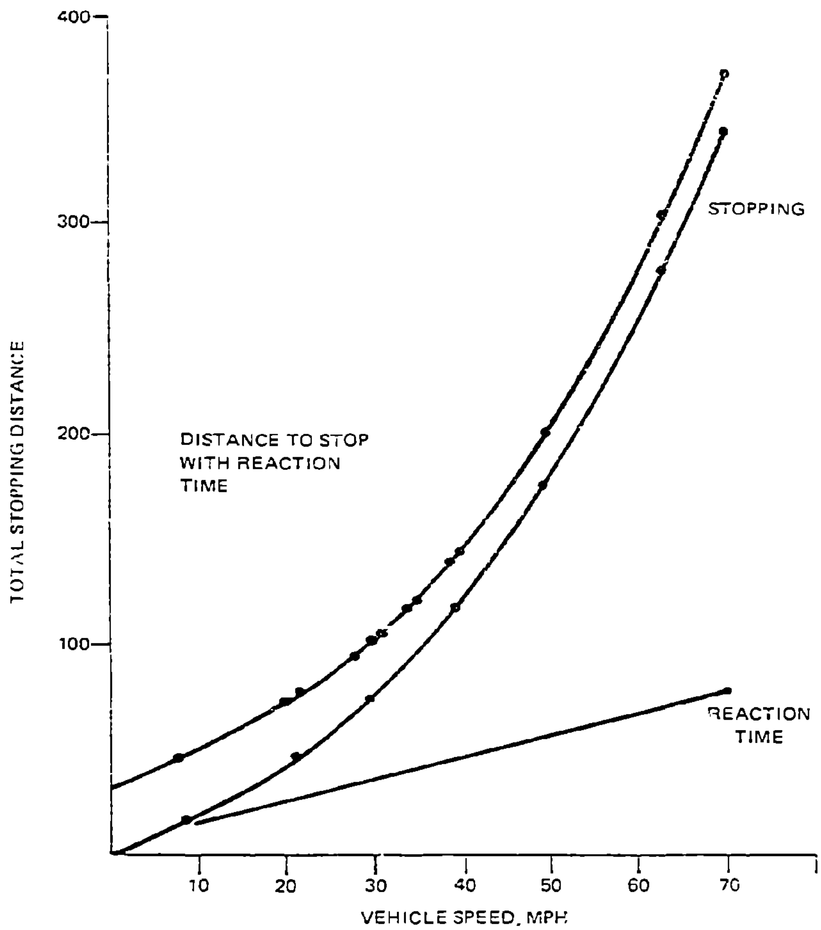


Figure 6–7. Stopping distance, dry pavement with 3/4 second reaction time.
Data – Sportsmanlike Driving

Table 6–8

Critical Train Speeds for Sites With No-Return Distances Greater Than 50 Feet

Site	Critical Point	Measured Sight Distance	Critical Train Speed: Driver Does Not Stop	Critical Train Speed: Driver Tries to Stop
New Midway	80', 28 mph	200'	70 mph	35 mph
Rt. 28 Calverton	75', 30 mph	90'	36 mph	18 mph
Rt. 28 Manassas	80', 31 mph	50'	19 mph	9.5 mph
California	70', 27 mph	90'	35 mph	17.5 mph

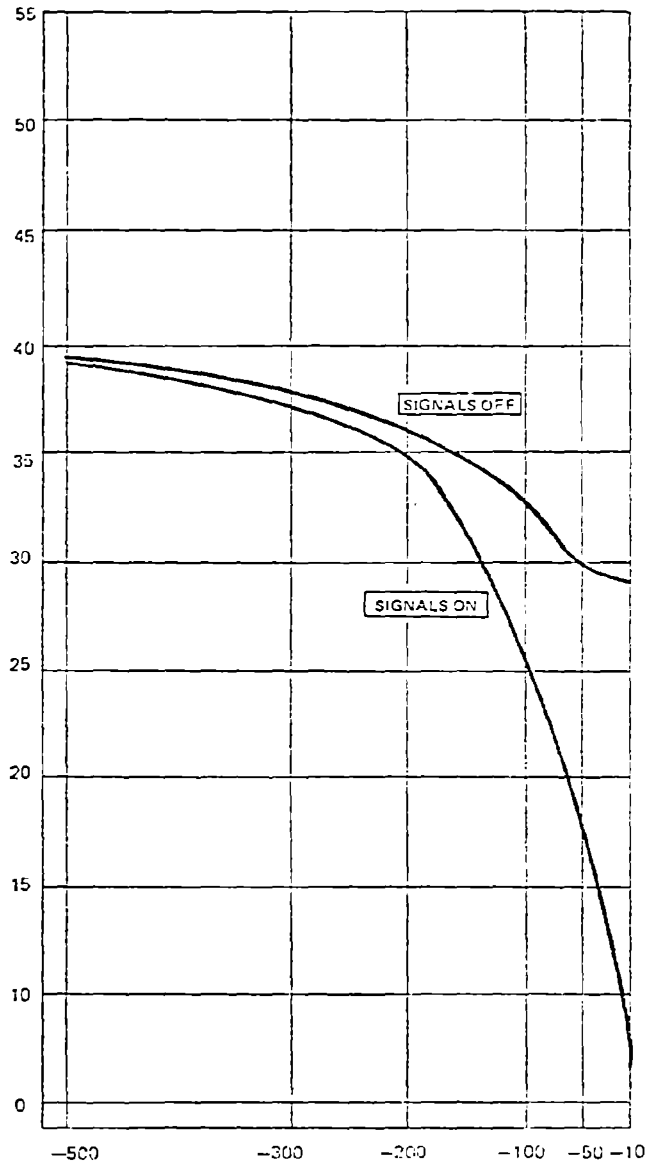


Figure 6-8. Mean speed profiles of vehicles approaching crossings with and without signal activation.

Signal Operations

The flashing signal at the six active crossings studied provided adequate visible warning times in every case observed. At all sites, the signal was activated by track circuits which were operated by the physical presence of a train, and these switch points were located 2,000 to 4,000 feet from the intersection. The activation of the signal was not always initiated when the train reached a particular point, in fact, variations of over 1,000 feet were observed. At Sunnyside Avenue, the train to crossing distances ranged from 1,498 feet to 3,665 feet. The detector was located at 2,640 feet for all four approaches (two tracks). This caused the warning times to vary considerably for trains going the same speed in addition to the variation due to the speed itself. Figure 6-9 shows selected warning times for various train speeds observed. Not shown are times greater than one and one-half minutes, such as the 11-minute, 49-second period caused by a crew train which stopped near a crossing.

Eight times during the study, signals were activated for no apparent reason, or by trains that failed to approach the crossing. These periods ranged from 15 seconds to over three and one-half minutes.

Signal Visibility. The alignment of the signal heads and the focusing of the lamps was noted for all active crossings. In general, they were found to be reasonably oriented. Measurements of signal intensity were not made, but the zones of visibility along the approach were noted. Figure 6-10 shows the data which were obtained.

The maintenance and inspection of the signals varied. The signals at the Michigan site were cleaned and inspected daily. The operation of the signals at the California sites was verified semi-monthly. At the remaining sites, no particular schedule was set, but a signal maintainer made his rounds to all the crossings assigned to him and this generally resulted in one or two visits per month, depending on the level of other work required of him. During data collection, we observed what must be the two extremes of maintenance. At the Michigan site, in less than five minutes, the maintainer manually activated the signals, visually verified the operation of all eight lamps and both bells, checked battery condition and other items in the signal control box, and then cleaned each lens. He stated that this was the routine *daily* procedure. At the California site, the maintainer, in less than one minute, opened the signal control box, manually tripped a relay, heard the bell strike one time, closed the box, and left. He said he never cleaned the signal heads since they get dirty again so quickly. The results of the maintenance programs produced signals which varied considerably in intensity, but none was considered to be less than adequate.

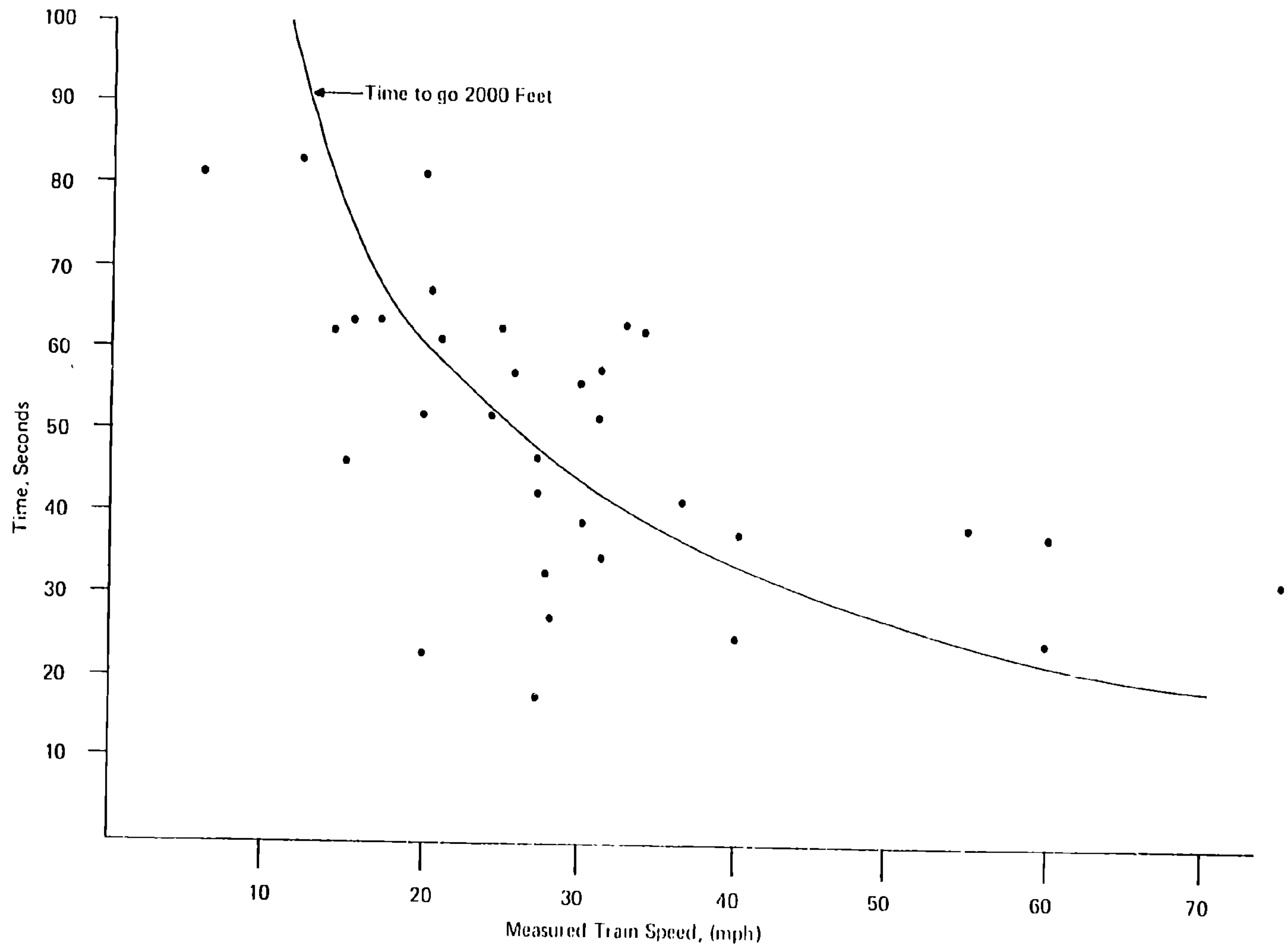
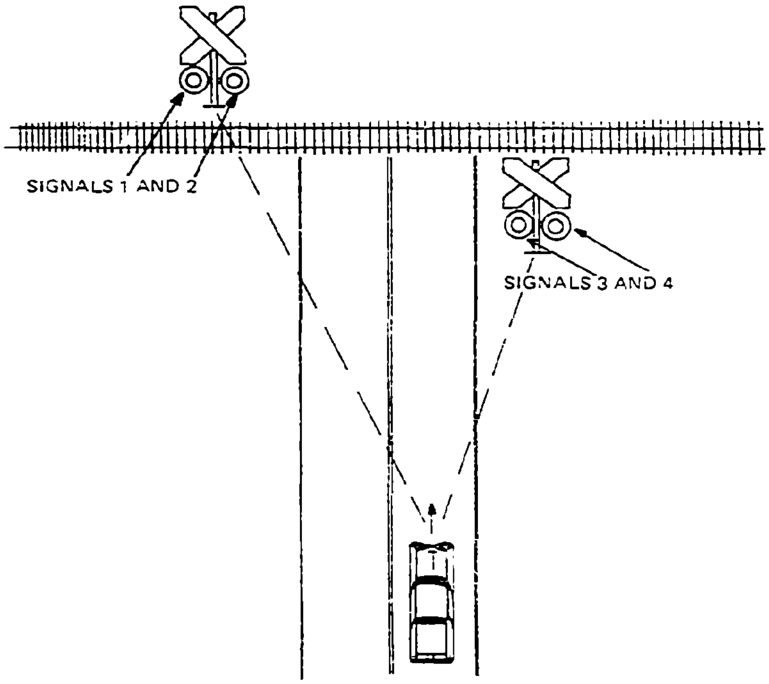


Figure 6–9. Warning time from signal activation to train arrival at all active crossings.



Initial Visibility of Signals During Approach

	Sign 1	Sign 2	Sign 3	Sign 4
Sunnyside Ave.	1540'	1540'	347'	311'
Fairview Ave.	1000+	1000+	180	350*
Va. Rt. 28	292	304	424	432
Grange Hall Rd., Mich.	2000	2000	2000	2000
Carson Ave., Texas	279	180	1200*	1200*
Central Ave., Calif.	1000	1000	300	1000

*Not visible within 190'.

Figure 6–10. Initial visibility of signals during approach.

A variety of aiming schemes were noted, as may be seen from the visibility chart, Figure 6-11. The two most unusual were Fairview Avenue, where the signal could not be seen by a motorist when he reached the "normal" stopping point, and at the Bryan, Texas, site which had two additional lamps aimed at the exit lane of the adjacent baseball park, but none were visible in the exit lane from the industrial parking lot which carried continual traffic.

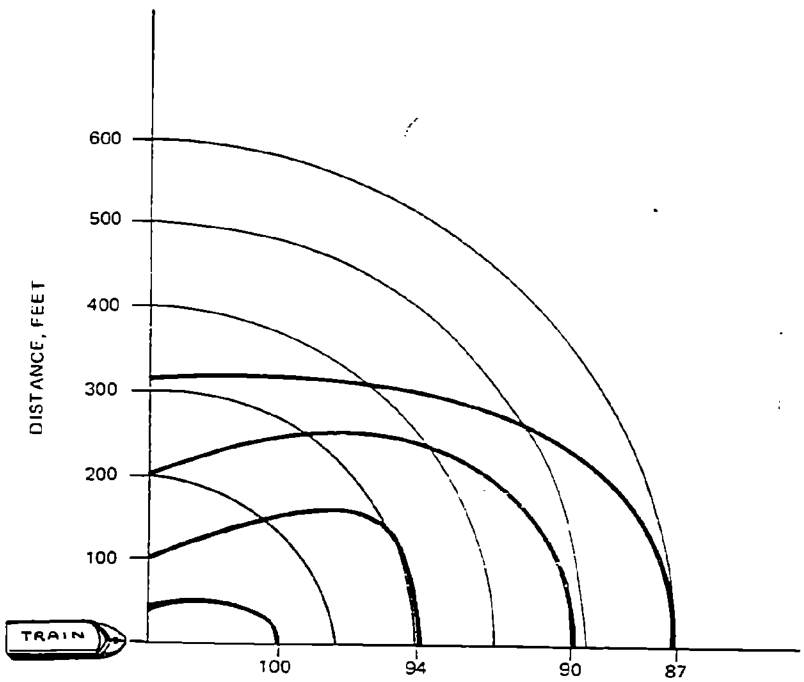


Figure 6-11. Typical sound level for locomotive whistles.

Whistle Operation. Another method by which the driver becomes aware of a train is by hearing the whistle. A previous study[1] found that a sound level of 87 dB was required for a typical driver to hear it. A plot of mean sound level intensity is presented in Figure 6-11 showing that for a 90° crossing angle, a car should be within 300 feet of the intersection to hear a train 400 feet away. This data is for late model cars with the windows closed, radio

[1] Aurelius, J.P. & Korobow, N. The visibility and audibility of trains approaching rail-highway grade crossings. Prepared by Systems Consultants, Inc., for Federal Highway Administration, Washington, D.C., May 1971.

playing softly, no conversation. It was observed that the train whistle was sounded more or less constantly when the train was within 500 feet of the intersection. The initial whistle time was recorded for each train. Figure 6-12 shows the audible warning time plotted by train speed. Note that the points are not consistent, indicating that the engineer did not always commence whistle signals at the "W" sign along the track.

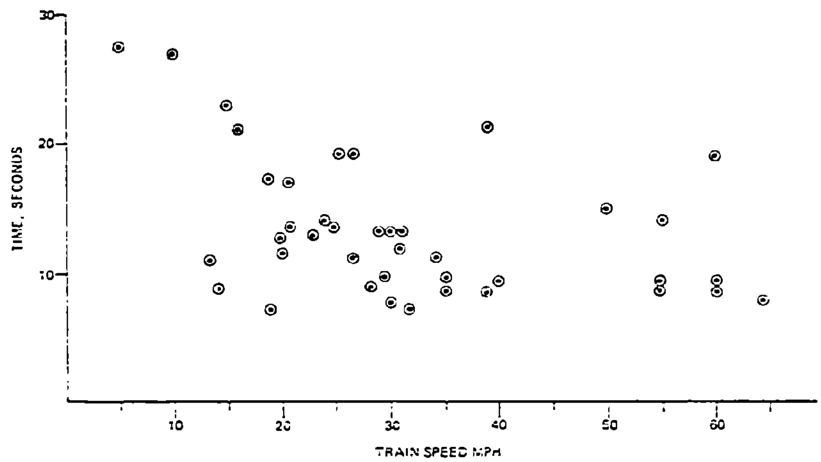


Figure 6–12. Audible warning time versus train speed.

Other Relationships

Estimates of the Number Killed in Grade Crossing Accidents and Frequency of Seeing Trains

A correlational analysis was done on the scaled mean frequency of respondent estimates of the number of motorists killed in grade crossing accidents and the number of times they estimated they actually saw trains at grade crossings. The correlation coefficient on these estimates across sites was 0.80. This suggests that the more often motorists actually see trains, the more fatalities they think result from grade crossing accidents. Unfortunately, however, estimates of the number killed did not correlate with the two measures of safety-oriented behavior (speed decrease and looking behavior). This might suggest that public campaigns should emphasize say, television pictures of trains moving through crossings rather than emphasizing accident statistics (and an increase in seeing trains at crossings did tend to be related to speed decreases [0.64] and looking [0.55]).

Measured Speed Across Track and Estimated Speed

The accuracy with which a driver can estimate his speed as he crosses the tracks is an interesting issue with safety implications. Correlations of individual estimates and measured estimates of speed across the track are shown in the last column of Table 6-9. Measured speed and the mean driver estimates of speed across the track at each of the nine sites can be compared. These values are also shown in Table 6-9 (in the fourth and fifth columns of that table). The correlation coefficient is .90 and the relationship is diagramed in Figure 6-13. Of particular interest is the fact that the mean estimated speed across the tracks at all tracks was less than the mean measured speed. The average underestimation ranged from three to 12 miles per hour with, not surprisingly, some suggestion that greater underestimates are associated with higher actual measured speeds. On the average, motorists were found to underestimate their speed by approximately 30 percent!

Table 6–9

Mean Measured Speeds at Trap VI (10 feet prior to the crossing) and Mean Drivers' Estimates of Speed When Crossing the Track

Crossing	Active Passive	No of Trains Observed	Mean Speed at Trap 6	Estimated Speed Across Track From Questionnaire							Mean Estimated Speed Across Track	Correlation Actual vs. Estimated Speed
				0-5	5-10	10-20	20-30	30-40	40-50	>50		
Linthicum	P	0	24	13	23	40	23	2	0	0	13.35	.391
New Midway	P	2	28	2	17	23	40	15	4	0	21.00	.392
Calverton	P	0	26	14	22	23	19	16	5	1	17.00	.659
Sunnyside	A	19	12	42	35	18	3	3	0	0	7.05	.393
Fairview Avenue	A	19	13	49	29	19	3	0	0	0	10.10	.231
Rt. 28, Manassas	A	4	29	9	17	31	28	12	0	1	17.10	.292
Michigan	A	6	30	30	10	18	33	29	0	0	20.80	.316
Texas	A	5	22	11	21	33	29	4	0	0	16.90	.425
California	A	2	24	5	15	31	33	14	0	0	18.70	.256

Underestimates of actual speed potentially denote a safer condition of the driver intends to beat the train to the crossing. However, they suggest a more hazardous condition if a train is approaching and the driver makes a last minute decision to stop. Analysis by individual respondent of measured and estimated speed in relation to other variables such as risk-taking, the frequency with which the motorist actually encounters trains at grade crossings, etc. is discussed in Chapter 7.

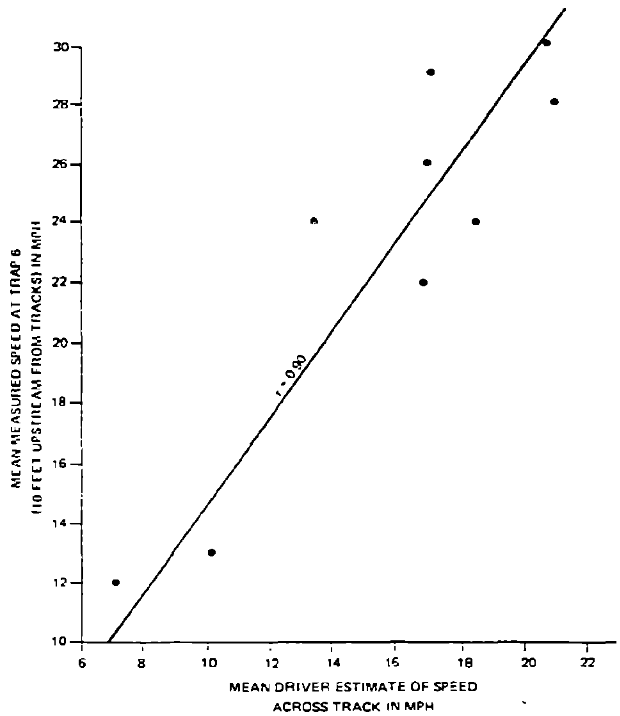


Figure 6–13. Relationship between mean measured speed at Trap VI (10 feet upstream from the track) and mean driver estimates of speed when crossing the track.

Observation of Traffic Control Devices

Figure 6-14 shows the percent of drivers at each site who indicate that they saw pavement markings on their approach to the grade crossing (□) and the percent who selected the correct pavement marking (T). It will be noted that at four of the sites (Sunnyside, Fairview Avenue, Michigan, and Texas), there actually were no pavement markings on the approach. However, at least 20 percent of the respondents at each of these sites indicated that they saw markings. At sites where pavement markings actually existed, the proportions who reported seeing them range from about 15 percent to 45 percent or from *lower* to *higher* proportions than reported seeing the markings when they actually weren't present. This may suggest that even at those sites where markings were present, very few really saw them. Support for this hypothesis lies in the fact that about half selected the correct marking whether the marking was present or not. That is, exposure to the marking does not appear to have significantly increased the accuracy of the drivers in picking it out of several alternatives. The above suggests that for pavement markings at least, the attentional demand of this countermeasure could be considerably increased.

