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GRADE CROSSING SAFETY
Studies & Reports

ANALYSIS OF NPRM STROBE LIGHTS ON LOCOMOTIVES

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FINAL REPORT

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16. Abstract

This regulatory analysis was prepared using the procedures developed in Railroad Safety Economics: A Guidebook for the Analysis of Regulations (prepared by IOCS, Inc., for the Federal Railroad Administration, February 1978). It includes an