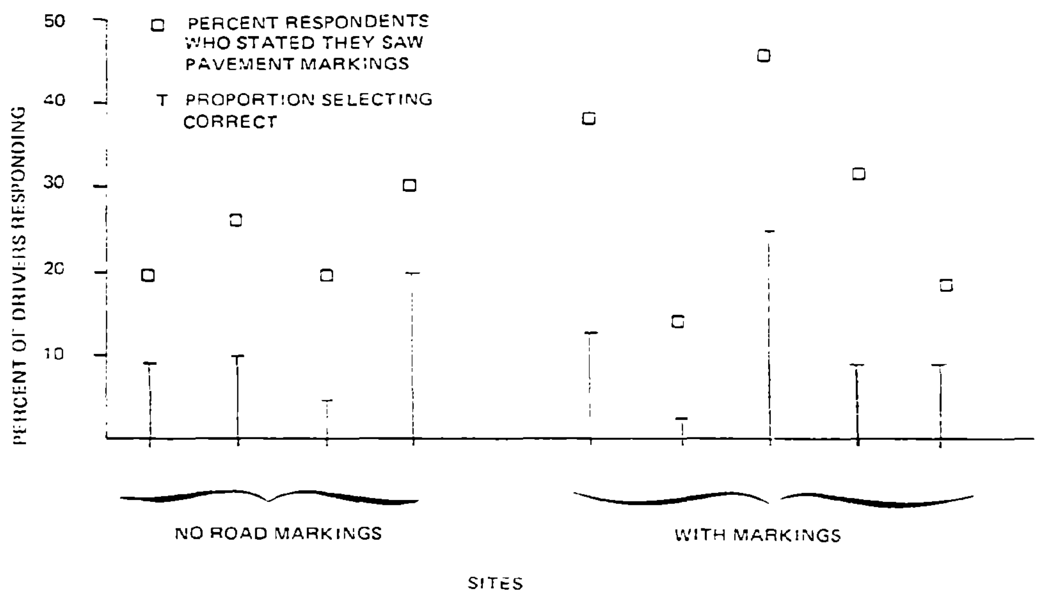


Figure 6-11. Driver observation of pavement markings at nine sites.

CHAPTER 7

DATA ANALYSIS

Philosophy of Analysis

The analysis of Phase II data was guided by the following study objectives:

1. To better understand the driver population and the behaviors they display at grade crossings.
2. To define a set of "safety oriented" behavioral measures that are both operationally meaningful and capable of reliable experimental measurement.
3. To isolate a set of driver characteristics that can serve as non-redundant predictors of driving performance.
4. To determine the extent to which the above behavioral and/or predictor variables can be used to develop and evaluate railway-highway countermeasures.
5. To suggest the most cost-effective set of measures applicable to countermeasures design and evaluation.

Status

Considerable effort was expended on editing and verifying the data base as explained in detail in Chapter 6. An extensive review of the corrected data during this project was undertaken. The data which were used in the final analysis consisted of the following sets.

- Distributions of responses to questionnaire and behavior items. For each measure the count and percent of the various responses were obtained, both for individual sites and groups of sites (e.g., active, passive, all).
- A correlation matrix (18 by 18) which compared constructed variables both from the questionnaire and behavior set. The eighteen parameters are described in Appendix B.
- A correlation set of the 176 elements (see Appendix B) versus the basic five behavior measures, frequency of seeing trains, estimated delay, legal requirement, age, and crossing familiarity.
- High and low safety Index quartile comparisons for all measures. This analysis ranked the drivers at each site by safety of behavior and performed statistical comparisons between the fourth of the subjects having the most safe behavior with the least safe quartile for each of the 176 parameters.

- Each of the above was available for each location at which data were obtained as well as for groups of sites. Examples of groupings which were examined were:
  - all vehicles
  - passenger cars
  - drivers with and without the influence of a train or signal
  - vehicles who did and did not have a lead vehicle nearby.

The most representative group, and that which was used, where appropriate, for the analysis which follows, was the set of drivers who did not have a lead vehicle within 500 feet, and who were not exposed to the influence of a signal or train. The following are presented in Appendices to this report:

- Physical data for the sites and driver behavior profile data (Appendix A).
- Definitions of the data base used and available for further study (Appendix B).

Performance Measures

The four performance measures which were used in the analysis were:

1. whether or not the driver looked for trains;
2. change in speed over the last 500 feet before the crossing;
3. the point of maximal speed change; and
4. the distance at which the stopping capability of the vehicle equals the distance to the crossing.

A driver with a high safety orientation is one who (1) looks for trains, (2) shows a speed decrease between 500 feet and the crossing which is greater than the mean speed decrease for his entry speed for all vehicles at the site, (3) shows a maximum deceleration in a zone further away from the tracks than the mean zone for all drivers, and (4) who maintains a speed such that he can always make a safe stop short of the crossing until he has eliminated the possibility of a train conflict.

Looking Behavior

Driver looking behavior was observed at both advance- and near-track locations as described earlier in this report. For the purposes of the analysis of the data, looking in either or both zones was counted as "looking." The Pearson Product-Moment correlations between looking in near and far zones and looking in either or both zones is shown in Table 7-1.

Table 7–1

Correlations of Looking With Looking in Two Zones

Site	Correlation Coefficient	
	Advance	Near
Sunnyside	.400	.786
Linthicum	.378	1.000
New Midway	.810	.640
Calverton	.653	.703
Route 26	.530	.910
Fairview	.169	.972
Michigan	.848	.518
Texas	.860	.515
California	.860	.698

All of the correlations in Table 7-1 are significant at the .01 confidence level except advance looking at Fairview. This site was the most restricted of the crossings studied as may be seen in the site diagram contained in Appendix A. Drivers were not observed to look in the advance zone at this crossing since there was no capability to see a hazard until the near zone.

Speed Reduction

The percent drop in speed over the instrumented approach to the crossing was defined as:

$$\frac{(\text{Speed at -500 feet})-(\text{Speed at -10 feet})}{\text{Speed at -500 feet}}$$

Due to the stability of the approach speed at individual crossings, the percent speed decrease is highly correlated with the speeds at the crossing. That is, a driver who reached the crossing at a low speed had a large speed decrease, and vice versa.

Table 7-2 indicates the relationship between speed decrease and the final speed measured ten feet before the crossing. All are significant at the .01 level.

Table 7–2

Correlation of Percent Speed Reduction With Final Speed

Site	Correlation
Sunnyside	−.951
Linthicum	−.458
New Midway	−.665
Calverton	−.949
Route 28	−.879
Fairview	−.753
Michigan	−.778
Texas	−.395
California	−.772

Zone of Maximum Deceleration

Speed data was obtained at six points along the approach to the crossing as described earlier. These defined five segments which were selected to require approximately equal transit time as the driver slowed for the crossing. The mean deceleration for each segment was calculated as:

$$\text{Deceleration} = \frac{\text{Speed change per segment}}{\text{Time to travel segment}}$$

The maximum of the five decelerations was noted, and the zone from 1 to 5 in which the maximum occured was used as an indicator of the behavior of the driver.

The magnitude of the maximum deceleration correlates highly with the percent speed reduction (over 0.6 in all cases). This relationship indicates that the population tends to brake for short periods during the approach such that the measured maximum deceleration resulted in the major proportion of the total speed decrease rather than making a smaller braking effort for a longer period of time. The mean deceleration figures in each zone for several entry speed states at the sites were examined. The point of maximum deceleration was generally found to be at 45 feet from the crossing. This proximity to the crossing indicates a population which waits as long as possible before slowing to the speed at which they desire to cross the tracks. This characteristic was also noted in the preliminary investigations made to determine how far from the crossing the first speed measurement should be made. It was found that virtually no speed change would occur beyond 500 feet.

Critical Distance

The determination of the point at which a driver cannot stop before reaching the crossing has been described earlier in this report. As would be expected, there is a high correlation between critical distance and the speed at the crossing (in all cases over 0.92).

A very large proportion of the drivers approached the crossings at speeds in excess of that which would permit a stop before the crossing. The stopping distance frequently exceeded the zone within which they could profitably look for trains. Table 7-3 shows the proportions observed. At all crossings a driver had to be within 100 feet to see at least 300 feet down the track in both directions. Measured sight distance at 100 feet is shown below.

Table 7–3
Summary of Drivers Who Exceed Stopping Distances
(No leader, no train influence subjects)

Site	N	Over 50'	Over 100'	Over 150'	Sight Distance*
Sunnyside	92	15%	1%	0%	230'
Linthicum	36	75%	8%	0%	180'
New Midway	89	77%	19%	3%	90'
Calverton	110	66%	44%	24%	75'
Route 28	106	89%	47%	7%	45'
Fairview	78	5%	0%	0%	90'
Michigan	101	94%	46%	9%	180'
Texas	90	70%	2%	0%	300'
California	81	94%	20%	1%	40'

*Distance a driver at 100' can see approaching train in the most restricted direction.

The mean number of drivers exceeding 100 feet for active crossings was 21 percent. For passive crossings, the mean was 29 percent. Such behavior is clearly more dangerous at passive crossings because no train detection assistance is provided. Yet, the proportion of drivers exhibiting such behavior was greater for the passive set of crossings.

The Behavior Index of Safety

The four measures above were combined to develop a single safety index which could be used to differentiate the behavior of the drivers. Since the relative magnitudes of the measures were very different, it was necessary to normalize each before making a single combined measure.

Examination of the measures obtained showed that the characteristics were definitely site-specific. Since there were major differences in the measures for sites in the *same* geographic area, no rationale could be made that regional differences caused the changes. The mean value within each site for each measure was subtracted from the measure to scale it to a mean of zero, and then divided by the site standard deviation of the measure to normalize the value. The resulting values were then combined with a weight of 1.0 for each, signed according to the direction of change required for more safe behavior. The resulting index therefore was:

Safety Index = looking + speed reduction – maximum deceleration point – critical distance

As was noted earlier, the behavior of the driver was clearly influenced by a proximate lead vehicle and obviously modified by the presence of a signal or train. Therefore, investigations based on behavior compared with other factors were performed using the subset of the total population referred to as leaderless, trainless vehicles.

The safety index thus compiled was distributed as shown in Figure 7-1. Since two of the variables (looking and point of maximum deceleration) were not continuous, several minor peaks appear in the distribution.

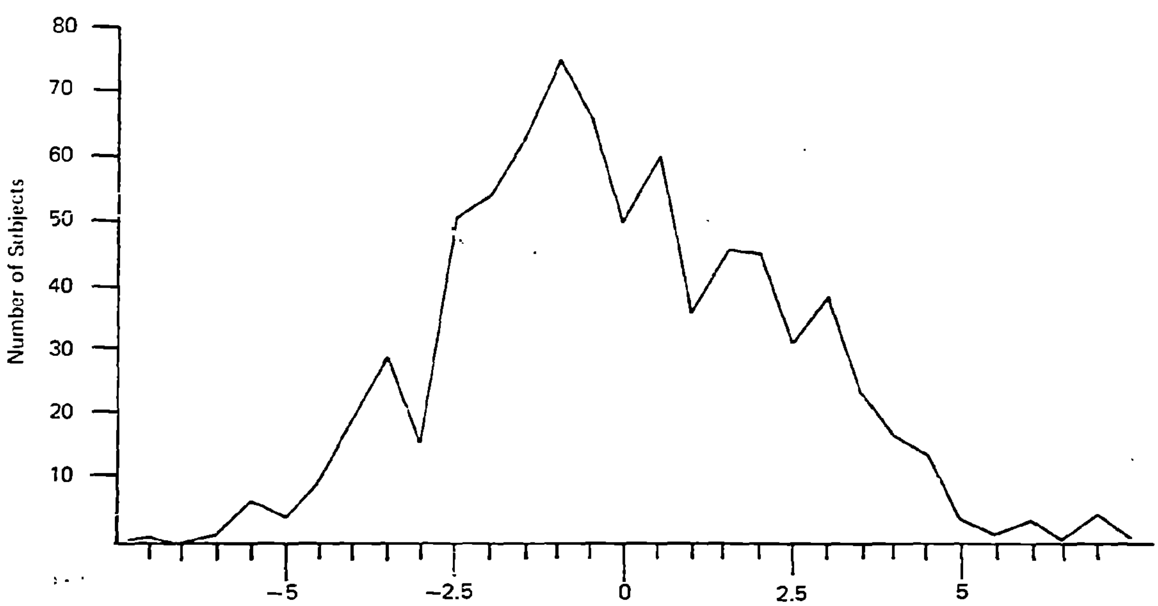


Figure 7–1. Distribution of the calculated safety index.

Relationships between Index Measures

The contribution of each variable to the safety index was examined. Table 7-4 shows the correlation of each measure with the others and the index. The extent to which a part correlates with the whole is more or less dependent on the fact that the whole contains the part. To determine the actual contribution, a part-whole correlation is shown in the last column. This calculation is essentially the correlation of each measure with the index composed of the other three measures.

Table 7–4

Correlation Matrix of Safety Index Components and the Index With and Without the Contribution of Each Measure

	L	R	P	C	SI	PW
L	1.000	.244	– .067	– .283	.622	.284
R		1.000	– .022	– .602	.729	.444
P			1.000	.065	– .450	.067
C				1.000	– .761	.496
Mean	.377	.316	4.086	73.034	0	
S.D.	.485	.315	.847	44.958	2.561	

KEY

L	Looking Behavior
R	Percent Speed Reduction
P	Point of Maximum Deceleration
C	Critical Stopping Distance
SI	Safety Index
PW	Part-whole Correlation

The part-whole correlation matrix shown in Table 7-4 is representative of the matrix for each site. Therefore only the combined figures are shown. It should be noted that the means and standard deviations in Table 7-4 for each of the measures are for the measure before it was normalized. The normalized mean of each is zero. The standard deviations of each equal one.

The point of maximum deceleration is clearly not related to the index composed of the other measures. If this element was an independent predictor of some other pertinent factor, the safety index would be strengthened by its inclusion. This was not found to be the case. however. Since both the critical distance and the point of maximum deceleration are highly related to the speed decrease and the speed at the crossing, an alternate index composed of looking behavior and the speed at the crossing was examined. No significant change in the relative ranking of behavior differences resulted.

Countermeasures Implications. The contribution of a countermeasure to grade crossing safety may be determined by a site-specific before/after study using. as a minimum, vehicle speed at the crossing and looking behavior as measures. The physical requirements for site selection pointed out earlier must be met. For example. speed reduction in advance of a rail-highway intersection which had unlimited visibility in both quadrants would obviously be detrimental to the safe and appropriate flow of traffic. The site characteristic which is most important to the validity of the measures developed by this study is restricted sight distance to oncoming trains.

Where the safety index is referenced in this report. the complete index containing all four elements was used.

Situational Variables

In addition to dependent and independent variables. there are a number of variables which may be classed as situational or intermediate. These variables may be treated as independent in bivariate analyses. At higher levels of analysis. they may be expected to modify the relationships between the performance measures already defined and the questionnaire items which are discussed below.

Variables classified as situational include the following:

- weather
- road conditions
- time of day
- active/passive crossing
- urban/sub-urban/rural crossing
- geographic location of the crossing
- frequency and schedule of trains at the crossing
- position of a vehicle approaching the crossing in relation to other vehicles
- roughness of the crossing
- sight distance to the crossing

- left-right distance at 50 feet, 100 feet, etc. from the crossing
- number of tracks at the crossing

Because this project was a pilot study, the data base was limited and insufficient to evaluate the effects of weather, road conditions, and time of day. Analyses were undertaken, however, in regard to the remaining variables and the performance measures previously defined. These are discussed below.

Active versus Passive Crossing Behavior

Introduction. It was hypothesized that driver behavior at active crossings would differ from that at passive crossings when no train was present or imminent. The direction of the differences would indicate more safety-oriented behavior at passive crossings.

The underlying assumption was that drivers will have perceived the existence of the signal at an active crossing and have some belief in its reliability. Thus, if the signal is not activated, the driver will approach the crossing with some degree of expectation that a train is not coming. The same cannot be said of passive crossings since identification of the approach of a train rests solely with the driver.

Unfortunately, there are confounding factors in the sites included in the study such as the high level of familiarity of the majority of the drivers with the crossings.

Discussion. The differences among the three passive crossings were substantial and, in fact, exceeded the difference in mean values of measures between all active and all passive crossings. The behavior measures showed a tendency toward increased looking behavior and earlier speed reduction at the passive crossings, but there was also a trend toward smaller speed decrease and greater critical distances at the passives. Figure 7-2 shows the mean speed profiles for active, passive, matched, and all crossings, for the two quartiles of the no leader, no train influence population having the highest and lowest safety index. Note that the graph is bounded by the passive set illustrating the greater difference in measured speed between safe and unsafe drivers for that category of crossing protection.

Examining the safe and unsafe quartiles of drivers at active and passive crossings some significant differences were noted. These were:

	Safe Quartile	Unsafe Quartile
Looking	t = 3.2 – P	N.S.
Speed Reduction	N.S.	t = 2.7 – A
Point Max. Decel.	N.S.	t = 3.6 – P
Critical Distance	N.S.	t = 4.9 – A
Safety Index	N.S.	N.S.

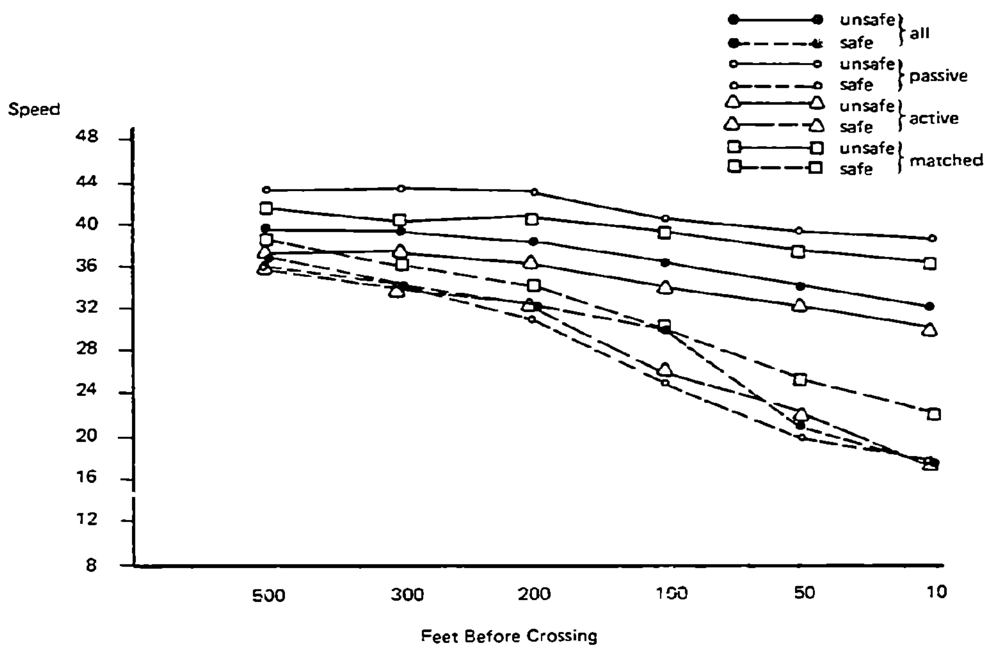


Figure 7–2. Speed profiles of drivers for four sets of crossings divided by the most safe and least safe index quartile.

The t - test values are shown in the list above for significant differences at the .05 level or greater. N.S. is entered where the difference does not reach the .05 level of significance. The crossing category showing more safe behavior is indicated as "A" or "P". Thus, for the safe one-fourth of the drivers at passive crossings, more looking behavior was noted. The least safe drivers showed a greater speed reduction percentage and had smaller critical distances, but decelerated later at active crossings. The result of the mixed behavior was to equalize the index of safety for corresponding quartiles at active and passive crossings.

The drivers sampled in this study believed that passive crossings are characterized by few trains (65 percent) but the majority believed that the speeds of these trains could be high. Only 39 percent believed trains operated at slow speeds over passive crossings. Nearly 21 percent of the drivers stated that all crossings had a train-activated signal or gate. A significant (.01) negative correlation (-.164) was found between how frequently the driver used the crossing at which data was collected and the statement that all crossings were active. We believe that drivers who had little or no experience with crossings were not aware of the distinction between the two crossing categories.

Countermeasures Implications. Realizing that the detection and avoidance of trains at passive crossings rests solely with the driver is the first step in the process of achieving a safe trip involving rail-highway intersections. There is evidence that the similarity of protection (advance signs, pavement markings, crossbucks) produces similar behavior in the two crossing situations. The driver should be able to identify a passive crossing as he approaches, and should be made aware of his responsibility at both categories.

Train Volume and Sight Distance

Introduction. Two hypotheses were formulated regarding the behavior of the population in response to actual hazard. These were:

- The greater frequency of trains at the project sites, the more driver behavior will be safety oriented (defined in terms of the performance measures described previously).
- The more limited the sight distance to the tracks, the more safety oriented will be driver performance.

Discussion. Correlations were examined for the above hypotheses. It was found that a significant correlation (r = .657) exists between looking behavior and the frequency of trains (trains per day). This result is attributed to the high familiarity of the respondent population with the study sites since there is no physical indication of the train volume at the crossings other than the active/passive category. Since the respondents indicated a belief that passive crossings had low train volumes, the correlation might be expected to be greater at active crossings if there were no other factors. The correlation between looking and train frequency for active crossings was 0.938.

The population was also observed to slow down in proportion to the train volume. The speed at the crossing correlated -.854 with train frequency. The other measures of performance also correlated with train volume.

Limited sight distance to oncoming trains was thought to be a factor which would influence safety behavior, but this was not supported by the data. Rather low correlations for looking behavior (r = 0.063) and speed measures with sight distance were found.

Countermeasures Implications. Since limited visibility to oncoming trains has been cited as a major contributing factor in accidents, a need exists to increase the looking behavior and reduce speeds appropriate to the capability of detecting trains. This is even more important at passive crossings, of course.

The strong relationships between safe behavior and train volumes implies that the expectancy of a hazard is a major factor in behavior modification. This is supported by the finding that there is a significant negative correlation between speed within 100 feet of crossings and the reported frequency of seeing trains. That is, the greater the speeds within 100 feet, the less frequently the driver saw trains.

Regional Differences

Introduction. Preliminary analysis indicated that no questionnaire differences would be found at the geographically matched sites but there would be behavioral (driver performance) differences.

Discussion. The statistical data compiled on each of the four crossings: Manassas, Virginia (Route 28), Bryan, Texas (Carson Avenue), Holly, Michigan (Grange Hall Road), and Milpitas, California (Central Avenue), for both the questionnaire responses and the behavioral measures, were examined by computer to detect significant deviations from the set. This examination included the eighteen variables derived from multiple items delineated in Appendix B of this report. In summary, only two measures were found to be pertinent: the mean age and the looking behavior.

The proportions of drivers looking at Michigan and Texas were 0.31 and 0.40, respectively. Route 28 near Manassas, Virginia, had a mean of 0.15 and the California site had a mean of only 0.05. (That is, at California, only five percent of the drivers were observed to look for trains.) Both of the latter crossings have very limited site distance in at least one quadrant: so limited, in fact, that a full stop would have been required to detect trains. If only one crossing had shown this low frequency of looking, a regional difference might be supposed. The Manassas site had much lower near-looking behavior than other, nearby crossings which had the same base of drivers. It was concluded that the driver is willing to accept the protection afforded by the signal and not look for trains when sight distance is limited to the extent that unusual behavior (e.g., stopping on a medium speed route) would be required. This anomaly is, therefore, believed to be a characteristic of the sites, not the region.

The deviation noted on the response to item 127 (see Appendix B) regarding age likewise is probably a characteristic of the site itself. The response to this question ranged from 2.45 (Texas) to 4.36 (Michigan). The California mean (3.31) and the Virginia mean (3.77) were not different from the local sites studied. Texas A & M is located at Bryan, Texas, and the evidence of a nearby student population is taken as the explanation for the low mean age. A retirement community of moble homes was located on Grange Hall Road in Holly, Michigan, contributing to the higher mean at that site.

The analysis showed a significant relationship between driver's age and the correct response to several items. These included the proportion of drunk drivers causing accidents, and the legal requirements for driver's behavior at grade crossings. This relationship confounded the examination of regional differences: the Michigan sample had significantly safer behavior measures for the respondents getting correct answers to legal knowledge, and a tendency to perform more safely when knowing the contribution of drunk drivers (did not reach significance).

Countermeasures Implications. Although no regional differences were demonstrated during this study, we are unwilling to state, on the basis of a brief sample of behavior across four rail-highway intersections, that there are no geographic characteristics which must be considered. In fact, there did exist implied differences that were not a part of this study such as the high proportion of Spanish-speaking drivers in Texas, the greatly increased use of air-conditioners in the summer in southern states, and the significant differences in the age of the cars in Texas and in Michigan (near Detroit). Enforcement of stipulated grade crossing be-behavior was shown to be an effective means of increasing behavioral safety as defined here. Several states have stop signs at most passive crossings but there is little enforcement of the requirement to stop: stopping behavior at passive crossings in these states does not appear to be particularly more prevalent than in other states. It must be concluded, therefore, that innovations in grade crossing protection must be examined in sufficient detail with regard to the probable response of motorists in the various states considering the characteristics of the region.

Questionnaire Items

The items included in the questionnaire were classified into ten categories:

- legal knowledge and enforcement
- knowledge of railway-highway safety
- perception and identification of grade crossing devices
- risk-taking
- familiarity with the crossing
- experiential characteristics
- demographic characteristics
- perception of grade crossing accident causation
- stated basis of actual behavior
- stated behavior

The discussion which follows is organized by category. A brief introduction, the phrasing of the items included, hypotheses tested, and countermeasures implications are provided for each category. Table 7-5 summarizes the items classified in each of the ten basic categories. Items refer to specific questionnaire section and element number (see also the form of the questionnaire, Chapter 5). To investigate the hypotheses presented below, several different types of analysis were used, as outlined in the introduction to this Chapter.

Table 7–5

Categories of Independent Variables and Items Included in Each Category

Legal Enforcement	Knowledge	Device Perception/ Identification	Risk-Taking	Familiarity	Experiential Characteristics	Demographic Characteristics	Perception of Accident Causation	Stated Basis of Behavior	Stated Behavior
III-1	III-8	II-1*	II-8**	II-1*	III-2	V-1	III-4	I-1*	I-1*
IV-6	III-10	II-2	IV-4*	II-3*	III-3	V-2	III-5	II-8**	I-2
	IV-1	II-3*	VI-Seat	II-8**	III-11	V-4	III-6	IV-6	I-3
		II-4	Belt Use	V-6	III-12	V-5	III-7		I-4
		II-5		V-8	IV-2	VI - Sex	III-9		I-5
				V-9	IV-3				I-6
					IV-4*				
					IV-5				
					V-3				

* indicates that this item appears in two categories
** indicates that this item appears in three categories

Legal Knowledge and Enforcement

Introduction. The issuance of state laws and their subsequent enforcement are directed at applying a coherent, consistent, and safety-related basis for driver behavior. Motorist familiarity with such laws and his knowledge of their enforcement should foster more consistent and safer behavior at railroad grade crossings. Conversely, educational countermeasures, e.g., driver education, renewal exams, and law enforcement countermeasures (selective enforcement) may be necessary to reinforce the positive impact supposedly associated with the understanding and adherence to these laws.

Items. Two items have been included in this category:

- III-1. According to state and local law, what should you have done at this railroad crossing just now?
- IV-6. Have you ever known anyone who got a traffic ticket for crossing a track when the signal was on or the gate was down?

Results. It was hypothesized that drivers more knowledgeable of the state law (Item III-1) and/or with more personal knowledge of the enforcement of violations (Item IV-6) would be more safety oriented. However, the proportion of drivers correctly answering Item III-1 in the lower quartile for the safety index equalled or exceeded those correctly answering this question in the upper quartile. A T-test was significant at the .05 level or better for passive sites and over all sites. In general, the within-site correlations between the safety index or its components and responses to Item III-1 confirmed this. Correlations were either not significant or negatively significant, with the exception of the Michigan sample (see Regional Differences).

With regard to personal knowledge of enforcement of violations, the proportions of respondents with such knowledge ranged from .03 to .08 with no significant differences between the upper and lower quartile drivers on the safety index.

Countermeasures Implications. The data do not support increasing driver awareness of legal regulations as a potential railroad grade crossing accident countermeasure. With regard to increased law enforcement (Item IV-6), the proportion of drivers who have personal knowledge of this countermeasure is too limited in the driver subpopulations to permit drawing any conclusions with regard to its effectiveness. Enforcement is known to be effective in behavioral modification on highways and is believed to be applicable to grade crossings.

Knowledge of Railway-Highway Safety

Introduction. Knowledge of the characteristics of the transportation system has historically been assumed to be related to on-the-road performance. One often stressed educational objective has been the imparting of "safety facts," most ubiquitously, fatality statistics. Acquaintance with the severity of the railway-highway safety problem is generally expected to instill in the driver a respect for a set of particularly hazardous conditions, i.e., the grade crossing.

Items. The three items included in this category were:

- III-8. How many motorists do you think were killed in accidents at railroad crossings last year in the United States?
- III-10. How many people do you think were killed in *all traffic accidents* on the streets and highways of the United States last year?
- IV-1. Do you recall receiving specific instructions or advice on railroad crossing safety?

Results. It was hypothesized that drivers in the upper quartile of the safety index would make higher estimates of the number of motorists killed at railroad crossings and the number killed in all accidents.

It was also predicted that drivers indicating that they had received specific instructions about railway-highway crossing safety would be more safety oriented than a matched group of drivers reporting no such exposure to railway-highway safety information.

Estimates of the number of drivers killed in railroad crossing accidents made by lower quartile drivers equalled or exceeded those made by drivers in the upper quartile of the safety index. The mean estimate was significantly greater for drivers at active crossings and for all sites. The mean estimate of the number of persons killed in all traffic accidents was also higher for drivers with lower safety indices and the difference was significant at the .05 level or better for all subgroups except passive sites. In general, the within-site correlations between the safety index or its components and estimates of the number of motorists killed were either not significant or a significant negative correlation was found. Both safe (upper quartile on the safety index) and unsafe (lower quartile on the safety index) drivers tended to underestimate the number of persons killed at grade crossings and in all accidents.

The mean ratio of the estimates of railroad crossing to total fatalities ranged from 3.96 percent to 6.26 percent. This approximates the actual contributions of rail-highway to total fatalities which is 2.7 percent. There were no significant differences between the ratios prepared from fatality estimates made by "safe" and "unsafe" drivers. This was confirmed by the within-site correlations between the safety index or its components and the fatality ratio. These correlations were not significant.

Countermeasures Implications. The fact that drivers tended to underestimate fatality statistics but that unsafe drivers made significantly higher estimates than safe drivers does not support the dissemination of fatality statistics as a potential countermeasure. These data are important because safety campaigns are frequently based on the premise that knowledge of the high number of motorist fatalities will be accompanied by more safety-oriented behavior.

Perception and Identification of Grade Crossing Devices

Introduction. Traffic control devices are designed to convey necessary warning, regulatory, or route guidance information to the driver. To further these ends, considerable energy and expense has gone into the design, deployment, maintenance, and standardization of traffic control devices. Thousands of railroad advance warning signs, pavement markings, crossbucks, and various types of active crossing devices have been installed. The expectation is that drivers will detect, understand, and appropriately interpret these traffic control devices. The driver's failure to perform any one of those necessary functions implies the failure of that traffic control device or device complex. Such a failure may be attributable to problems inherently associated with the device such as design, deployment, and maintenance; or possibly, human motivational or habit patterns.

Items.

- II-1. What was your *first* indication you were approaching a railroad grade crossing?
- II-2. If you saw an advance sign way up the road, what do you remember about the sign?
- II-3. Did you know how many sets of tracks there were before you reached the crossing?
- II-4. How many sets of tracks were there at this crossing?
- II-5. If you saw markings painted on the road, what do you remember about them?

Results. There were no significant differences between safe and unsafe drivers in terms of the item selected as the first indication of an approach to a railroad grade crossing. Of drivers who saw the advance sign for the crossing, the proportions correctly identifying its color, shape, and symbol are shown below:

		Passive	Active	Matched	All
Color	Safe	.75	.65	.75*	.67
	Unsafe	.86	.36	.20	.52
Shape	Safe	1.00	.69	.60	.75
	Unsafe	.71	.54	.44	.60
Symbol	Safe	.64	.77	.64	.73
	Unsafe	.64	.75	.76	.71

*Indicates significant difference by the t-test at .05 level or better.

Reference to the table shows that about three-quarters of both safe and unsafe drivers correctly recalled the color, shape, and symbol of the advance sign. The greatest difference between safe and unsafe drivers was the increased tendency of safe drivers to correctly identify the color of the advance sign, a difference which reached significance at the matched sites.

With regard to Item II-3, no significant differences were found between safe and unsafe drivers in their prior knowledge of the existence of the tracks. As for the actual number of tracks at the crossing (Item II-4), a larger proportion of the drivers classified in the safety-oriented group correctly identified the actual number of tracks at the crossing. This difference reached significance for data grouped across all sites.

Of drivers who noted markings on the road prior to the crossing (Item II-5), a significantly larger proportion of the safe drivers (0.78) correctly identified the symbol than the unsafe drivers (0.22) at passive sites. There were no significant differences between drivers classified as safe compared to those classified as unsafe at the active, matched, or across all sites.

Countermeasures Implications. There is a suggestion from the above data that drivers classified as safe by the safety index tend to be more observant of the crossing and the signs and markings associated with it. Unfortunately, it is difficult to determine which effect is causal. In other words, does the quartile of drivers classified as safe merely reflect those who tended to be aware of the crossings and therefore responded to it by more safety-oriented behavior? Or, does the quartile of drivers classified as safe really represent a generally more safety-oriented group of which a tendency to be more perceptive of railroad crossing devices is merely one characteristic? Several points suggest that the drivers classified as safe do truly represent a more safety-oriented group. First, nearly all drivers were local and thus were familiar with the existence of the crossing. Second, other safety-oriented behavior tends to be associated with this group.

Risk-Taking

Introduction. It is generally agreed that the tendency to take risks varies among drivers (and also varies for a particular driver at different points in time). The location of a driver along the risk-taking continuum will influence and modify his behavior. Knowledge, past experience, and short term personality/attitude characteristics contribute to the degree of risk which a driver will accept at any given time.

Items. Three of the items included in the questionnaire may be used as indirect measures of the tendency of the respondent drivers to take risks. These Are:

- II-8. Is a train scheduled to come by about now?
- IV-4. Have you ever crossed a track when the signal was on?
- Part VI. Was the driver using his seat belt if the car was so equipped? (This item was filled in by the questionnaire administrator.)

Of the above items the second and third have the greatest face validity as indirect measures of a driver's tendency to take risks. However, Item IV-4 will clearly be related to factors other than risk-taking such as familiarity with the crossing. Item II-8 has the least face validity as an indicator of risk. Answered in the affirmative, it may indicate familiarity with the crossing and the associated frequency/schedules of trains or it may indicate a cautious driver.

When the responses of drivers classified as safe and unsafe by the safety index were reviewed, it was found that there were no significant differences in the proportion of drivers who had crossed against the signal in any of the four groups of sites (active, passive, matched, all sites). Of those drivers who had crossed against the signal, there were no significant differences in the reasons cited for their behavior with the exception of "the train was far away." This reason was cited significantly more often by the drivers classified as unsafe at all active crossings studied.

More drivers classified as safe by their performance were wearing seat belts. This difference was significant for drivers studied at active sites.

Except at the matched group of sites, more safe drivers responded "Yes" to the question "Is a train scheduled to come by about now?" However, no differences reached the .05 level of significance.

The within-site correlations between these items and the safety index or its components were generally not significant. Any significant differences were not consistent across sites and are thus probably attributable to Type 1 error.

Countermeasures Implications. If the above questions are accepted as relating to risktaking, there is a suggestion that drivers classified as safe may have a lower tendency to take risks than drivers classified as unsafe on performance measures. The extreme weakness of the relationship, however, indicates that countermeasures development along other lines is likely to be more productive.

Familiarity With the Crossing

Introduction. One dimension along which drivers do differ is their degree of familiarity with the grade crossings studied. The frequency of trains at the crossing, their scheduled occurrence, relative speed, track roughness, reliability of signaling devices (at active crossings), and the average length of delay accompanying the actual passage of a train are some examples of the factors of which a familiar driver may have knowledge and which will influence his behavior. Thus, a number of hypotheses relating in varying degrees of directness to driver familiarity with the crossing may be derived.

Items. The following questionnaire items relate to familiarity of drivers with the grade crossings studied:

- II-1. What was your *first* indication you were approaching a railroad crossing? (One of the response categories was "knew it was there.")
- II-3. Did you know how many sets of tracks there were before you reached the crossing?
- V-6. How long have you lived there? (from a subcategory of the preceding question – where do live?)
- V-8. How often do you drive across these tracks?
- V-9. How far do you live from this railroad crossing?

Results. Of the above items, V-8 relates most directly to familiarity with the crossing. For all groups of sites, a high degree of familiarity with the crossings was found. The mean response was between "once or twice a week" and "about once a day." Only nine percent of the drivers sampled could be classified as unfamiliar (i.e., drivers who had driven over the tracks only once or twice before or who were driving across them for the first time).

Frequency of using the crossing was found to be inversely related to looking behavior and the the percent of speed reduction. This correlation was based on the rather small percentage of unfamiliar drivers but is believed to be real. Very familiar drivers also stated that signals always warn you in plenty of time to stop. Accident investigations showed that drivers who were involved in railroad accidents were likely to live nearby and cross the tracks frequently. Frequency of use was correlated .342 with the proximity the driver lived from the crossing (significant at the .01 level).

The other items included in this category did not individually relate to other measures, nor did the frequency of using the crossing being studied correlate significantly with other measures for any individual grouping of sites.

Countermeasures Implications. The weak but consistant relationship between careless behavior and familiarity with the crossing indicates that the familiar driver is a potentially productive target for countermeasure concepts. This is particularly true in view of the accident history of such drivers.

The less safe performance of highly familiar drivers has implication for the design of countermeasure evaluation studies since a novel change at a crossing may be expected to produce a strong short-term increase in safety measurements which will be reduced after some acclimation period.

The converse to the above findings, that highly unfamiliar drivers have consistently more safe behavior, tends to reduce the requirement for educational programs designed to explain new countermeasure installations of some types.

Experiential Characteristics

Introduction. "Experiential characteristics" refers to a driver's totality of experience with railroad grade crossings. Experiential characteristics are a function of the miles driven per year, the number of years of driving experience, and the number and type of grade crossings encountered during the motorist's driving history.

Items. Nine of the items included in the questionnaire have been classified in this category of independent variables. These are:

- III-2. Do all railroad crossings have a signal or gate that warns you when a train is coming?
- III-3. Do all railroad crossings have a sign way up the road warning you that there is a crossing ahead?
- III-11. If a crossing does not have a signal, it usually means that:
  Only a few trains use the crossing
  Only slow trains use the crossings
- III-12. Signals at crossings:
  Always tell you when a train is coming
  Warn you in plenty of time to stop
- IV-2. What is the average delay that you have experienced when stopped at a railway crossing?
- IV-3. How long does it generally take a train to reach the crossing after the warning signal goes on?
- IV-4. Have you ever crossed a track when the signal was on?
- IV-5. How often do you see trains at railroad crossings:
- V-3. About how many miles a year do you drive?

Results. The first four items relate to the accuracy of the driver's perception of the characteristics of railroad grade crossings. It will be recalled that safe drivers tended to more accurately characterize the particular grade crossing at which they were interviewed (see preceding section titled Perception and Identification of Grade Crossing Devices). In view of this finding, it might be expected that safe drivers could more accurately characterize grade crossings in general (Items III-2 and III-3). However, significant differences in the responses to these questions by safe and unsafe drivers responding correctly to these two items are shown below:

Table 7–6

The Proportion of Motorists Classified as Safe and Unsafe Who Responded Correctly to the Items Listed

Item	Active		Passive		Matched		All	
	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe
III-2. Do all railroad crossings have a signal or gate that warns you when a train is coming?	.82	.83	.73	.81	.76	.83	.76	.82
III-3. Do all railroad crossings have a sign way up the road that warns you that there is a crossing ahead?	.37	.38	.52	.47	.53	.48	.47	.44

The above suggests that accuracy of general knowledge of grade crossing devices is not what accounts for any increased accuracy of perception of safe drivers at particular sites.

Turning attention to the next two items, the underlying assumptions with which safe and unsafe drivers view signals at crossings appear to be similar. No significant differences were found in the proportions of motorists responding negatively to each of the alternatives listed as shown below.

Table 7–7

The Proportion of Safe and Unsafe Motorists Responding Negatively to Each of the Items Listed

Item	Active		Passive		Matched		All	
	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe
III-11. If a crossing does not have a signal, it usually means that:								
only a few trains use the crossing	.21	.15	.38	.33	.38	.31	.33	.27
only slow trains use the crossing	.62	.55	.61	.59	.58	.55	.61	.57
III-12. Signals at crossings								
always tell you when a train is coming	.30	.29	.43	.42	.46	.39	.39	.37
warns you in plenty of time to stop	.15	.18	.19	.20	.16	.18	.18	.19

The next four items deal with driver experience with trains and/or activated signals. At the passive sites, the unsafe drivers reported significantly more delay when stopped at a crossing than safe drivers. This is an interesting finding with implications for understanding the behavior of the two groups.

The sample of drivers (all sites) which stated the longest delays had been experienced were found to be the most unfamiliar drivers. This group was characterized by infrequency of train observations and living farther from the crossing than the mean distance. Long delay statements were highly correlated with long signal on-train arrival estimates.

At active crossings, interviews with drivers who crossed against a signal when a train was visible were the type most often rejected from the sample during the data reduction phase. This was caused most frequently by incomplete questionnaire forms followed by "form not obtained" cases. The latter occurred when a driver selected for interview refused to cooperate. Therefore, it is concluded that behavior associated with beating a train to the crossing is a direct result of the impatience of the driver. This result was also a contributing factor in accident causes of some types.

Miles driven per year is also an indicator of driver experience, but one which would be expected to relate even less directly to driver performance *at grade crossings* than the items already discussed. Thus, the finding of no significant differences between the safe and unsafe drivers in terms of miles per year is not surprising. Except at Calverton, there were also no significant correlations between miles driven per year and the safety index.

Countermeasures Implications. The data indicate that unsafe driving practices may be the result of an impatient driver, but as this trait is associated with external variables (which caused the driver to believe he could not tolerate delay) countermeasures of the educational type are indicated over other types of countermeasure.

Accuracy of perception and differences in perception of grade crossing devices and their meaning do not appear to differ between drivers classified as safe or unsafe by performance measures. The highly familiar drivers in this study do not appear to depend on the crossing warning devices to detect the crossing.

Demographic Characteristics

Introduction. Difference in driver behavior has been related to such demographic characteristics as age and sex. Knowledge, experience, and attitudes have also been related to demographic characteristics. Behaviorally relevant demographic variables can be used to identify target populations for educational countermeasures or design populations for the evaluation of traffic control devices and procedures.

Item. The items which have been classified in this category are:

- V-1. Your occupation
- V-2. How old are you?
- V-4. In what state did you get your first drivers' license?
- V-5. Where do you live? (City and state)
- Part VI. Sex (This item was filled in by the questionnaire administer.)

Results. No significant differences in the age (Item V-2) of drivers classified as safe versus those classified as unsafe were found for the grouped data at passive sites, active sites, matched sites, or across all sites. Males were disproportionately distributed in the unsafe quartile at all sites. This preponderance of males was significant at active crossings and across all sites.

Over 90 percent of the drivers sampled at all sites resided locally. No significant relationships were found between the state in which the driver first obtained his license (Item V-4) and his likelihood of being included in the unsafe or safe quartile of drivers as defined by performance measures. The same was true with regard to current residence (Item V-5).

Countermeasures Implications. Demographic information as related to behavior is particularly useful for isolating target groups for countermeasures application. Both the type of countermeasure and its method of application may be realistically tailored to particular target groups if these can be defined. The one significant relationship found was between sex and performance suggesting that males are more likely to be at risk than females. However, this is in conflict with the accident data discussed in Chapter 2 where there was some indication of a differential involvement of females. Thus, unfortunately, the data do not permit identifying a particular demographic group as having high payoff for countermeasures application.

It should be noted that the reason for including Item V-5 (Where do you live?) was that the accident data show that many grade crossing accidents involve local residents. However, as was pointed out in Chapter VI, the vast majority of drivers at grade crossings are local residents. Thus, that they constitute a sizable proportion of grade crossing accident drivers can be attributed to exposure to the occurrence of a train as much as to the alternate explanation of over confidence based upon familiarity. The fact that a weak but probable relationship was found between familiarity and unsafe performance at the grade crossing supports both exposure and overconfidence as the explanations for the accident data.

Perception of Grade Crossing Accident Causation

Introduction. Of particular interest in this category of variables is whether the accuracy of a driver's perception or knowledge of the factors which have been linked to grade crossing accidents is significantly related to his behavior at grade crossings. For example, imagine two drivers, both sober, approaching an active crossing in daylight in clear weather. One driver believes that most grade crossing accidents occur at passive crossings at night under poor weather conditions and that the involved driver is drunk. The other driver believes the opposite – that most grade crossing accidents occur at active crossings in the daytime under good weather conditions and that alcohol has little relationship to grade crossing accidents. If the beliefs of each of these drivers is strong, it does not seem unlikely that their behavior at grade crossings will be different.

Items. Five items on the questionnaire provide information on driver perception of factors related to accidents at grade crossings. These are:

- III-4. Most accidents occur at crossings:
  - having gates or lights
  - without gates or lights
- III-5. Most railroad crossing accidents occur:
  - after dark
  - during the day
- III-6. Most railroad crossing accidents occur during:
  - bad weather (fog, rain, snow)
  - clear weather
- III-7. Most accidents at crossings having signals are due to:
  - driver carelessness
  - signals that fail to work
- III-9. How many of the above accidents involved a driver who would be considered drunk under the law?

Results. No significant differences were found between the responses of safe and unsafe drivers to the above items with the exception of Item III-5. At passive crossings, significantly more safe drivers indicated that most grade crossing accidents occur during the day. There are reasons for viewing this relationship with caution. First, it was found only in the passive site grouped data and not confirmed by the data collected at active or matched sites.

Second, of the three passive sites, a significant correlation between the safety index and the response to this question was found only at Calverton.

Third, in a large number of significance tests, some spurious significant relationships will occur by chance alone (Type 1 error). The probability of a Type 1 error is equal to the level of significance selected. Because significant differences between safe and unsafe drivers were not found for the active or matched sites or on other items of similar content, the one relationship found may well be attributable to a Type 1 error.

With regard to other items, the responses to Item III-7 are of interest. At least 94 percent of the drivers in both the safe and unsafe quartiles and across all groups of sites attributed accidents at crossings having signals to driver carelessness rather than to the alternative, signal failure. This suggests that nearly all drivers think that a driver has to bear responsibility for a grade crossing accident. However, there are questions which remain to be answered. How do drivers view their own likelihood of carelessness? Does a belief in driver carelessness as an accident cause affect performance in a positive fashion? Does the fact that most drivers did not select the signal failure category suggest that most drivers think that signals never fail?

Countermeasures Implications. The data do not support a relationship between driver perception of accident causation and his performance at a grade crossing. Thus, this study does not support application of countermeasures designed to change driver perception of grade crossing accident causation as a means of obtaining more safety-oriented driver behavior.

Stated Basis of Actual Behavior

Introduction. Several of the questionnaire items provide direct or indirect measures of the reasons underlying the observed behavior of the drivers included in the study. These items should provide some insight into effective means of altering behavior which is hazardous or otherwise undesirable (e.g., unwarranted slow speed with consequent impeding of traffic flow).

Items. The three most important items included in this category are:

- I-1. When you first realized that you were approaching a crossing, did you slow down? (Several of the response categories refer to reasons for slowing down.)
- II-8. Is a train scheduled to come by about now?

- IV-6. Have you ever known anyone who got a traffic ticket for crossing a track when the signal was on or the gate was down?

Results. No significant differences were found between safe and unsafe drivers on Items II-8 and IV-6. With regard to Item I-1, of those drivers who reported slowing down significantly more unsafe drivers than safe drivers selected as their reason "because tracks are usually bumpy." The relationship was significant for active, matched, and across all sites. The only other significant relationship was that significantly more safe drivers than unsafe drivers at active sites selected the "other reason" category (rather than the alternatives: "in order to match the speed of the vehicle in front of you;" to "check for signals and trains," and "because tracks are usually bumpy").

Countermeasures Implications. Fewer drivers would probably slow down if the expectation of track roughness were removed and grade crossings were universally smooth. This would probably result in more uniform traffic flow and possibly fewer car-car accidents but it might also result in more train-car accidents at grade crossings.

Stated Behavior

Discrepancies may exist between what a driver thinks he did and what he actually did. This issue was examined by comparing the stated behavior of the safe and unsafe drivers. Since the actual behavior of these two groups differed, it would be expected that the behavior reported by these two groups would also differ – if the drivers were aware of their actions and accurately reported them.

Unfortunately, response to a questionnaire may not be a fully accurate indicator of what the driver really thinks he did. Among other things, questionnaire response may be biased by what the driver thinks he ought to have done. However, the questionnaire is the only indicator being used on this project of driver's perception of his behavior on his approach to the crossing. Therefore, several items were used to elucidate perceived driver behavior.

Items. The items which have been included in this category are:

- I-1. When you first realized you were approaching a crossing, did you slow down?
- I-2. Did you listen for a train?
- I-3. Did you roll down your window?
- I-4. Did you look down the tracks before crossing?
- I-5. Did you come to a complete stop before crossing the tracks?
- I-6. How fast do you think you were going when you crossed the tracks?

Results. Of considerable interest was whether there would be significant differences between the safe and unsafe groups on their responses to these questions or whether both groups would state that they behaved in the same way. In general, it was found that there were significant differences between the two groups and that these were in the same direction as actual behavior. In other words, more safety related behavior, such as looking and/or listening for trains was reported by that quartile of drivers designated as "safe" by the safety index. Safe drivers estimated that they were traveling at a lower speed than unsafe. The following table summarizes these results for the four groups of sites. Significant differences at the .05 level or better are starred.

Table 7–8

Significant Differences (*)
in Reported Behavior by Safe and Unsafe Drivers

Item	Passive	Active	Matched	All
I-1. Did you slow down?		*	*	*
I-2. Did you listen for a train?	*	*		*
I-3. Did you roll down your window?				
I-4. Did you look down the tracks?	*			*
I-5. Did you come to a complete stop?		*		*
I-6. How fast were you going?	*		*	*

In all cells not starred, the differences between the safe and unsafe groups were in the same direction as were the differences that reached the .05 level or better.

Countermeasures Implications. These data suggest that drivers are aware of their behavior and remember it with some degree of accuracy. What is needed is further elucidation of the underlying reasons for the differences in behavior of the drivers classified as safety oriented and those classified otherwise. The difference does not seem to lie in unsafe drivers believing their behavior was different from what it actually was.

Summary

Measures of Behavior

Four measures of driver behavior were obtained. These were shown to be highly interrelated. An adequate description of the safety-related behavior of the driver consists of whether the driver looked for trains, the speed of the vehicle at the crossing, and the percent speed reduction over the 500 feet preceding the crossing. The sensitivity of these measures to a change in protective devices has been demonstrated only for crossings where there is a restriction to sight distance until the driver is within 150 feet of the crossing.

Behavioral Differences

No consistent significant differences were found to exist between driver behavior at active and passive crossings. The high level of familiarity with the crossing appears to explain the strong relationship between train volume and safe behavior. Severe restrictions to visibility did not increase the frequency of looking behavior.

Regional Differences

No clear relationship was established between any of the measures and the geographic location of the crossing. It was concluded, however, that the sample was inadequate to reject regional differences as a possibility.

Driver Knowledge

The data did not support increasing driver awareness of legal regulations as a potential accident countermeasure. There are indications, however, that enforcement of required behavior is a factor in accident reduction.

An inverse relationship was found to exist between estimates of fatalities statistics and safe behavior. The data do not support fatality statistics publication as a countermeasure.

Driver Awareness

Drivers who were observed to perform more safely more frequently correctly identified or remembered the characteristics of protective devices at the crossing. It cannot be stated, however, that knowledge or recognition of the devices at a crossing contributes in a direct causal fashion to individual performance.

High driver familiarity with a particular crossing was shown to reduce looking behavior and the percent of speed decrease over that of very unfamiliar drivers. This result, supported by the accident investigations, makes this category of driver a candidate for countermeasure programs. Evaluation of candidate countermeasures may be made more difficult by the high probability of a strong acclimation effect.

Risk Taking

It was found that drivers who performed less safely according to the behavior measures, tended to score more highly as risk-takers. The only element which clearly reached significance, however, was the use of seat belts. Risk-taking does not appear to be a productive consideration in countermeasure development.

Experiential Characteristics

Drivers who report long delays when stopped at grade crossings, tended to behave less safely. Drivers who crossed against an activated signal were most frequently found in the unsafe quartile and were generally observed to be in a hurry to complete their trip. Accuracy of perception and differences in perception of grade crossing devices did not differentiate drivers.

Demographic Characteristics

The population sample indicated a very stable group in that the drivers nearly always lived in the community where the crossing was located, and had first obtained their license to operate a motor vehicle in the state where the crossing was located. This relation was true even in the suburbs of Washington, D.C.

The proportion of males and females in the sample approximated their proportions in rail-highway accidents. There was no significant difference in the proportions of females in the safe and unsafe driver quartiles. However, male drivers were overrepresented in the group of unsafe drivers. Both exposure to grade crossings and over confidence of highly familiar drivers are felt to be factors in accident causation.

Perception of Grade Crossing Accident Causes

The data do not support a relationship between driver perception of accident causation and performance at crossings. Thus, the study did not support application of countermeasures designed to change driver accident perception as a means for obtaining more safety-oriented behavior.

Stated Behavior

Drivers tend to reduce speed for grade crossings due to track roughness. This was cited most often as the motivation for speed reduction by drivers who did not look for trains or were otherwise categorized as unsafe drivers.

Drivers were found to report having performed actions such as looking for trains, lowering windows, reducing speed, etc. in relation to actually having performed them. Unsafe drivers did not state (believe) that they had performed more safely than they were observed to have performed.

CHAPTER 8

FIELD EVALUATION OF RAILWAY–HIGHWAY GRADE CROSSING ACCIDENT COUNTERMEASURES

This chapter provides guidelines for undertaking a field evaluation of railway-highway grade crossing accident countermeasures. A cost-effective evaluation is one which begins with careful development of the particular countermeasures to be installed and evaluated. This step is one which is frequently omitted. However, its completion is vital if a maximum number of effective countermeasures and minimum number of countermeasures of low utility are to be included in an expensive field study. The basic framework for a field evaluation thus includes the following steps:

A. Development of Countermeasures
   1. Development of countermeasure concepts
   2. Selection of countermeasures

B. Development of Countermeasures Evaluation Methods
   1. Specification of driver and site characteristics
   2. Specification of behavioral measures
   3. Specification of knowledge, attitudinal, and self-report measures

C. Development of Experimental Design and Procedures
   1. Extent of generalization required
   2. Data collection procedures
   3. Data analysis procedures

D. Validation by Accident Reduction

The discussion is organized around each of the above steps as a topical or subtopical heading. The examples used are based upon the knowledge and experience gained by project personnel in the course of the study. Thus, it assumes that the reader is familiar with Chapters 1 to 7. Other investigators might emphasize other features depending upon their particular knowledge, experience, and hypotheses concerning grade crossing accident causative factors and their familiarity with alternate measures, methods, and techniques. Because the objective is to provide a framework for extensive field investigations based on this demonstration study, the discussion is deliberately brief.

Development of Countermeasures

Development of Countermeasure Concepts

The initial effort should be a means-free identification of countermeasures concepts. Only after the most likely concepts have been identified should the investigator identify the means by which the concept might be implemented. The reason is that means-contaminated conceptualizations are constrained by inherent implications of feasibility and cost. Thus, a means-free conceptualization increases creative latitude. After countermeasures concepts have been identified, attention can be turned to derivation of specific countermeasures and to the selection of those which are to be included in the evaluation.

The following framework is useful for developing countermeasures concepts:

- identification of accident-related behaviors. These are the behaviors which countermeasures will be expected to modify.
- Specification of behavioral objectives for the countermeasures. Behavioral objectives are more specific and may be directed to particular components of each accident-related behavior.
- Derivation of countermeasures concepts.

Table 8-1 illustrates the use of the above framework to derive countermeasures concepts. This study found that the major accident-related behaviors are those listed in the table. Behavioral objectives and some countermeasures concepts are also presented.

A listing of countermeasures concepts of potential value is presented in Table 8-2. The major focus of the countermeasure and the rail-highway component modified are compared for each entry.

Selection of Countermeasures

The concepts defined above are then used to suggest potential countermeasures. All potential countermeasures which could conceivably apply should be listed. The following criteria are then applied to eliminate, modify, or support each countermeasure:

- Driver characteristics and limitations.
- Equipment reliability and cost.
- Legal, political, and social considerations.
- Identification of required educational/informational backup for the countermeasure.

Driver characteristics and limitations involve a review of human factors design considerations as well as vehicle capabilities and limitations. Preliminary studies may be indicated to evaluate driver acceptance of candidate countermeasures, particularly those which are novel or which impact on more than the grade crossing *per se* (such as in-vehicle warning systems and crossing elimination by closing).

Table 8–1

Development of Countermeasures Concepts

Accident-Related Behaviors	Behavioral Objectives	Countermeasures Concepts
Failure to detect crossing	Increase search Make search more efficient • driver • devices • environs	Increase number of sense modalities through which information is transmitted (e.g., rumble steps) Remove competing or blocking stimuli Increase conspicuity of warning devices Provide information on relation of warning device to crossing (e.g., distance to crossing) Improve driver scan patterns
Failure to look for train	Increase perceived hazard Increase discrimination of active vs. passive crossings Increase driver feeling of responsibility for accident	Increase knowledge of accident/fatality statistics Make warning devices for active and passive crossings distinctive
Failure to see train or warning device	Increase search Make search more efficient • driver • train/device • environs	Increase number of sense modalities through which information is transmitted (e.g., vibration) Remove competing or blocking stimuli Increase conspicuity of train or device
Failure to listen for train	Increase listening for train	Increase probability of listening
Failure to hear train warning device		Remove competing auditory stimuli Increase attention
Failure to slow sufficiently that a stop is possible	Reduce motorist speed on approach	Inform motorist of critical stopping distance Inform motorist of limited sight distance
Inaccurate judgment of arrival of train at crossing	Improve motorist estimates of relative speed	Assist motorist in estimation of speed of train at track
Failure to respond to active warning device	Increase driver response to warning devices	Increase credibility of active devices

The tendency of drivers to incorrectly identify the legal requirement of crossing signals implies at least partial failure of that device to convey the intended message. No rationale was developed in this study which supports the concept of completely different characteristic devices for differentiation of rail intersections from other highway intersections other than historical precedent.

The legal liability of the agency which installs and maintains intersection traffic control devices has been clearly established only for the rail intersection. Until the railroad is relieved of the responsibility for grade crossing protection, countermeasure innovation and countermeasure evaluation projects must fully consider the legal position of the railroad.

Table 8–2

Listing of Countermeasures Concepts of Potential Value

Countermeasures		R–H Component Modified					Major Focus					
Number	Description of Countermeasures	Crossing and/or Roadway	Traffic Control Device	Train	Motor Vehicle	Driver	Reduce P of Trains at Crossing	Reduce P of Motor Vehicles at Crossing	Increase P of Detecting A Crossing	Increase Awareness of Trains Presence	Increase P of Detecting A Motor Vehicle	Reduce Necessary Stopping Distance
1	Grade separation	x					x	x				
2	Closing the crossing	x					x					
3	Distinct differences active/passive	x							x			
4	Change in roadway geometrics	x							x	x		x
5	Change in railway geometrics	x							x	x	x	
6	Crossing repairs and modifications	x										x
7	Pull off areas before the crossing	x										x
8	Skid resistant pavement	x										x
9	Rumble strips	x							x			
10	Clearing visual obstructions near the crossing	x							x	x	x	
11	Illumination around the crossing	x							x	x	x	
12	Wheel level illumination on far side of crossing	x							x	x		
13	Rerouting certain motor vehicles		x					x				x
14	Requiring certain or all motor vehicles to stop		x						x	x		x
15	Decreased roadway speed limits		x						x	x		x
16	Decreased train speeds		x							x	x	
17	Static advanced warning device		x						x			
18	Dynamic advanced warning device		x						x			
19	Static warning device at crossings		x						x			
20	Dynamic warning device at crossings		x						x			
21	Active advanced warning device		x							x		
22	Active warning device at crossing		x							x		
23	Pavement markings and delineators		x						x			
24	Rerouting certain classes of trains			x			x			x		
25	Rescheduling certain trains			x			x			x		

Table 8–2 (Continued)

Listing of Countermeasures Concepts of Potential Value

Countermeasures		R–H Component Modified					Major Focus					
Number	Description of Countermeasures	Crossing and/or Roadway	Traffic Control Device	Train	Motor Vehicle	Driver	Reduce P of Trains at Crossing	Reduce P of Motor Vehicles at Crossing	Increase P of Detecting A Crossing	Increase Awareness of Trains Presence	Increase P of Detecting A Motor Vehicle	Reduce Necessary Stopping Distance
26	Automatic object sensors at crossings			x							x	
27	Better train braking systems			x								x
28	Better auditory warning systems for trains			x						x		
29	Brighter headlight systems for trains			x						x	x	
30	Flashing beacons for trains			x						x		
31	Running lights for trains			x						x		
32	Reflective train side panels or colors			x						x		
33	In-vehicle alerting system				x				x			
34	Train activated in-vehicle signaling system				x					x		
35	Better motor vehicle braking systems				x							x
36	Extended beam headlight systems for motor vehicles				x				x	x		
37	Periodic motor vehicle inspection				x				x	x		x
38	Rerouting motor vehicles (school busses)				x			x				
39	Information conveyed through licensing					x			x	x		x
40	Periodic license renewal					x			x	x		x
41	Medical check-up associated with relicensing					x			x	x		x
42	Public information campaigns					x			x	x		x
43	Strict law enforcement					x			x	x		x
44	Driver education in high school etc.					x			x	x		x

Equipment reliability and cost are frequently highly related factors. The cost of long term maintenance is often the largest single cost item. A cost-effective countermeasure may well be one which has less than fail-safe reliability but does aid the driver in safe operation of his vehicle. The fail-safe concept has, unfortunately, been a historical requirement of grade crossing protection to the extent that courts may be expected to render judgments against the agency responsible for protection in the event of a vehicle-train accident even in the case of a driver who fails to heed a warning signal. These legal caveats, coupled with political and social considerations (such as complaints by nearby residents of "excess" sound levels for crossing bells) has made grade crossing innovation a difficult program to implement.

In addition to the above criteria, some innovative protective systems may be made acceptable and effective only when coupled with a successful program which informs the crossing user of the system, its operation, and its limitations. Without this step some types of countermeasures systems can actually increase the hazard to segments of the population.

An additional and complementary consideration is the expectancy of a driver as he negotiates a rail-highway intersection in the presence or absence of a train. Where expectancy and actuality are in inverse relationship, driver decisionmaking and consequent behavior may be particularly inappropriate. For example, malfunctioning signal lights tend to foster an expectancy that the signal does *not* indicate the presence of a train. This example was found to be a contributing factor in accident investigation. Therefore, in the selection of particular countermeasures, consideration should be given to driver expectancy. Additional countermeasures may suggest themselves or the relative merit of some countermeasures may be shifted.

Development of Countermeasure Evaluation Methods

The methods presented in this report assume that a comparison is to be made between behaviors under alternate protective systems (e.g., a before/after study).

Specification of Driver and Site Characteristics

Types of Drivers of Intrest. The countermeasure concept which led to the countermeasure necessarily implies a target population. The sample to be observed in the study must be clearly defined so that the study design can insure that the target population whose behavior is to be modified is adequately represented in the data. The population toward which the countermeasure is directed may be "unfamiliar," "local," "commuter," or "normal," for example. Except for special purpose countermeasures, the "normal" population is generally indicated.

Class of Rail-Highway Intersection of Interest. The countermeasures concept determines the type of crossing to receive intervention. This element should be described in complete detail. That is, the urban/rural/suburban character should be defined as well as the appropriate vehicle/train volumes and the desired variation in volumes or flow. Competing stimuli in terms of business or residential vehicle movements and other competition for the driver's attention such as commercial messages should be specified.

The characteristics of the approach to the crossing must be specified. There is an indication that blind crossings and crossings reached immediately after a turn are overrepresented in the accident summaries. Both cases may be expected to require specific countermeasures.

This study dealt only with one type of site characterized by restricted visibility to trains until the driver was within 150 feet of the crossing and the absence of conflicting stimuli along the approach. Behavior at such locations was in response to the grade crossing stimuli and therefore measures of behavior were measures of the driver's response to the crossing situation.

At an open crossing, where the driver can determine visually from a distance that no train is present, looking behavior cannot be detected by covert observation. A previous study showed that changes in speed are due to recalled or perceived track roughness. At crossings such as those reached after a turn or in a congested urban area, looking behavior may be available but other measures are generally confounded by the external factors. Further study is indicated to determine measures suitable for the evaluation of countermeasures to be applied at the types of crossings not dealt with in this study.

Selection of Sites. The final selection of the sites to be studied depends on the above determinations as well as others. In general, selection of sites is the most important factor in the success of the study. Appropriate sites are those which:

1. Contain an adequate sample of the target population.
2. Meet the required characteristics of the crossing in terms of the countermeasure to be evaluated.
3. Do not contain uncontrolled variables such as anticipated construction, population changes, etc.
4. Are not unique, and permit generalization.
5. Are appropriate to the data collection method and technique.
6. Do not produce a relationship between countermeasures and site characteristics of potentially increased hazard.

Specification of Behavioral Measures.

Four behavioral measures were evaluated in this study. These were: 1) looking for trains: 2) percent reduction in speed in the zone extending from 500 feet in advance of the crossing to ten feet in advance of the crossing: 3) the segment of the approach profile where maximal deceleration ocurred: and 4) the distance from the crossing within the 500 feet preceding the crossing where the driver's speed exceeded that permitting a stop before the crossing. In addition, a campesite safety under utilizing these four measures was derived.

The sites used in the study included a variety of types (active/passive, urban/rural, etc.). However, all were characterized by limited sight distance – such that the driver could not productively look for trains in one or both quadrants at greater than 150 feet from the crossing.

For the crossings studied, high correlations were found among the behavioral measures. Further analysis showed that for study sites of limited sight distance, looking behavior, speed at the crossing and speed reduction were valid, sensitive, and sufficient measures of driver performance. Accordingly, these measures are recommended in the full-scale countermeasures evalution study for limited sight distance grade crossings.

Specification of Self-Report Measures.

This study failed to support a requirement for further measures of driver knowledge and attitude. There is, however, a need for a limited survey during the field evaluation of countermeasures to determine if the driver observed or was exposed to the countermeasure. In addition, it may be fruitful to sample demographic and other driver characteristics during long term studies to determine whether a change in the driver population at the study site accounts for changes in countermeasures effectiveness.

Development of Experimental Design and Procedure

It is assumed that the experimenter contemplating a large-scale field evaluation study is aware of the general principles of experimental design appropriate to before/after studies. The specifics of the design are a function of the number of countermeasures to be evaluated, the number of sites at which each countermeasure is to be tested, the approach to be used to eliminate or assess the contribution of confounding variables, and similar characteristics. Accordingly, this discussion is limited to aspects particularly appropriate to the evaluation of grade crossing countermeasures and the provision of guidelines concerning the data collection procedures and anlaysis techniques found to be particularly useful in this demonstration study.

Extent of Countermeasures Generalization Required

The candidate countermeasure may be found to be effective only at certain levels of luminance, size, shape or color, location in respect to the crossing, during night or day, in certain seasons, etc. It is necessary to provide for the required generalization within the study design and to insure an adequate representation of appropriate data for all conditions.

Data Collection Procedures

Looking Behavior. The zone of useful looking behavior in advance of a crossing should be well defined by an abrupt increase in sight distance at a point within two hundred feet of the crossing. Observations of looking behavior are best made from the driver's side of the vehicle to eliminate glare from windshields. The head movements observed in a zone near the crossing due to looking for trains are large and easily detected although observer training and periodic testing was found to be vital. Drivers are scored as "looked" or "did not look." Additional information such as the direction in which the driver first looks was not found to be useful.

One observer can reliably obtain looking data over as much as one hundred feet of road when positioned within fifty feet of the road near the crossing end of the zone provided that the next car to be observed does not enter the zone until the observer can readjust to the starting point. The use of binoculars was found to be unnecessary and actually reduced reliability, increased the time required between vehicles, and contributed greatly to fatigue.

The observers must be concealed from the driver's view. The zone should be clearly marked from the observer's viewpoint but be unobtrusive to the driver. Radio communications and scheduled rest periods were found to be useful in obtaining reliable data, particularly when multiple observers are used for two zones.

Speed Measures. The least expensive, reliable technique for obtaining measures of vehicle speed is with a spot radar. The use of that instrument requires training which cannot be covered here. It should be noted, however, that interference will be experienced whenever more than one vehicle is within the beam width, and the radar will lock onto and track the source of the strongest echo. Vehicles moving away from the antenna will generally preempt speed measurements of vehicles coming toward the antenna until the latter is somewhat closer than the retreating vehicle.

The indicated radar speed will be accurate only if the beam is approximately parallel to the path of the target. This factor limits the location of the antenna to the edge of the lane being studied and to nearly straight sections of road. The optimum was found to be to locate the antenna on a utility pole about twenty feet above the road. It was found to be more convenient to measure speeds from the downstream side of the crossing as less camouflage was required of the data collection point. A typical maximum cable length between the antenna and the readout device is 200 feet.

By observation of the vehicle position and the speed reading, data points are noted at a consistent point about 500 feet prior to the crossing and again as the vehicle reaches the painted stop lines near the first rail.

Additional amplifying information is useful such as vehicle type (see text), time of day, whether a professional driver was involved, and the crossing-related events such as whistles, signal activations, train arrivals and departures, etc. If the target population is restricted, the apparent category of the subject should be noted.

Interviews. Communications between the crossing observers and the interview staff is necessary. The interview site should be located well downstream to preclude interference or modification of the behavior being measured. This study found that distances up to a half mile were appropriate if the subject did not have an alternate route available. The techniques of correctly identifying and eliciting the cooperation of selected subjects is fully covered in Chapter 5.

It should be noted that there is almost certain to be a marked acclimation effect for some period after the countermeasure is applied. A control site, preferably one which is used by the same population, should be used to both verify that the countermeasure has been noted and is effective and to help account for unexpected variations.

The baseline data should be of sufficient size to insure the determination of significant differences for the level of change expected. The section on Validation by Accident Reduction refers to this factor.

Data Analysis

An appropriate data analysis procedure is to compare the means and standard deviations of the results of the data collection periods. The desired level of significance may be determined with the t test for differences in means. Other statistical analysis procedures may be used as appropriate.

The entire population contained within the data may not be appropriate to the analysis. For example, school busses and fuel trucks may be overrepresented in the before data, and the atypical behavior of these vehicles should not be allowed to influence the conclusions. The target population defined above should be examined separately to detect appropriate changes.

For some countermeasures concepts, a subset of the population may be adversely affected. Analysis of the data should include an examination of all subsets.

Another useful technique is the examination of the effect of the countermeasure on the extremes of the sample, such as the most safe and least safe quartiles. A countermeasure may be found to reduce the adverse behavior of the fourth of the population which showed poor performance. The researcher must decide if the improvement achieved for the target population warrants the application of the countermeasure.

To conclude that a countermeasure has enchanced the safety-related behavior of the subjects, it is necessary that both speed reduction and looking behavior change in the appropriate direction by a significant amount. For example, a candidate countermeasure which implied a high degree of grade crossing roughness might result in an increased speed reduction without a corresponding increase in looking behavior. A countermeasure which was located too close to the crossing or was of insufficient size for the population to note the message in time, could result in an increased looking behavior at the crossing without a corresponding speed reduction.

Validation by Accident Reduction

While the development and short term evaluation of candidate countermeasure systems can be performed using the information and techniques presented above, the ultimate test of the countermeasure is the actual change in the number and severity of accidents. The determination of accident reduction is a very difficult task as it necessarily involves a long term study. The length of time required to accumulate statistically significant data permitting a judgment necessarily confounds the picture due to seasonal changes, population movements, and changes in the nature of the experimental site itself such as road resurfacing, construction in the vicinity, etc.

The situation is not hopeless, however, only difficult. The constraints mentioned above can be minimized or at least controlled by evaluation of a countermeasure at a large number of similar sites for a shorter time. The major drawbacks to this option are that a sufficient number of comparable locations may not exist within the jurisdiction of the agency doing the evaluation, and the evaluation demands that the candidate countermeasure be the only change allowed to occur during the period of the study. The latter constraint is frequently the most difficult to achieve since an accident reduction program is often the impetus which led to the countermeasure evaluation, and a large number of techniques are simultaneously applied, making the evaluation of any single one impossible to determine.

As an example of the length of the program required to validate a countermeasure by accident reduction, the following calculations are presented. The object is to calculate the number of years required for a statistical determination of accident reduction due to a single countermeasure system.* The information required is:

1. the accident history of the site,
2. the desired confidence level, and
3. the expected efficiency of the countermeasure.

the accident history of the site is assumed to be available for the last five years. Six years ago, a major change was made which probably modified the characteristics of the site to the extent that previous accident data do not apply. Assume the following history of accidents at the test site:

Year	Number of Accidents
1	2
2	3
3	4
4	3
5	3

It should be noted that there were a few more accidents than are noted above, but that they are of a type at which the countermeasure was not directed, such as a rear-end collision between cars near the crossing which was clearly not related to the existence of the crossing.

The selected significance level is .05. We have reason to believe that our countermeasure will be effective in reducing the probability of an accident, and have reason to estimate the magnitude of the efficiency of the countermeasure.

The historical accident data can be summarized for our hypothetical crossing as:

$$N_1 = 5 \text{ years}$$

$$\overline{X}_1 = 3 \text{ accidents/year}$$

$$\sigma_1^2 = 0.4$$

$$\sigma_1 = 0.64$$

*The same calculations may be used to determine the number of subjects, observations, hours, etc. for any before/after study.

Since we have no reason to predict otherwise, the variance of the data for the "after" phase will be assumed to be the same, 0.4. The equation for the t test may be written as:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}} \qquad (1)$$

and if the variance is constant,

$$N_2 = \frac{N_1 \ \sigma^2 \ t^2}{(\overline{X}_1 - \overline{X}_2)^2 \ N_1 - \sigma^2 \ t^2} \qquad (2)$$

All of the terms of equation 2 are known except t. The value for t is obtained from a table of distributions of t. Values for t with a confidence level of .05 are given in Table 8-3 below. To find the degrees of freedom (d.f.), add the two sample sizes (years of before data plus years of after data) and subtract two. Since the years of after data (N_2) is not known, an estimate is made for the d.f., the equation is solved for N_2, a new d.f. is then calculated, etc. until an agreement is reached between N_2 and d.f.

Table 8–3
Distribution of t for A = .05 (one-tailed)

d.f.	t
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812
20	1.725
23	1.714
30	1.697
40	1.684
60	1.671
120	1.658
∞	1.645

Appended from Standard Mathematical Tables, 12th ed., Chemical Rubber Publishing Co., 1959

If we examine the denominator of equation 2, we find that it is equal to zero when:

$$(\bar{X}_1 - \bar{X}_2)^2 N_1 = \sigma_1^2 t^2 \qquad (3)$$

At this point, N_2 is infinite. It will be a real positive number for $(\bar{X}_1 - \bar{X}_2)$ greater than $\sqrt{\sigma_1^2 t^2 / N_1}$. For our hypothetical crossing, we calculated that:

$$N_1 = 5$$

$$\sigma_1 = 0.64$$

$$\bar{X}_1 = 3$$

For an infinite number of years, $t = 1.645$. Solving equation 3, we find that $\bar{X}_2 = 2.54$ which is 15.5 percent better than $\bar{X}_1$, the mean accident rate before the countermeasure.

Therefore, for a crossing with an accident history over five years such as was presented at the beginning of this section, one would require an infinite evaluation period for a countermeasure with less than 15.5 percent effectiveness. If we presume a 20 percent effective countermeasure, significant data would be obtained in about 20 years (d.f. = 23, t =1.714). A countermeasure which was so outstanding that it produced a 30 percent reduction in accidents, could be evaluated in only 3.3 years (d.f. = 6, t = 1.943). Of course, assuming a group of sites which were alike in all material respects was available, the 20 percent effective countermeasure could be evaluated in two years if installed at ten such crossings.

The small sample of years in the before data is responsible for the large effectiveness required of the countermeasure. If ten years of data had been available which resulted in the same mean and variance, a countermeasure with an effectiveness of 11 percent could be evaluated. As is generally true of statistical tests, the smaller the change to be detected, the larger the sample size must be.

Conclusions

The lack of sufficient quantity of appropriate accident data and associated causative factors precludes the use of accident events to validate countermeasures on an individual crossing basis. While the general use of effective innovations in grade crossing protection throughout a large region coupled with appropriate educational efforts must result in accident reduction, the cost of entering such a program to evaluate the innovation is prohibitive. The more cost-effective methods of evaluation as presented in this study are therefore preferred and are recommended.

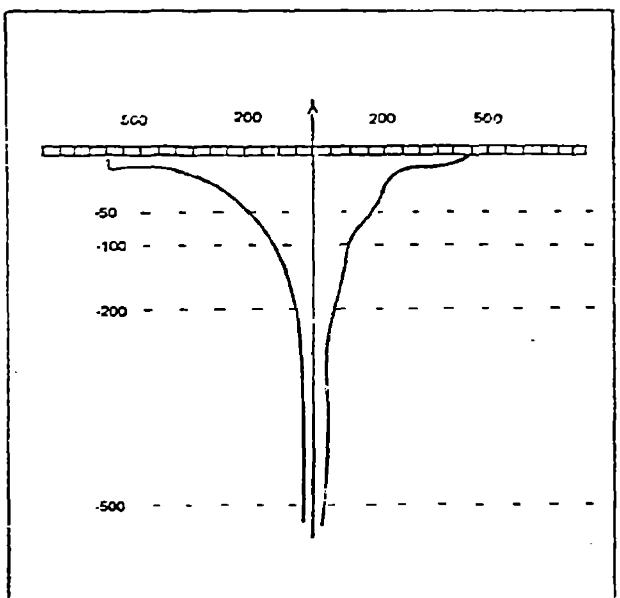
APPENDIX A

SITE DESCRIPTIONS AND CHARACTERISTICS

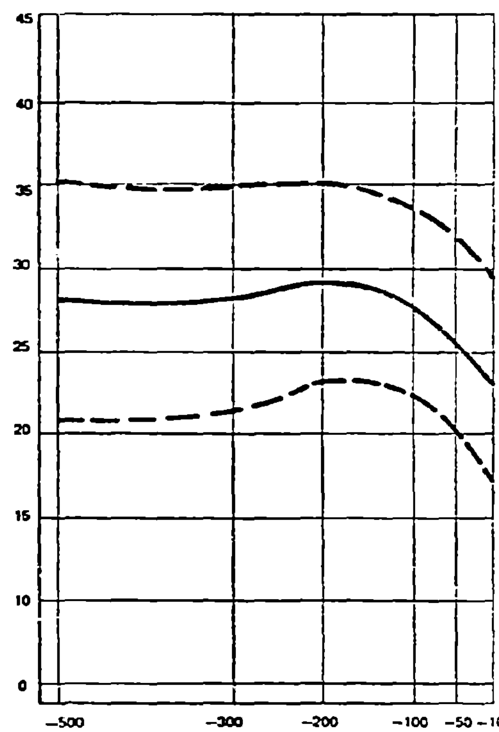
This appendix contains information on each of the nine sites at which data were collected. Included are the dates and times of observation, vehicle and train characteristics, protection descriptions, graphs showing the measured sight distances available to the driver along the approach to the crossings, and the measured mean and standard deviations of speeds. The plan views of the crossing are oriented with the instrumented section of road below the crossing and the interview site at the top of the page. The scale is not linear. Indicated distances were measured from the crossing along the driver's path to the element being referenced.

TABLE OF CONTENTS

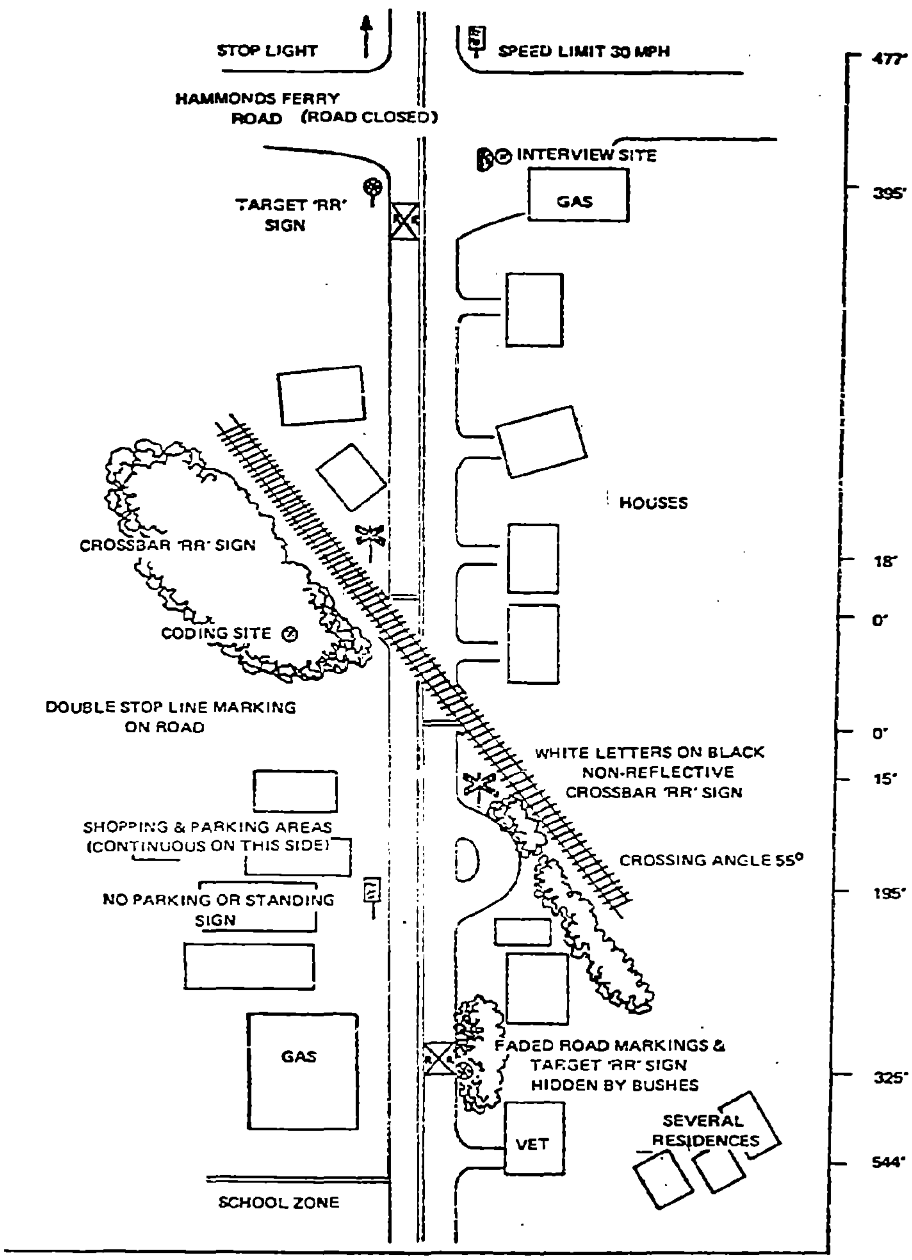
Site	Route 170, Linthicum, Maryland
Dates	July 17, 18, 1972
Times	1030 – 1745, 1030 – 1430
Railroad	Baltimore – Annapolis Railway Company
Number of Tracks	1
Advance Warning	Standard Sign, Pavement Markings
Distance	325 Feet
Crossing Protection	White Letters on Black Crossbuck
Double Stop Lines?	Faded
Reflectorized Crossbuck?	No
Number of Tracks Sign?	No
Trains Observed	0
Range of Train Speeds	–
Posted Speed Limit	30 MPH
Mean Hourly Volume	293
Number of Drivers Who Stop Without Signal/Train	10



Sight Distance along Approach to Crossing

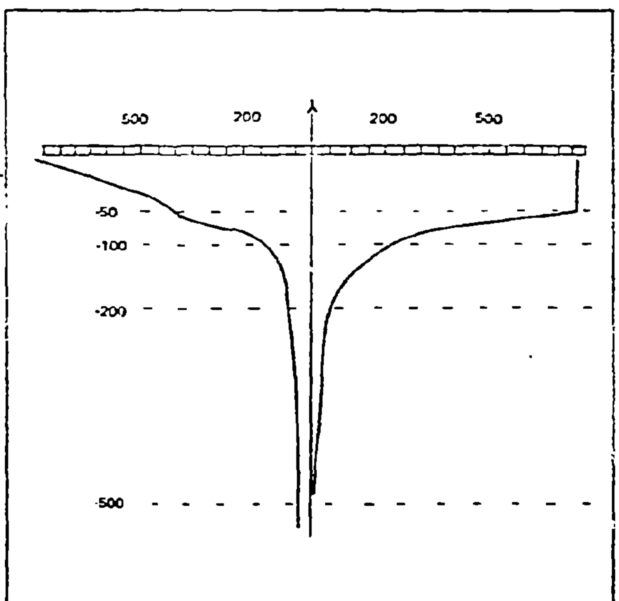


Mean Speed and Standard Deviation all Vehicles

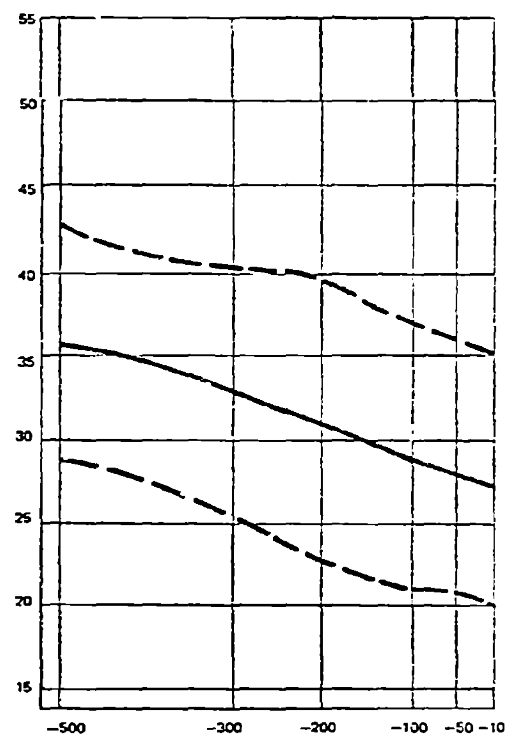


Maryland Rt. 170, Linthicum, Maryland.

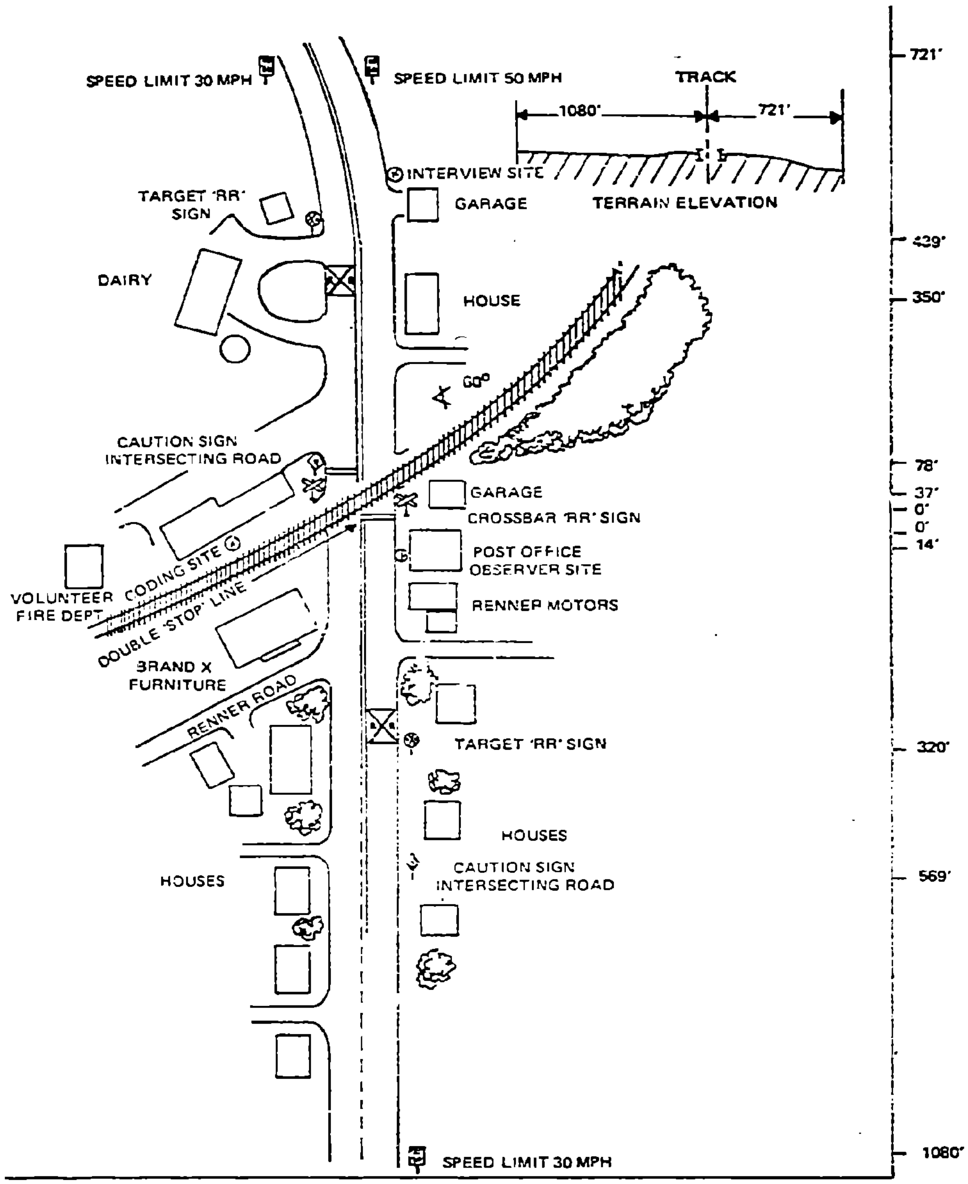
Site	Woodsboro Pike, New Midway, Maryland
Dates	July 19, 20, 1972
Times	1225 – 1930, 1305 – 1605
Railroad	Penn Central Transportation Company
Number of Tracks	1
Advance Warning	Standard Sign, Pavement Markings
Distance	320 Feet
Crossing Protection	Black Letters on White Crossbuck
Double Stop Lines?	Yes
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	Yes
Trains Observed	2
Range of Train Speeds	12 – 14 MPH
Posted Speed Limit	30 MPH
Mean Hourly Volume	67
Number of Drivers Who Stop Without Signal/Train	2



Sight Distance along Approach to Crossing

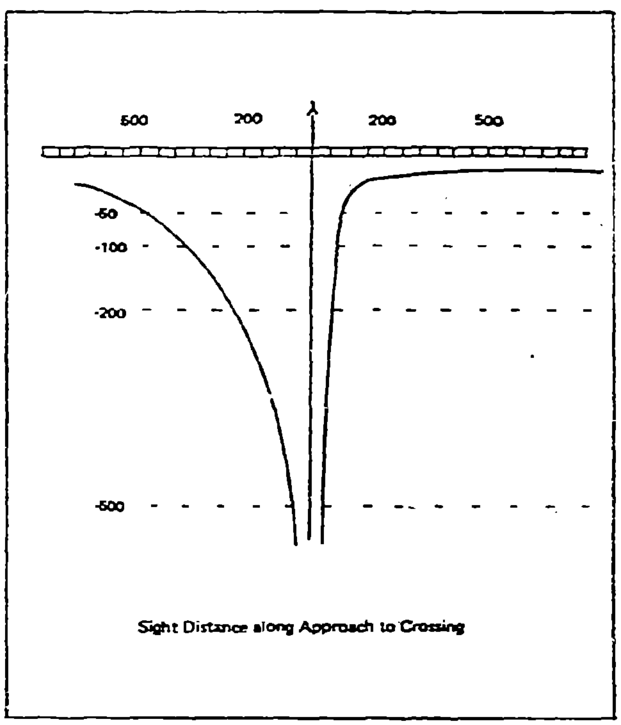


Mean Speed and Standard Deviation
all Vehicles

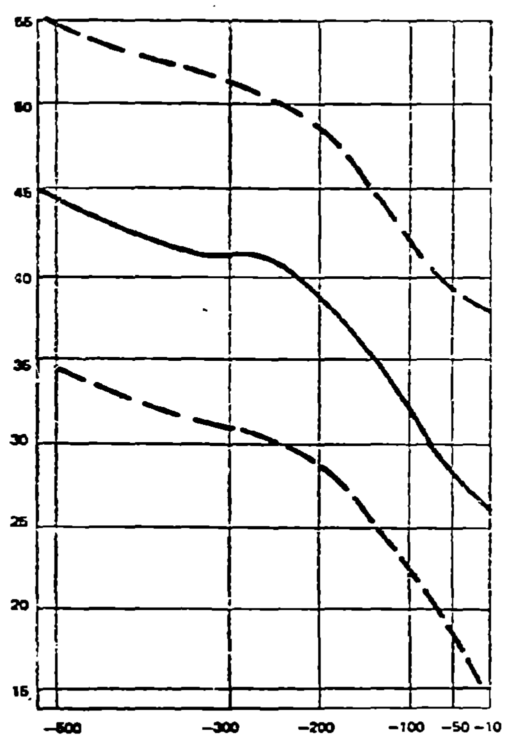


Woodsboro Pike, New Midway, Maryland.

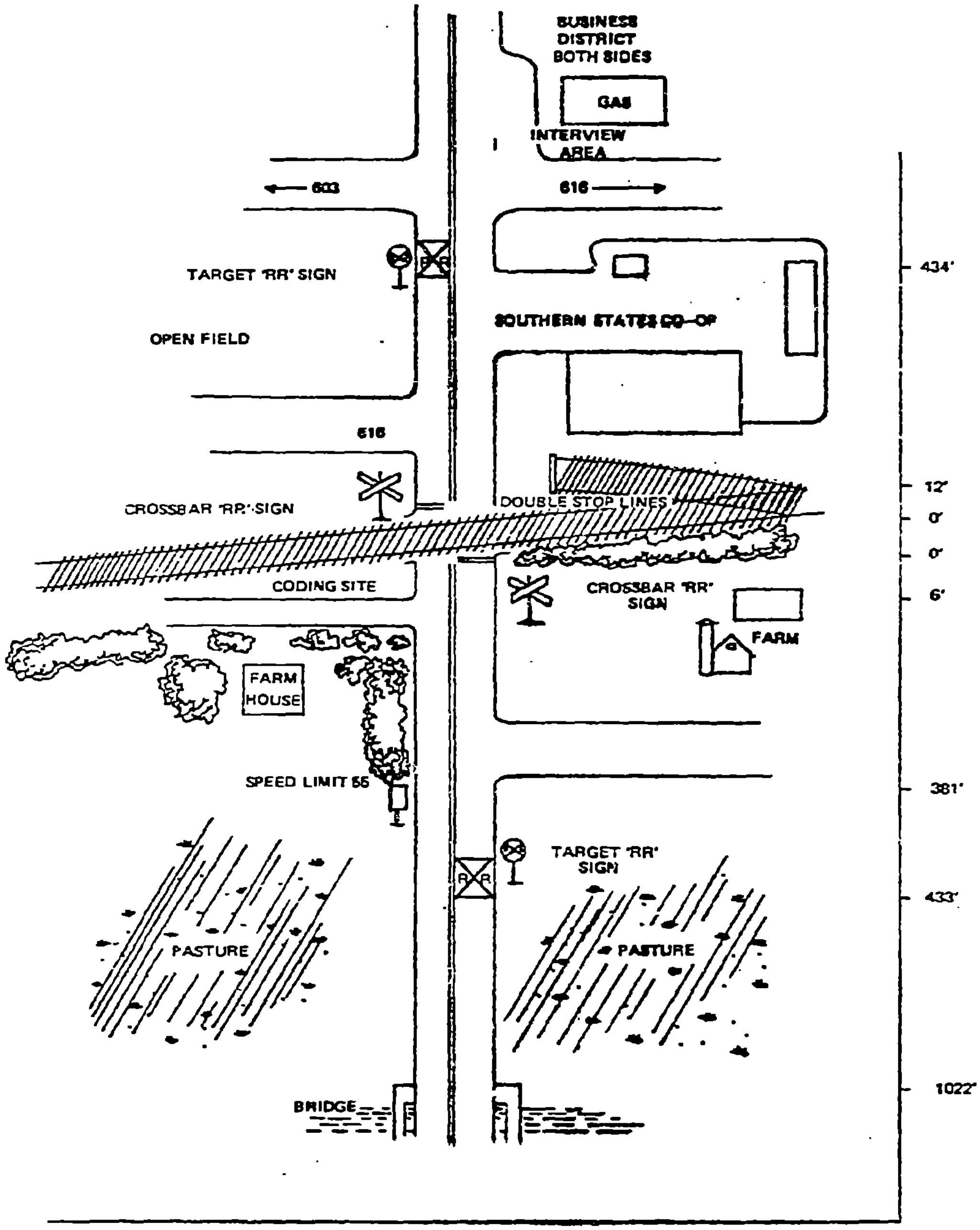
Site	Route 28, Calverton, Virginia
Dates	July 26, 27, 1972
Times	0835 – 1601, 0830 – 1746
Railroad	Southern Railway System
Number of Tracks	1
Advance Warning	Standard Sign, Pavement Markings
Distance	433 Feet
Crossing Protection	Black Letters on White Crossbuck
Double Stop Lines?	Yes
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	No
Trains Observed	0
Range of Train Speeds	–
Posted Speed Limit	55
Mean Hourly Volume	48
Number of Drivers Who Stop Without Signal/Train	19



Sight Distance along Approach to Crossing

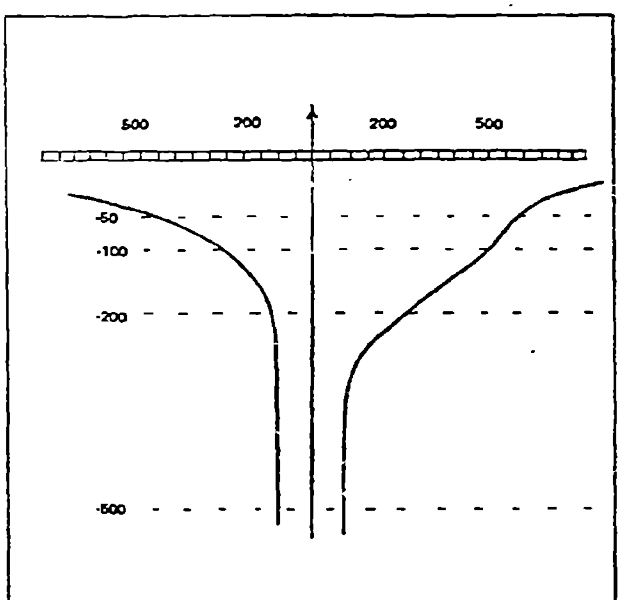


Mean Speed and Standard Deviation
all Vehicles

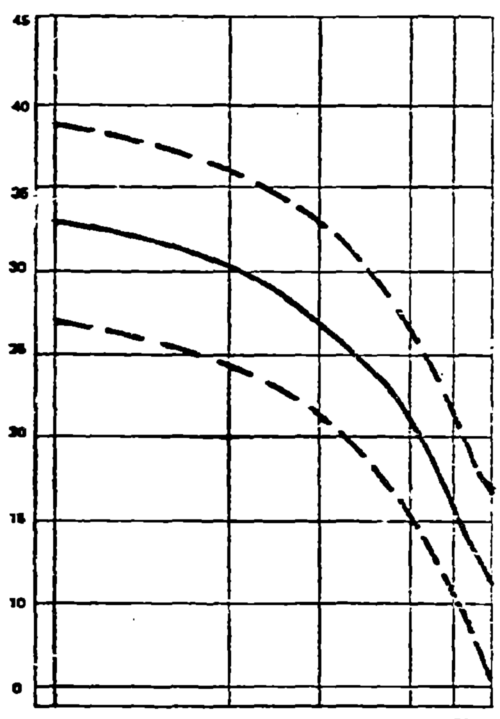


Virginia Rt. 28, Calverton, Virginia.

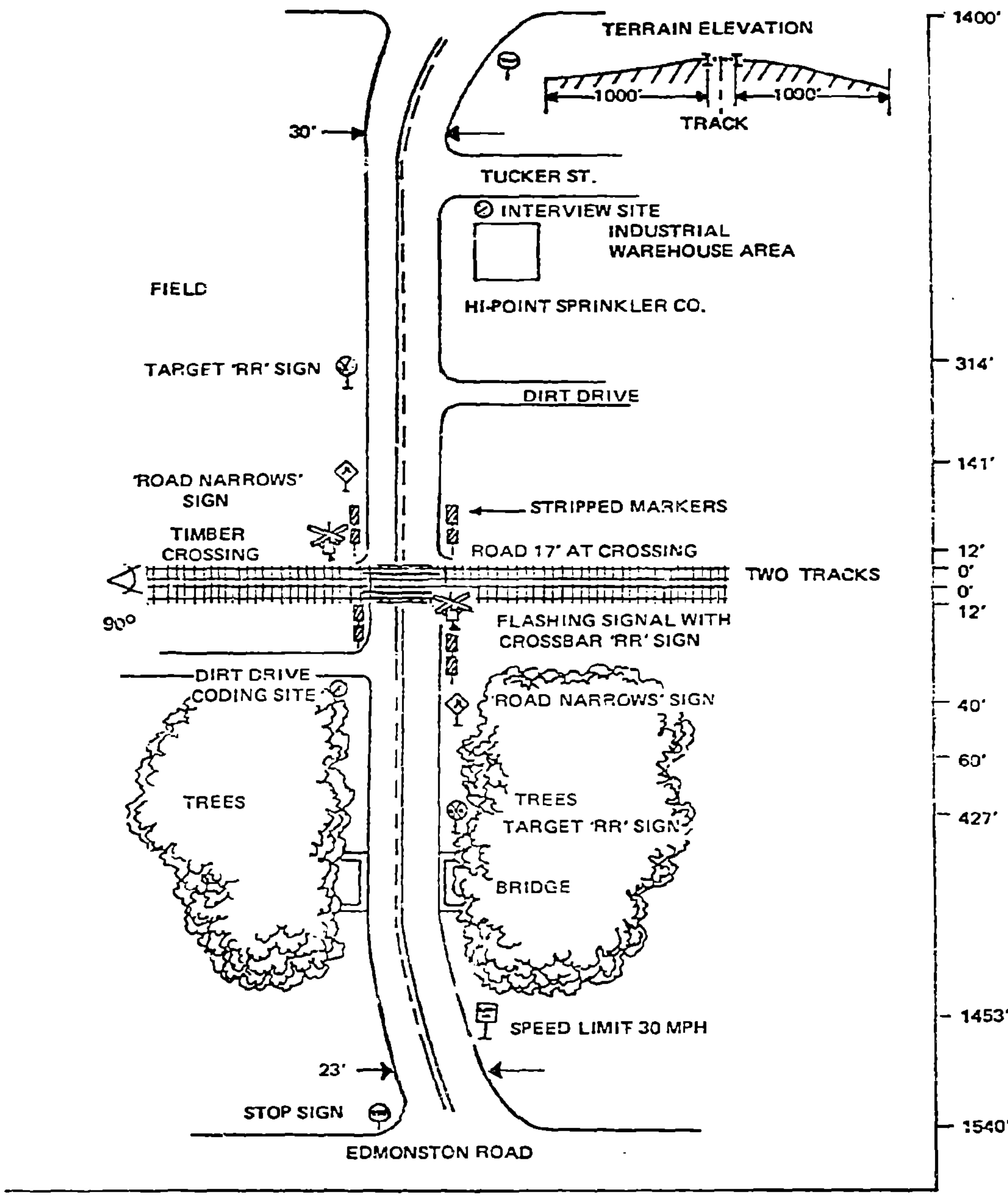
Site	Sunnyside Avenue, Beltsville, Maryland
Dates	July 10, 11, 1972
Times	1021 – 1845, 1345 – 1846
Railroad	Baltimore and Ohio Railroad Company
Number of Tracks	2
Advance Warning	Standard Sign
Distance	427 Feet
Crossing Protection	Black Letters on White Crossbuck, 4 Flashers, 6 Reflector Panels
Double Stop Lines?	No
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	Yes (Also "Stop on Red Signal")
Trains Observed	19
Range of Train Speeds	26 – 75 MPH
Posted Speed Limit	30 MPH
Mean Hourly Volume	167
Number of Drivers Who Stop Without Signal/Train	44



Sight Distance along Approach to Crossing

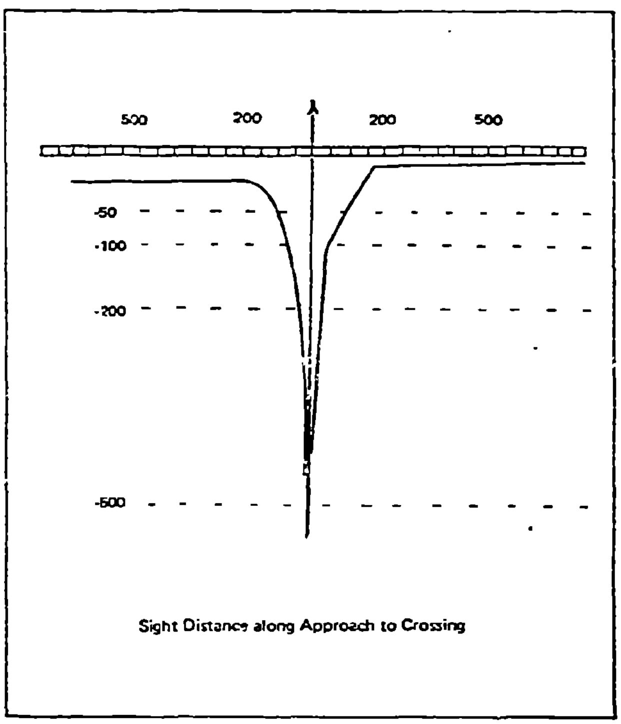


Mean Speed and Standard Deviation all Vehicles

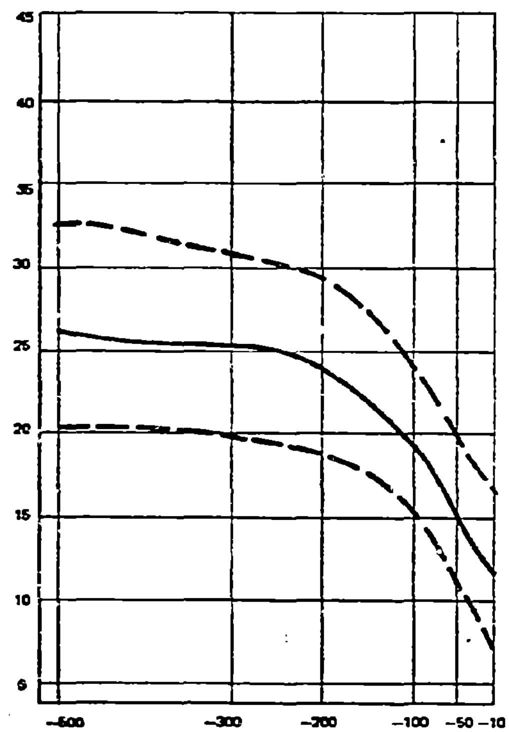


Sunnyside Avenue, Beltsville, Maryland.

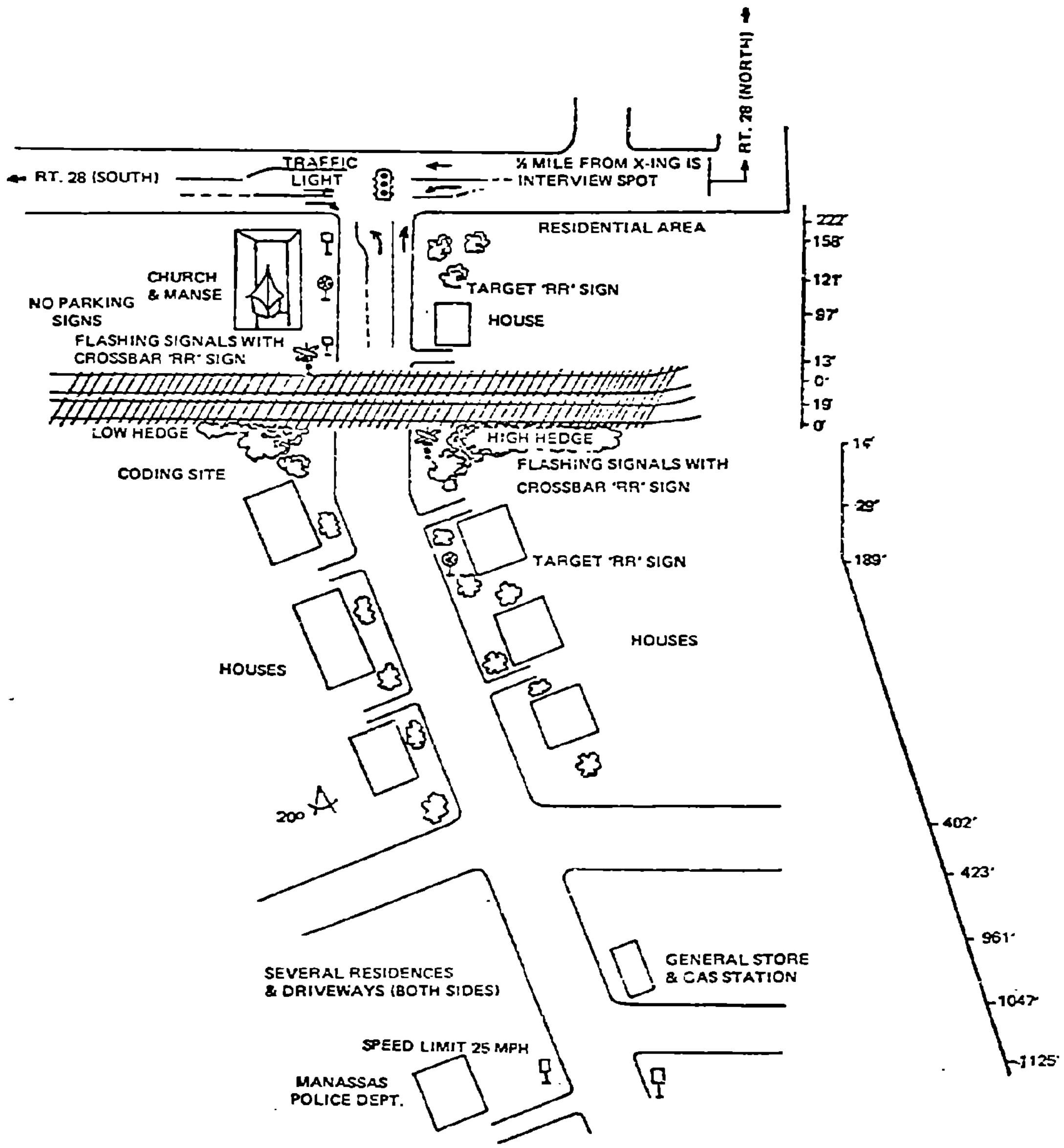
Site	Fairview Avenue, Manassas, Virginia
Dates	August 9, 10, 1972
Times	0950 – 1800, 0900 – 1358
Railroad	Southern Railway System
Number of Tracks	2
Advance Warning	Standard Sign
Distance	189 Feet
Crossing Protection	White Letters on Black Crossbuck, 4 Flashers
Double Stop Lines?	No
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	Yes
Trains Observed	19
Range of Train Speeds	5 – 39 MPH
Posted Speed Limit	25 MPH
Mean Hourly Volume	145
Number of Drivers Who Stop Without Signal/Train	39



Sight Distance along Approach to Crossing

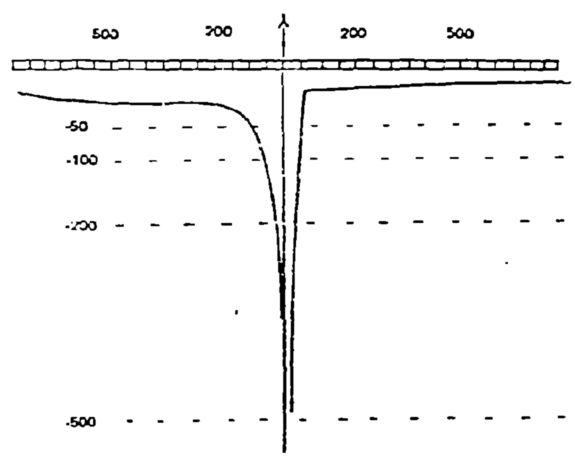


Mean Speed and Standard Deviation
all Vehicles

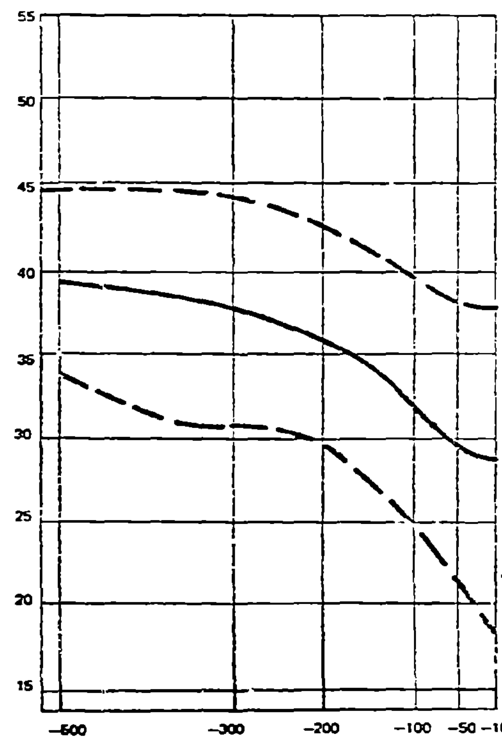


Fairview Avenue, Manassas, Virginia

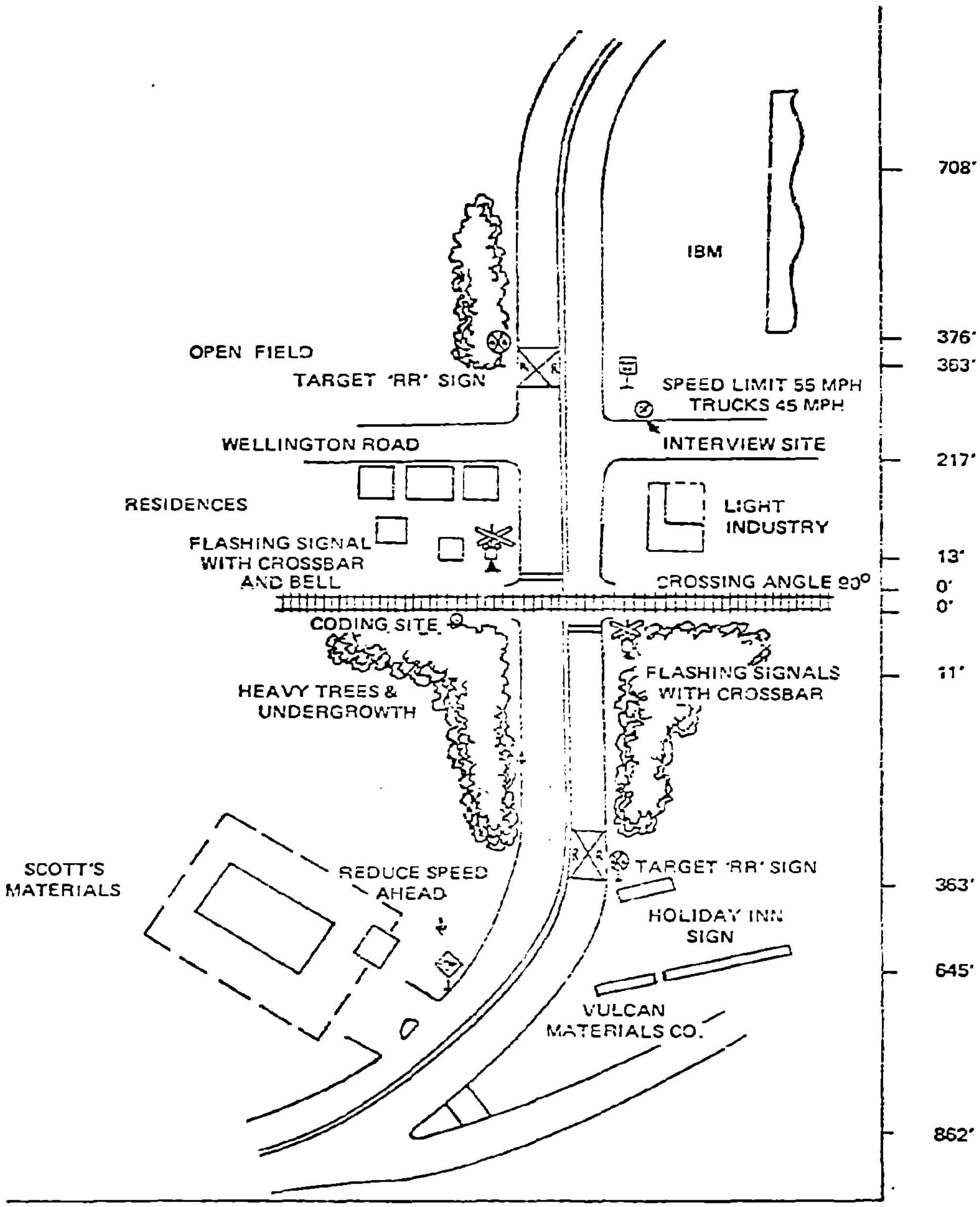
Site	Route 28, Manassas, Virginia
Dates	August 2, 3, 1972
Times	0910 – 1800, 0900 – 1329
Railroad	Southern Railway System
Number of Tracks	1
Advance Warning	Standard Sign, Pavement Markings
Distance	363 Feet
Crossing Protection	Black Letters on White Crossbuck, 4 Flashers, 1 Bell
Double Stop Lines?	Yes
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	No
Trains Observed	4
Range of Train Speeds	0 – 12
Posted Speed Limit	45 MPH
Mean Hourly Volume	191
Number of Drivers Who Stop Without Signal/Train	10



Sight Distance along Approach to Crossing

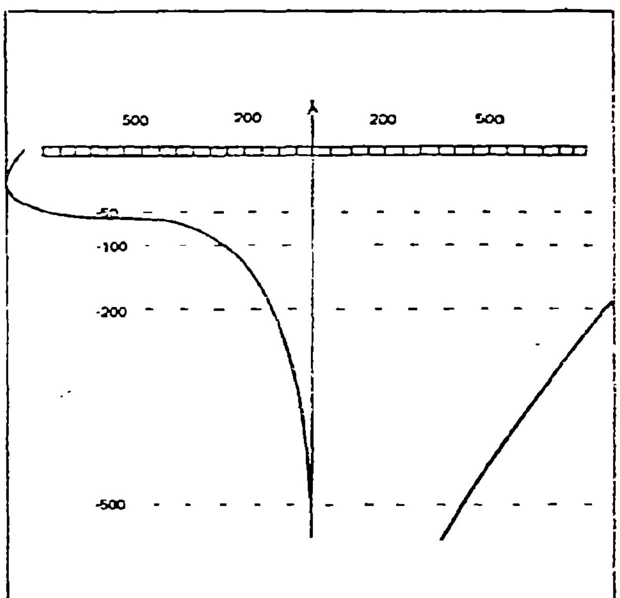


Mean Speed and Standard Deviation
all Vehicles

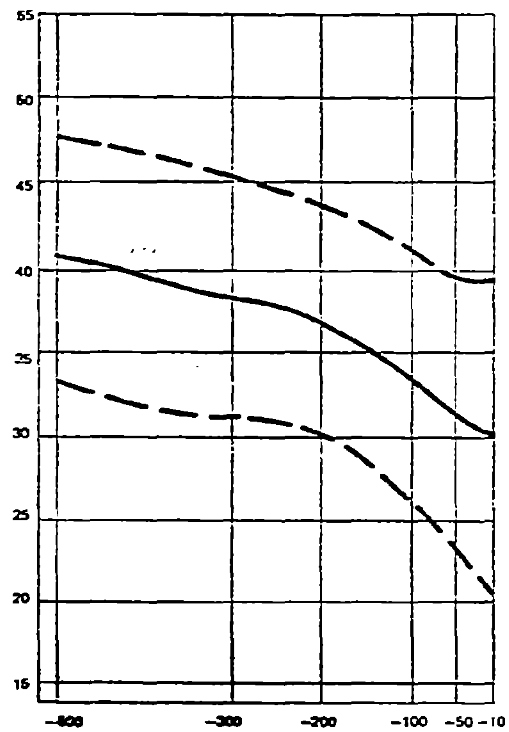


Virginia Rt. 28, Manassas, Virginia.

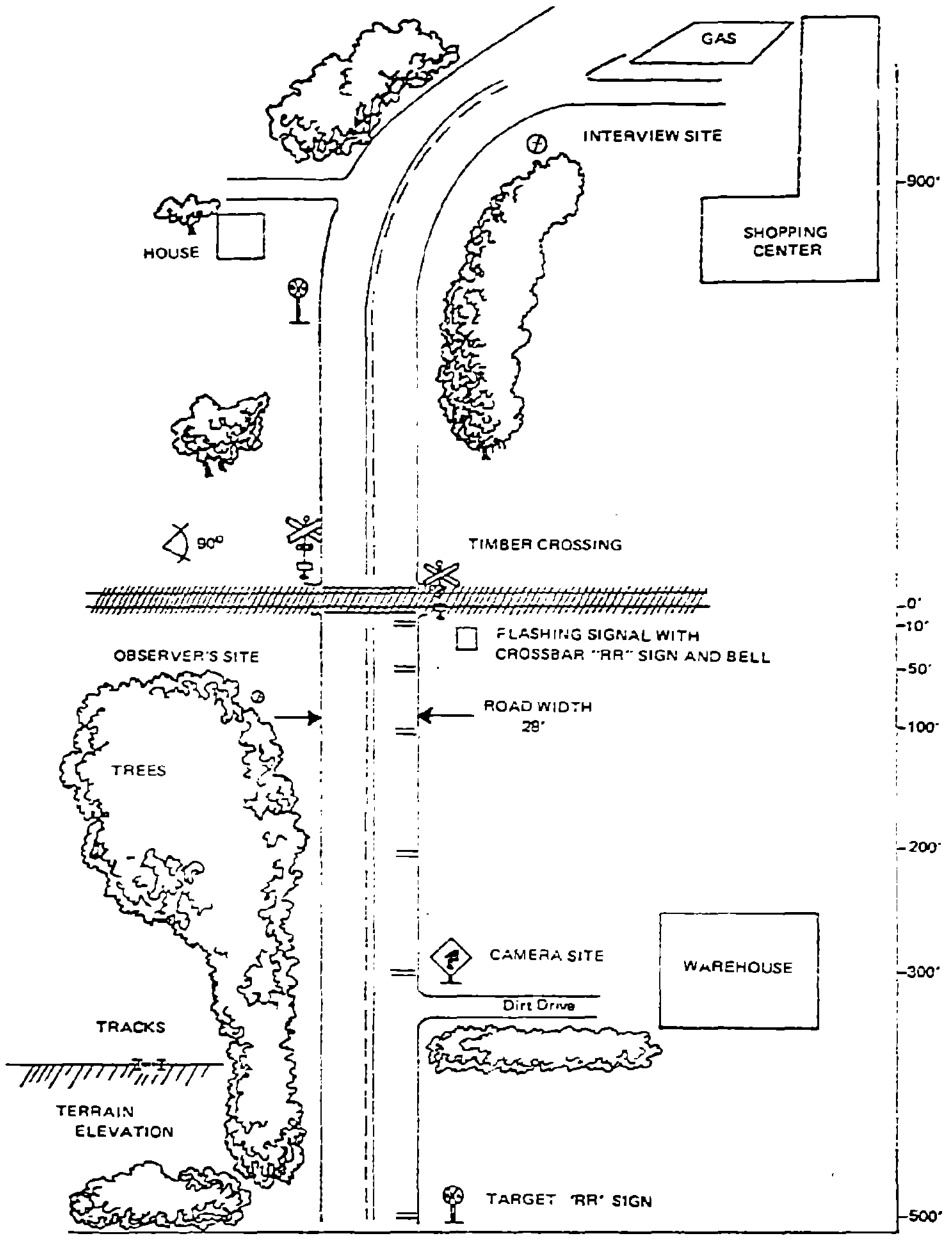
Site	Grange Hall Road, Holly, Michigan
Dates	July 25, 26, 1972
Times	0943 – 1600, 1155 - 1715
Railroad	Chesapeake and Ohio Railway Company
Number of Tracks	1
Advance Warning	Standard Sign
Distance	500 Feet
Crossing Protection	Black Letters on White Crossbuck, 4 Flashers, 2 Bells
Double Stop Lines?	No
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	No ("Stop on Red Signal")
Trains Observed	6
Range of Train Speeds	18 – 33
Posted Speed Limit	45 MPH
Mean Hourly Volume	154
Number of Drivers Who Stop Without Signal/Train	3



Sight Distance along Approach to Crossing

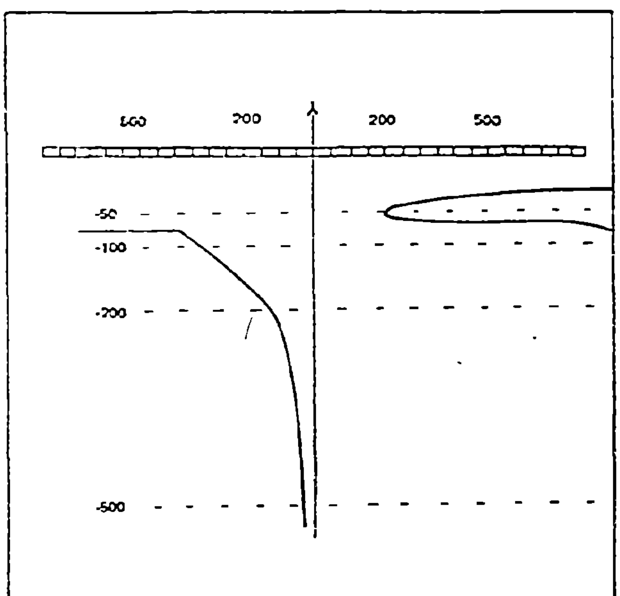


Mean Speed and Standard Deviation
all Vehicles

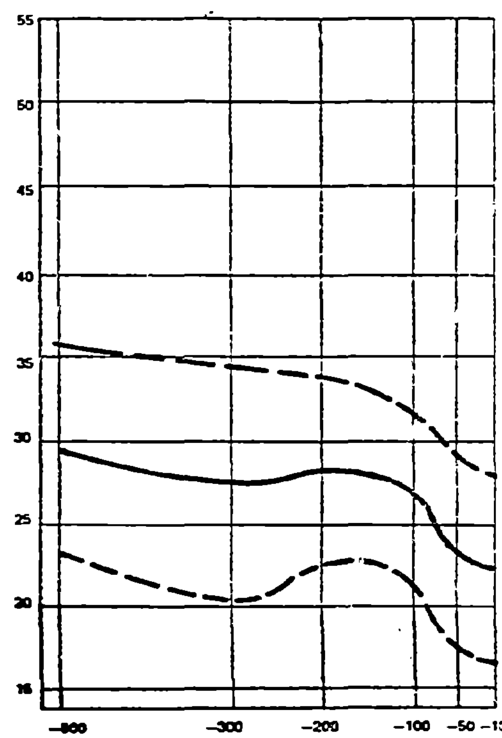


Grange Hall Road, Holly, Michigan.

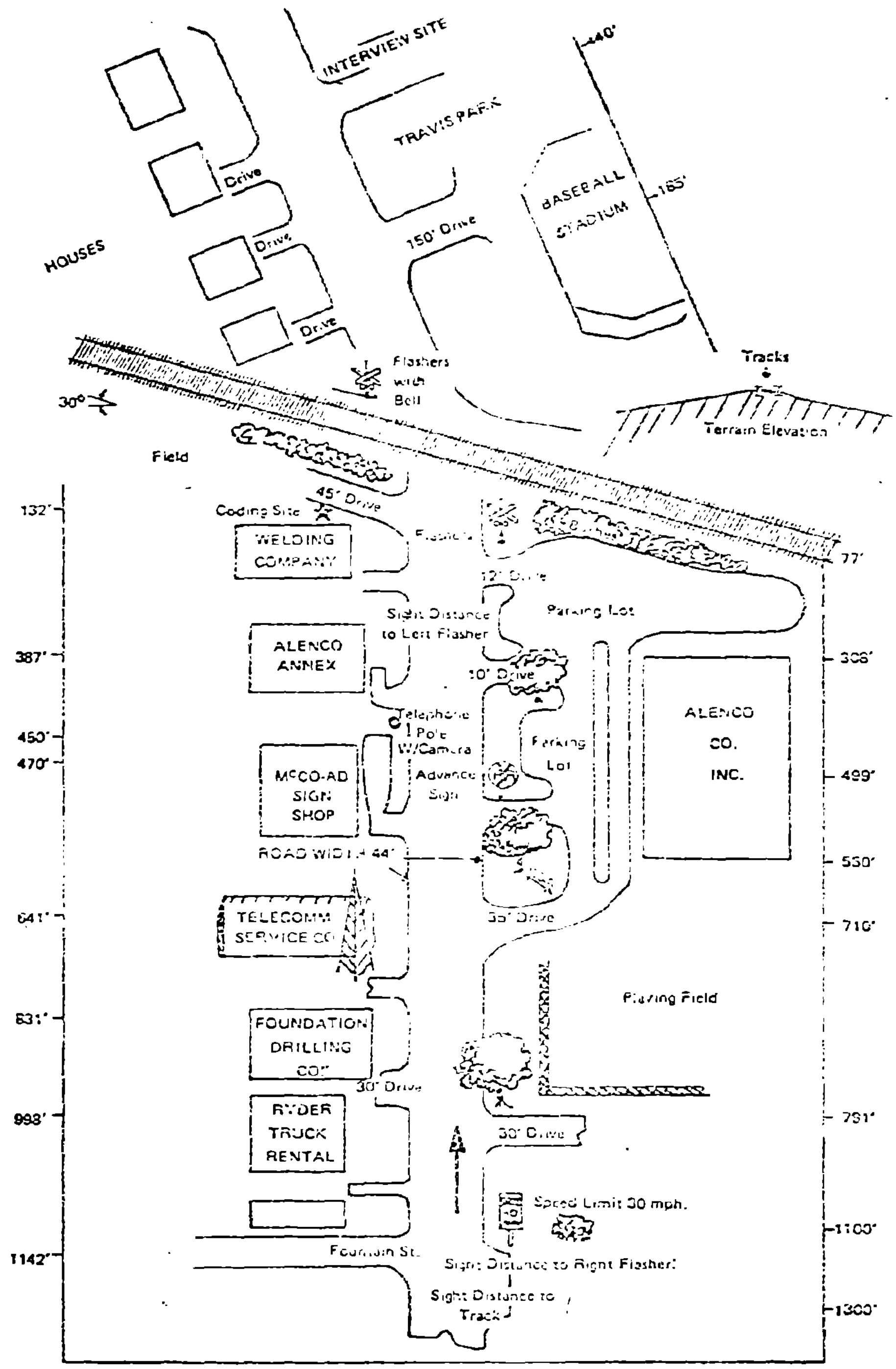
Site	Carson Avenue, Bryan, Texas
Dates	July 31, August 1, 1972
Times	1338 – 1800, 1000 – 1545
Railroad	Southern Pacific Railway Company
Number of Tracks	1
Advance Warning	Standard Sign
Distance	499 Feet
Crossing Protection	Black Letters on White Crossbuck, 4 Flashers, 1 Bell
Double Stop Lines?	No
Reflectorized Crossbuck?	Yes
Number of Tracks Sign?	No
Trains Observed	5
Range of Train Speeds	6 – 31 MPH
Posted Speed Limit	30 MPH
Mean Hourly Volume	165
Number of Drivers Who Stop Without Signal/Train	0



Sight Distance along Approach to Crossing

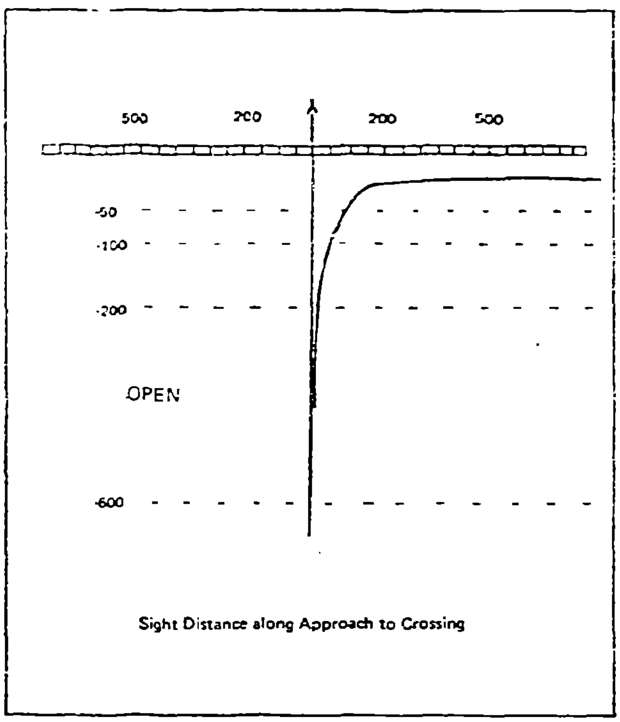


Mean Speed and Standard Deviation
all Vehicles

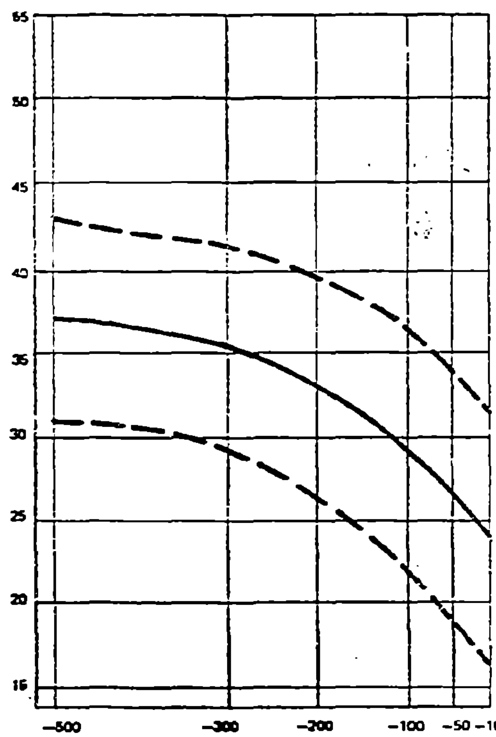


Carson Avenue, Bryan, Texas.

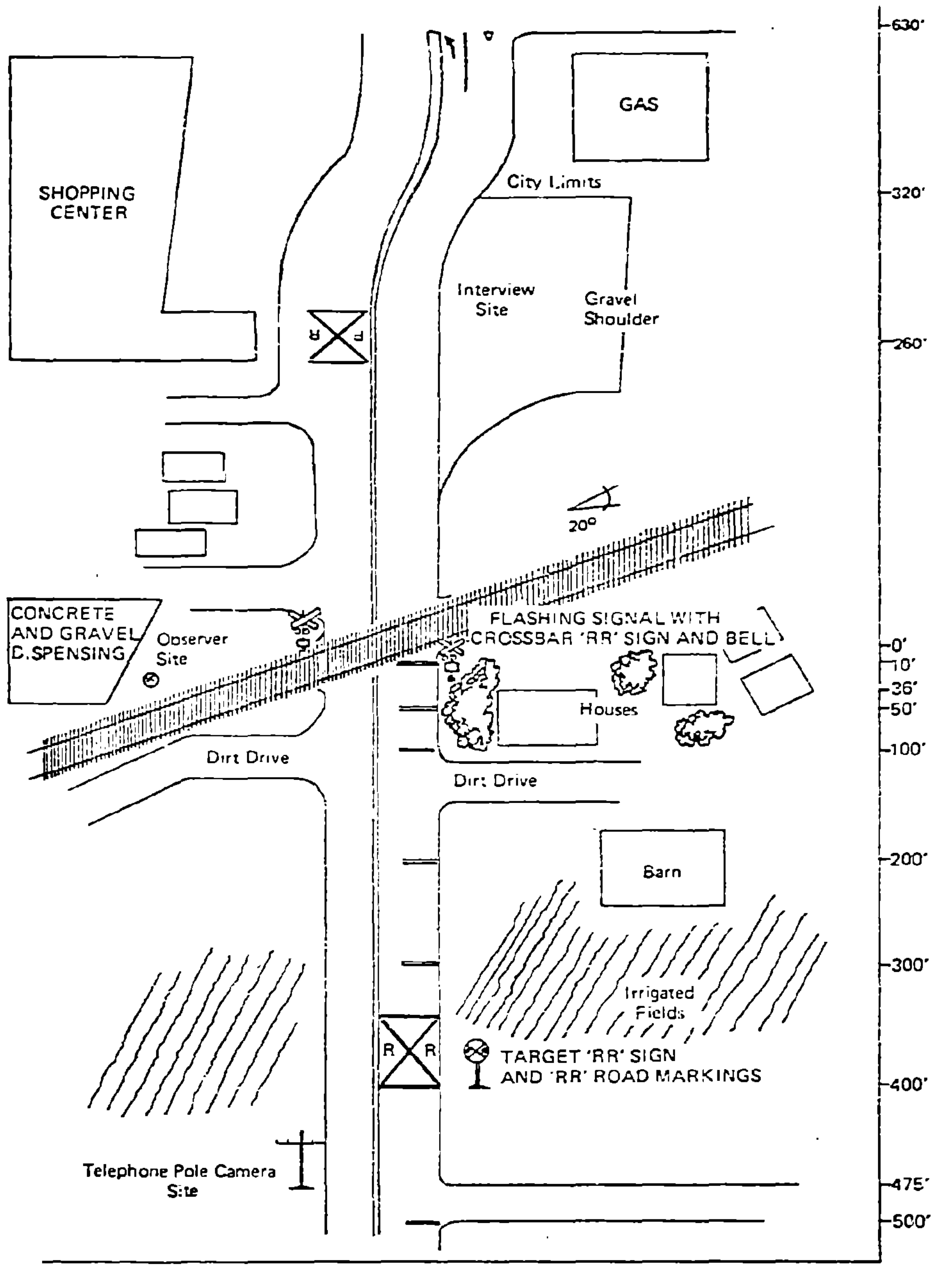
Site	Central Avenue, Milpitas, California
Dates	August 9, 10, 1972
Times	1000 – 1645, 1015 – 1555
Railroad	Western Pacific Railroad Company
Number of Tracks	1
Advance Warning Distance	Standard Sign, Pavement Markings 400 Feet
Crossing Protection Double Stop Lines? Reflectorized Crossbuck? Number of Tracks Sign?	Black Letters on White Crossbuck, 4 Flashers, 1 Bell Yes Yes No ("Stop on Red Signal")
Trains Observed	4
Range of Train Speeds	15 – 20
Posted Speed Limit	35 MPH
Mean Hourly Volume	291
Number of Drivers Who Stop Without Signal/Train	3



Sight Distance along Approach to Crossing



Mean Speed and Standard Deviation
all Vehicles



Central Avenue, Milpitas, California.

APPENDIX B

DEFINITION OF VARIABLES

Included in this appendix are the definitions of variables used for the data analysis conducted during this study. The first section defines the 176 fields of data recorded for each subject as applicable. The second section defines composite variables used in the generation of a large correlation matrix.

APPENDIX B

CONTENTS

Data Elements Recorded for Each Subject

Item	Description
1	Indicates which form of the questionnaire a subject was given. The following table shows which items were included on each form. Columns for items which were not administered to the subject are filled with 9s.

Items included on Form

FORM	1–29	30–45	46–81	82–104	105–130	131–144	145–176
1	X	X		X		X	X
2	X	X	X		X		X
3	X		X	X		X	X
4	X			X	X	X	X

2 Subject Number

3 Site

- 0 Sunnyside
- 1 Linthicum
- 2 New Midway
- 3 Calverton
- 4 PW28
- 5 Fairview
- 6 Michigan
- 7 Texas
- 8 California

4 Sorting Code

5 Time at Trap 1 - Hours, Minutes

6 Analysis Output Sequence Number

7

Vehicle type	Wheelbase
0 Motorcycles, compacts	< 8.5'
1 Standard cars	< 12.0'
2 Small 2-axle trucks	< 15.0'
3 Large 3-axle trucks	< 15.0'
4 Bus, 2 or 3 axle	> 15.0'
5 Semi, 4 or more axles	

8 Is there a vehicle between subject and crossing at subject's Trap 1 time?

yes = 1 no = 0

9 Lead vehicle type

Item	Description
10	Speed of lead vehicle at Trap 6 x 10 mph
11	Did subject driver look in advance area? yes = 1 no = 0
12	Did subject driver look in near area? yes = 1 no = 0
13	Speed of subject at Trap 1 x 10 mph
14	Speed of subject at Trap 2 x 10 mph
15	Speed of subject at Trap 3 x 10 mph
16	Speed of subject at Trap 4 x 10 mph
17	Speed of subject at Trap 5 x 10 mph
18	Speed of subject at Trap 6 x 10 mph
19	Tailway at Trap 1 if data not available = 9999
20	Percentage of change in tailway, (Trap 6 tailway ÷ Trap 1 tailway) x 100 If > 999 = 999. If < 1 = 1.
21	Was any missing data interpolated for? yes = 1 no = 0
22	Trap after which maximum deceleration occurred
23	Maximum deceleration expressed in ft/sec^2 x 10
24	Percentage of change in headway, (Trap 6 headway ÷ Trap 1 headway) x 100 If > 999 = 999. If < 1 = 1.
25	Headway at Trap 1 (expressed in feet). If not available = 9999.
26	Minimum time headway x 10. If > 999.9 = 999.9
27	Did vehicle stop? yes = 1 no = 0
28	Month
29	Day

Item	Description	Code
30	Sorting Code	1-4
31	Sorting Code	0000-9999
32	Subject Safety Index, (Item 105 + 106 - 107 - 108) x 1000	
33	Sorting Code	1
34	When you first realized you were approaching a crossing, did you slow down?	
	no.	(√= 0, blank = 1)
35	yes, in order to match the speed of the vehicle in front of you.	(blank = 0, √ = 1)
36	yes, so you could check for signals and trains	(blank = 0, √ = 1)
37	yes, because tracks are usually bumpy . .	(blank = 0, √ = 1)
38	yes, other.	(blank = 0, √ = 1)
39	Did you listen for a train?	
	yes	1
	no	0
40	Did you roll down your window?	
	it was down	(blank = 0, √ = 1)
41	yes	1
	no	0
42	Did you look down the tracks before crossing?	
	no	0
	left only	1
	right only	2
	both ways	3
43	no	0
	left only	1
	right only	1
	both ways	2
44	Did you come to a complete stop before crossing the tracks?	
	yes	1
	no	0
45	How fast do you think you were going when you crossed the tracks?	
	0-5 mph	0
	5-10 mph	1
	10-20 mph	2

Item	Description	Code
	20-30 mph	3
	30-40 mph	4
	40-50 mph	5
	over 50 mph	6
46	Sorting Code	1-4
47	Sorting Code	0000-9999
48	Looking (If S looked either place)	
	yes	1
	no	0
49	Sorting Code	2
50,51	What was your <u>first</u> indication you were approaching a railroad grade crossing?	
	an advance sign way up the road	0
	markings painted on the road	1
	saw the sign at the crossing	2
	knew it was there	3
	saw a train	4
	saw the lights flashing at the crossing .	5
	saw the tracks	6
52	If you saw an advance sign way up the road, what do you remember about the sign?	
	did not see an advance sign	(✓= 0, blank = 1)
53	the color:	
	if answer correct	1
	if incorrect	0
54	white	0
	yellow	1
	red	2
55	the shape:	
	if answer correct	1
	if incorrect	0
56	○	0
	□	1
	△	2
	▽	3
57	the symbol:	
	if answer correct	1
	if incorrect	0
58	X	0
		1
	RR	2
	R X R	3

Item	Description	Code
59	Did you know how many sets of tracks there were before you reached the crossing?	
	no	(✓= 0, blank = 1)
60	yes, remembered from when I was here before	(blank = 0, ✓ = 1)
61	yes, could see the tracks	(blank = 0, ✓ = 1)
62	saw sign showing the number of tracks . .	(blank = 0, ✓ = 1)
63	How many sets of tracks were there at this crossing?	
	if answer correct	1
	if incorrect	0
64	one	0
	two	1
	three	2
	four	3
	five	4
	don't know	5
65	If you saw markings painted on the road, what do you remember about them?	
	did not see any markings	(✓= 0, blank = 1)
66	the symbol:	
	if answer correct	1
	if incorrect	0
67	×	0
		1
	RR	2
	R×R	3
68	Was there anything that might have made it hard to tell if a train was coming?	
	no	(✓= 0, blank = 1)
69	yes, could not see very far down the tracks	(blank = 0, ✓ = 1)
70	yes, had to watch the vehicle ahead . . .	(blank = 0, ✓ = 1)
71	yes, people near the crossing were distracting	(blank = 0, ✓ = 1)
72	yes, other	(blank = 0, ✓ = 1)
73	What additions to the warning sign way up the road would have improved your confidence in approaching this crossing?	
	an indication of the number of tracks . .	(blank = 0, ✓ = 1)

Item	Description	Code
74	an indication of the type of device at the crossing	(blank = 0, √ = 1)
75	an indication of distance to the crossing	(blank = 0, √ = 1)
76	a suggested approach speed	(blank = 0, √ = 1)
77	flashing lights on the sign that are turned on by the train	(blank = 0, √ = 1)
78	adequate as is	(blank = 0, √ = 1)
79	other improvement suggestions	(blank = 0, √ = 1)
80	Is a train scheduled to come by about now?	
	yes, I think so	1
	no, I don't think so	0
	I don't know	9
81	yes, I think so	0
	no, I don't think so	1
	I don't know	2
82	Sorting Code	1-4
83	Sorting Code	0000-9999
84	Percentage of speed reduction, (Trap 1 velocity - Trap 6 velocity ÷ Trap 1 velocity) x 100	
85	Sorting Code	3
86	According to state and local law, what should you have done at this railroad crossing just now?	
	if answer correct	1
	if incorrect	0
87	stopped	0
	slowed down and been ready to stop, if necessary	1
	maintained speed unless you saw or heard a train	2
	no state law about speed at these crossings	3
88	Do all railroad crossings have a signal or gate that warns you when a train is coming?	
	yes	0
	no	1

Item	Description	Code
89	Do all railroad corssings have a sign way up the road warning you that there is a crossing ahead?	
	yes	0
	no	1
90	Most accidents occur at crossings:	
	having gates or lights	0
	without gates or lights	1
91	Most railroad crossing accidents occur:	
	after dark	0
	during the day	1
92	Most railroad crossing accidents occur during:	
	bad weather (fog, rain, snow)	0
	clear weather	1
93	Most accidents at crossings having signals are due to:	
	driver carelessness	1
	signals that fail to work	0
94	How many motorists do you think were killed in accidents at railroad crossings last year in the United States?	
	if answer correct	1
	if incorrect	0
95	less than 100	0
	100 - 500	1
	500 - 1000	2
	1000 - 1500	3
	1500 - 2000	4
	more than 2000	5
96	How many of the above accidents involved a driver who would be considered drunk under the law?	
	if answer correct	1
	if incorrect	0
97	about 10%	0
	about 25%	1
	about 50%	2
	about 75%	3
	about 90%	4
98	How many people do you think were killed in <u>all traffic accidents</u> on the streets and highways of the United States last year?	

Item	Description	Code
	if answer correct	1
	if incorrect	0
99	less than 1,000	0
	1,000 - 5,000	1
	5,000 - 10,000	2
	10,000 - 20,000	3
	20,000 - 30,000	4
	30,000 - 40,000	5
	40,000 - 50,000	6
	50,000 - 60,000	7
	60,000 or more	8
100	If a crossing does not have a signal, it usually means that:	
	only a few trains use the crossing	
	yes	0
	no	1
101	only slow trains use the crossing	
	yes	0
	no	1
102	Signals at crossings:	
	Always tell you when a train is coming	
	yes	0
	no	1
103	Warn you in plenty of time to stop	
	yes	0
	no	1
104	Ratio of railroad deaths to total deaths x 100	
105	(Looking -Site Mean Looking ÷ Site σ Looking) x 1000	
106	(Speed Reduction -Site Mean Speed Reduction ÷ Site σ Speed Reduction) x 1000	
107	(Trap Maximum Deceleration -Site Mean Trap Maximum Deceleration ÷ Site σ Trap Maximum Deceleration) x 1000	
108	(Critical Point -Site Mean Critical Point ÷ Site σ Critical Point) x 1000	
109	Do you recall receiving specific instruction or advice on railfoad crossing safety?	
	no	(0 =√, 1 = blank)
110	yes, in driver education classes in school	(0 = blank, 1 =√)

Item	Description	Code
111	yes, in other driver training	(0 = blank, 1 = ✓)
112	yes, through safety campaigns (radio, TV, etc.).	(0 = blank, 1 = ✓)
113	yes, in a driving license applicant's manual	(0 = blank, 1 = ✓)
114	yes, other	(0 = blank, 1 = ✓)
115	What is the average delay that you have experienced when stopped at a railway crossing?	
	0 - 30 seconds	0
	30 - 60 seconds	1
	2 minutes	2
	5 minutes	3
	10 minutes	4
	over 10 minutes	5
116	How long does it generally take a train to reach the crossing after the warning signal goes on?	
	0 - 10 seconds	0
	10 - 20 seconds	1
	20 - 60 seconds	2
	1 - 2 minutes	3
	2 - 4 minutes	4
	over 4 minutes	5
117	Have you ever crossed a track when the signal was on?	
	no	(0 = ✓, 1 = blank)
118	yes, train was stopped	(0 = blank, ✓ = 1)
119	yes, train was moving slowly	(0 = blank, ✓ = 1)
120	yes, train was far away	(0 = blank, ✓ = 1)
121	yes, no train in sight	(0 = blank, ✓ = 1)
122	yes, other cars were crossing the tracks	(0 = blank, ✓ = 1)
123	yes, vehicles behind me wanted to cross .	(0 = blank, ✓ = 1)
124	yes, police or railroad officials signaled me to cross	(0 = blank, ✓ = 1)
125	yes, did not see the signal	(0 = blank, ✓ = 1)
126	yes, other	(0 = blank, ✓ = 1)
127	How often do you see trains at railroad crossings?	

Item	Description	Code
	1 time out of every 2 times you cross a track	0
	1 time out of every 10 times you cross a track	1
	1 time out of every 25 times you cross a track	2
	1 time out of every 50 times you cross a track	3
	1 time out of every 100 times or more . .	4
128	Have you ever known anyone who got a traffic ticket for crossing a track when the signal was on or the gate was down?	
	yes	1
	no	0
129, 130	Which of the following are the two most effective measures to reduce crossing accidents?	
	more gates at crossings	0
	better warning signals at crossings . . .	1
	better warning signs way before the crossing	2
	improved driver education	3
	public safety campaigns	4
	stricter law enforcement	5
	require trains to whistle before crossing the road	6
	require trains to have more lights . . .	7
	lower speed limits for vehicles	8
	require trains to slow down before crossing the road	9
	all vehicles should stop at crossings . .	10
	signal in your vehicle that is turned on by an approaching train	11
131	Sorting Code	1-4
132	Sorting Code	0000-9999
133	Sorting Code	0-8
134	Sorting Code	5
135	Your Occupation	
	Salesman	1
	Repairman	2
	Truck Driver	3
	Research Scientist	4
	Housewife	5

Item	Description	Code
	Student	6
	Engineer	7
	Secretary	8
	Government Worker	9
	Contractor	10
	Technician	11
	Retired	12
	Teacher or Minister	13
	Laborer	14
	Construction Trade	14
	Postal Employee	15
	Self-Employed	16
	Military	17
	Policeman	18
	Waitress	19
	Bartender	20
	Draftsman	21
	Real Estate	23
	Artist	24
	Bank Employee	25
	Store Clerk	26
	Chauffeur	27
	Airline Employee	28
	Computer Operator	29
	Payroll Clerk	30
	Writer	31
	Fireman	32
	Farmer	33
	Plumber	14
	Barber, Hairdresser	34
	Nurse	35
	Justice of the Peace	36
	Bookeeper or Accountant	37
	Printer	38
	Veterinarian	39
	Keypunch	40
	Editor	41
	Mechanic	42
	Gas Station Attendant	43
	Attorney	44
	Processor	45
	Insurance	46
	None - Miscellaneous	48
136	How old are you?	
	16-20	0
	21-25	1

Item	Description	Code
	26-30	2
	31-35	3
	36-40	4
	41-45	5
	46-50	6
	51-55	7
	56 or over	8
137	About how many miles a year do you drive?	
	less than 5,000	0
	5,000 - 10,000	1
	10,000 - 15,000	2
	over 15,000	3
138	In what state did you get your first drivers license? (see item 162)	
139	Where do you live? coded by state only (see item 162)	
140	local	1
	non-local	0
141	How long have you lived there?	(# of years, 0 = less than 1 year)
142	What is the reason for your drive (vacation, going to work, going shopping, etc.)?	
	Working or Going to Work	1
	Returning Home	2
	Shopping	3
	Visiting	4
	Going to Doctor's	5
	Going to Baseball Game	6
	Going to Library or Post Office	7
	Enjoyment, Pleasure	8
	Going to School	9
	Going to Lunch	10
	Funeral	11
	Vacation	12
	Get Car Repaired.	13
	Get Haircut	14
143	How often do you drive across these tracks?	
	this is the first time	0
	once or twice before	1
	about once or twice a month	2
	about once or twice a week	3
	about once a day	4
	more than once a day	5

Item	Description	Code
144	How far do you live from this railroad crossing?	
	0-1/2 mile (up to 10 blocks)	0
	1/2-1 mile (10 to 20 blocks)	1
	1-2 miles	2
	2-5 miles	3
	5 miles or more	4
145	Sorting Code	1-4
146	Sorting Code	0000-9999
147	Sorting Code	0-9
148	Sorting Code	6
149	Weather	
	clear	1
	cloudy	2
	foggy	3
	other	4
150	Time of interview - 24 hour clock	0000-2400
151	Roadway conditions	
	dry	1
	wet	2
	ice	3
	snow	4
	other	5
152	Type of vehicle	
	passenger car	1
	small truck	2
	large truck	3
	tractor-trailer	4
	school bus	5
	commercial bus	6
	motorcycle	7
	other	8
153	Type of vehicle	
	passenger	1 (if 1 above)
	other	2 (if 2-8 above)
154	Driver's window position	
	closed	1
	partly opened	2
	fully opened	3

Item	Description	Code
155	Reason for selecting this vehicle	
	stopped when signal was off	1
	first to stop for signal or train	2
	crossed against signal or when train was visible	3
	nth vehicle	4
	other	5
156	Did vehicle stop for the train or signal	
	did not stop for train or signal	0 (if 3 above)
	yes	1 (if 2 above)
	no train or signal	9 (if 1, 4, or 5 above)
157	Radio	
	on	1
	off	0
	none	8
158	Air conditioner	
	on	1
	off	0
	none	8
159	Seat belt	
	on	1
	off	0
	none	8
160	Shoulder harness	
	on	1
	off	0
	none	8
161	Year of vehicle	00-99
162	State Licensed*	
	Alabama	1
	Alaska	2
	Arizona	3
	Arkansas	4
	California	5
	Colorado	6
	Connecticut	7
	Delaware	8
	Florida	9
	Georgia	10
	Hawaii	11

*Code 99 if data not collected

Item	Description	Code
	Idaho	12
	Illinois	13
	Indiana	14
	Iowa	15
	Kansas	16
	Kentucky	17
	Louisiana	18
	Maine	19
	Maryland	20
	Massachusetts	21
	Michigan	22
	Minnesota	23
	Mississippi	24
	Missouri	25
	Montana	26
	Nebraska	27
	Nevada	28
	New Hampshire	29
	New Jersey	30
	New Mexico	31
	New York	32
	North Carolina	33
	North Dakota	34
	Ohio	35
	Oklahoma	36
	Oregon	37
	Pennsylvania	38
	Rhode Island	39
	South Carolina	40
	South Dakota	41
	Tennessee	42
	Texas	43
	Utah	44
	Vermont	45
	Virginia	46
	Washington	47
	West Virginia	48
	Wisconsin	49
	Wyoming	50
	District of Columbia	51
	Foreign vehicles	52
163	Sex of driver	
	male	1
	female	0

Item	Description	Code	Number of responses
164	Number of occupants including driver		
	1	1	
	2	2	
	3	3	
	4	4	
	5	5	
	6	6	
	7	7	
	8 or more	8	
165	Driver wearing glasses		
	no	0	
	yes	1	
166	Sunglasses		
	no	0	
	yes	1	
167	Other windows opened		
	left vent	1	
	right vent	2	
	left rear	3	
	right rear	4	
	right front	5	
	tail gate	6	
	multiple windows	7	
168	Windshield foggy		
	yes	1	
	no	0	
169	Vehicle defects		
	door doesn't close	1	1
	valve rattle	2	1
	crunched fender or bumper	3	2
	broken tail- or headlight	4	4
	windshield leaks	5	1
	missing	6	1
	tailpipe rattling	7	1
	loud	8	2
	truck bed unsturdy	9	1
	back window covered	10	2
	hood banged in	11	1
	back window stickers	12	4
	seats back too far for size of driver . .	13	1
	poor condition	14	3
	age of vehicle (old)	15	14
	no tailgate (on truck)	16	1

Item	Description	Code	Number of responses
170	Physical defects - driver		
	deaf	1	0
	cataracts	2	1
	problem with eyes	3	1
	pregnant	4	5
	used crutches or walking chair	5	2
	very young	6	3
	very old	7	10
	throat trouble (speech bad)	8	1
	illiterate	9	6
	shakey	10	1
	drunk	11	1
	spacey, tired, or high (not coherent) . .	12	1
	eating while driving	13	2
	noisy children	14	1
	noisy dog	15	1
	baby being held in front seat	16	1
	van with both back doors open	17	1
171	What first caused vehicle to stop		
	saw the train	1	
	heard the train's whistle or bell	2	
	heard the train's rumble	3	
	heard the bell at the crossing	4	
	saw the crossing signal lights	5	
	saw the gates coming down	6	
	saw the other motorists stopping	7	
	usually stop	8	
	always stop	9	
	other	10	
172	What first caused vehicle to stop		
	saw something	1 (#1, 5, 6, or 7 above)	
	heard something	2 (#2, 3, or 4 above)	
	habit	3 (#8 or 9 above)	
173	What caused vehicle to continue across tracks ahead of train		
	train was stopped	0	
	train was moving slowly	1	
	train was far away	2	
	no train in sight	3	
	other cars were crossing tracks	4	
	vehicles behind me wanted to cross . . .	5	
	police or railroad officials	6	
	did not see the signal	7	
	other	8	

Item	Description	Code
174	What caused vehicle to continue across tracks ahead of train	
	train movement	0 (#0, 1, 2 above)
	did not see signal or train	1 (#3, 7 above)
	social pressure	2 (#4, 5 above)
175	How fast did driver think train was moving	
	0-10 mph	0
	10-20 mph	1
	20-30 mph	2
	30-40 mph	3
	40-50 mph	4
	50-60 mph	5
	60-70 mph	6
	over 70 mph	7
	did not see train	8
176	Distance at which stopping distance plus 3/4 second reaction time equals distance to the track (expressed in feet).	

CORRELATION MATRIX OF BEHAVIOR

ATTITUDE AND KNOWLEDGE ITEMS

The following material describes the correlation matrix of the eighteen variables defined below. The information presented within each cell was:

- Number of subjects
- Correlation of row element with column element
- Lower limit of .01 confidence interval
- Upper limit of .01 confidence interval
- Mean of X (column)
- Standard deviation of X
- Mean of Y (row)
- Standard deviation of Y

Correlations were made for each of the nine locations at which data were collected, and for groups consisting of all sites, passive sites, active sites and the geographically matched sites. Complete sets of data were obtained for all vehicles, passenger vehicles, those without a lead vehicle within 500 feet at the time the subject was 500 feet from the rail-highway grade crossing, and combinations of these.

A significant result (.01 level) was indicated by a confidence interval which did not include zero.

Variable Definitions
for
Correlation Matrix

Variable 1

Description. Knowledge of railroad crossing annual fatalities and all traffic accident fatalities. Score based on picking correct response to the following questions.

Q 94 How many motorists do you think were killed in accidents at railroad crossings last year in the United States? answer = 3

Q 99 How many people do you think were killed in all traffic accidents on the streets and highways of the United States last year? answer = 7

Derivation. Each individual was scored 0 for an incorrect answer, 1 for a correct answer to each question, and the scores summed. Therefore, the score totals were either 0, 1, or 2.

Interpretation. Scores provide an indication of the individual's knowledge of the actual number of railroad crossing and highway fatalities.

Variable 2

Description. Knowledge of railroad crossing annual fatalities and all traffic accident fatalities. Score based on actual response to Q 94 and Q 99 (See Variable 1).

Derivation. The response categories were assigned a score as follows:

Responses to Q 94		Responses to Q 99	
less than 100	0	less than 1000	0
100 - 500	1	1000 - 5000	1
500 - 1000	2	5000 - 10,000	2
1000 - 1500	3	10,000 - 20,000	3
1500 - 2000	4	20,000 - 30,000	4
more than 2000	5	30,000 - 40,000	5
		40,000 - 50,000	6
		50,000 - 60,000	7
		60,000 or more	8

The scores for both questions were summed. Therefore the score total ranged from 0 to 13 (5 + 8).

Interpretation. Scores provide a rank indication of the individuals' perceptions of fatalities involved in railroad crossing accidents and all traffic accidents.

Variable 3

Description. Relative magnitude of railroad fatalities to all motor vehicle fatalities.

Derivation. Score expressed as a ratio of the actual response to Q 94 to the actual response of Q 99 (See Variable 2).

Interpretation. Scores indicate the individuals' perceptions of the importance of railroad crossing fatalities relative to all highway accident fatalities.

Variable 4

Description. Knowledge of railroad grade crossing signs and signals and accident causation. Score based on picking correct response to the following seven questions.

Q 88 Do all railroad crossings have a signal or gate that warns you when a train is coming? yes or nc

Q 89 Do all railroad crossings have a sign way up the road warning you that there is a crossing ahead? yes or no

Q 90 Most accidents occur at crossings:
having gates or lights,
without gates or lights.

Q 91 Most railroad crossing accidents occur: after dark, during the day.

Q 92 Most railroad crossing accidents occur during: bad weather (fog, rain, snow), clear weather.

Q 93 Most accidents at crossings having signals are due to: driver carelessness, signals that fail to work.

Q 96 How many of the above accidents (railroad crossing fatalities) involved a driver who would be considered drunk under the law? About 10%, 25%, 50%, 75%, 90%.

Derivation. Each question was scored 0 for an incorrect answer and 1 for each correct answer. The scores for all seven questions were summed. Scores could range from 0 to 7.

Interpretation. Scores provide an indication of the individual knowledge of railroad crossings and railroad crossing accidents.

Variable 5

Description. Knowledge of railroad crossing state and local laws and knowing anyone ticketed for breaking such laws. Score based on picking the correct response to the following two questions.

Q 88 According to state and local law, what should you have done at this railroad crossing just now?

stopped

slowed down and been ready to stop, if necessary

maintained speed unless you saw or heard a train

no state law about speed at these crossings

Q 128 Have you ever known anyone who got a traffic ticket for crossing a track when the signal was on or the gate was down?

yes

no

Derivation. Each question was scored 0 for an incorrect answer and 1 for a correct answer. The scores were summed. Scores could range from 0 to 2.

Interpretation. Score provides an indication of the person's knowledge of state/local laws on railroad crossings and his knowledge of any enforcement of these laws.

Variable 6

Description. Indication of how often individual drives across the tracks and how far he lives from the site. Based on responses to the following two questions.

Q 143 How often do you drive across these tracks?

this is the first time	0
once or twice before	1
about once or twice a month	2
about once or twice a week	3
about once a day	4
more than once a day	5

Q 144 How far do you live from this railroad crossing?

0-1/2 mile (up to 10 blocks).	0
1/2 to 1 mile (10 to 20 blocks)	1
1-2 miles	2
2-5 miles	3
5 miles or more	4

Derivation. The responses to each question were assigned the "score" value indicated above and summed as follows:

Score Q 143 + (4 -Score Q 144)

Question 144 is weighted so that the farther one lives from the crossing the lower the score. Scores could range from 0 to 9.

Interpretation. Socre provides an indication of the individual's familiarity with the site, the higher the score the greater the familiarity with the crossing.

Variable 7

Description. Indication of individual's familiarity with the site and knowledge of train schedule. Based on responses to the following two questions.

Q 60 Did you know how many sets of tracks there were before you reached the crossing?

no

yes, remembered from when I was here before

Q 80 Is a train scheduled to come by about now?

yes, I think so

no, I don't think so

Derivation. Each question was scored 1 for a yes and 0 for a no. The scores were summed and could range from 0 to 2.

Interpretation. Scores provide an indication of familiarity with the site, the higher the score the greater the level of familiarity.

Variable 8

Description. Age of the driver based on the response to the following item.

Q 136 How old are you?

	Category
16-20	0
21-25	1
26-30	2
31-35	3
36-40	4
41-45	5
46-50	6
51-55	7
56 or over	8

Derivation. Each age group was assigned the category number indicated above.

Interpretation. Driver's age, eight categories (the higher categories for the older age groups).

Variable 9

Description. Indication of individuals signal obeying behavior and seat belt/shoulder harness usage. Based on the response to the following question.

Q 117 Have you ever crossed a track when the signal was on?

no	0
yes	1

And observations regarding restraint system usage

Q 159 Seat belt

on	1
off	0

Q 160 Shoulder harness

on	1
off	0

Derivation. Each item was scored as indicated above and the scores summed as: (1 + Q 159 + Q 160 - Q 117)

Interpretation. Drivers who were observed to use available safety equipment and who stated that they do not violate traffic control devices form a safer set of drivers.

Variable 10

Description. Knowledge of advance sign and number of tracks at the site. Based on responses to the following questions.

Q 52 Did you see an advance sign way up the road?

yes	1
no	0

Q 53 Do you remember the color?

white
yellow — correct = 1
red

Q 55 the shape?

○
□
△
▽

correct = 1

Q 57 the symbol?

correct = 1

Q 63 How many sets of tracks were there at this crossing?

correct answer = 1

Derivation. Each item was scored as indicated and the scores summed.

Interpretation. The index provides an indication of the accuracy of the individual's observation of the presence of and characteristics of the advance warning sign as well as his observation of the number of tracks.

Variable 11

Description. Indicates individual's perception of the reasons/purposes of railroad crossing signals. Based on responses to the following questions.

Q 100 If a crossing does not have a signal, it usually means that:

only a few trains use the crossing

yes 0

no 1

Q 101 only slow trains use the crossing

yes 0

no 1

Q 102 Signals at crossings:

Always tell you when a train is coming

yes 0

no 1

Q 103 Warn you in plenty of time to stop

yes 0

no 1

Derivation. Each item was scored as indicated above and the scores summed. Scores could range from 0 to 4.

Interpretation. The response to the above questions provides an indication of the level of understanding of railroad protective systems, and the level of confidence individuals have in being protected from a train hazard.

Variable 12

Description. Indicates sex of driver as follows:

Q 163 Sex of driver

male	1
female	0

Derivation. Coded as indicated.

Interpretation. Indicator of demographic characteristics.

Variable 13

Description. An indication of the individual's crossing behavior in terms of stopping, looking and listening. Based on responses to the following questions.

Q 36 When you first realized you were approaching a crossing, did you slow down so you could check for signals and trains?

yes	1
no	0

Q 34 Did you listen for a train?

yes	1
no	0

Q 41 Did you roll down your window?

yes	1
no	0

Q 43 Did you look down the tracks before crossing?

no	0
left only	1
right only	1
both ways	2

Q 44 Did you come to a complete stop before crossing the tracks?

yes 1

no 0

Derivation. Coded as indicated above. Scores summed, can range from 0 to 5.

Interpretation. These elements constitute a self-reporting measure of hazard detection behavior.

Variable 14

Description. An indication of the driver's looking behavior. Based on the following two observations.

Q 11 Did subject driver look in advance area?

yes 1

no 0

Q 12 Did subject driver look in near area?

yes 1

no 0

Derivation. A driver who looked for trains in either or both areas was assigned a score of 1.

Interpretation. Drivers who were observed to look for trains during their approach to a crossing have a higher probability of detecting a train and are therefore considered safer drivers than the balance of the population.

Variable 15

Description. The percent speed reduction from a point 500 feet in advance of the crossing to a point 10 feet before the crossing.

Derivation. Speeds measured at the above two points were used to calculate P, where $P = (V_{500} - V_{10} \div V_{500})$

Interpretation. A driver who decelerates during the approach to a crossing is presumed to be more concerned about the hazard of the intersection than a driver who does not do so. A large number represents a greater speed decrease.

Variable 16

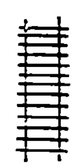
Description. A measure of the point of maximum deceleration.

Derivation. The driver's speed at six points along the approach to a crossing, and his time between pairs of points were used to calculate mean deceleration figures between pairs of points. The value assigned is the point number (1 to 5) preceeding the segment where the maximum mean deceleration was calculated.

Interpretation. A driver who changes speed from 50 to 20 miles per hour during the approach to a crossing but who slows down early in the approach is considered to have a greater opportunity to detect hazard than another driver who slows down very late in the approach.

The points were assigned as shown below. A larger number refers to a later deceleration.

Distance	500'	300'	200'	100'	50'	10'
Point Number	1	2	3	4	5	6



Variable 17

Description. The distance before the crossing when the speed of the vehicle is such that a maximum effort would not be adequate to stop before reaching the crossing.

Derivation. The speed profile for each vehicle was converted to an equation stating distance from the crossing as a function of velocity. This function was subsituted into the equation for the minimum stopping distance required of a typical passenger vehicle as a function of speed including an assumed typical 0.75 second reaction time, and a solution was calculated for the approaching vehicle's critical distance.

Interpretation. A driver who approaches a crossing with no capability to stop is less able to avoid a train conflict than a driver who is able to stop his car. A larger number refers to less safe behavior.

Variable 18

Description. A computed "safety index" combining Variables 14, 15, 16, and 17.

Derivation. Normalized values (obtained by subtracting the site mean and dividing by the standard deviation) for variables 14, 15, 16, and 17 were combined as follows:

(Variable 14 + Variable 15) - (Variable 16 + Variable 17)

or ("Looking Index") + (Speed Reduction Ratio) - (Point of Maximum Deceleration) - ("Critical Distance")

The values can range from -10 to +10. The mean of the index for each site is zero.

Interpretation. The safety index indicates the relative safety behavior of drivers based on looking for trains, reducing speed, slowing down early in the approach, and maintaining a stopping capability. The higher the index, the more safe the behavior.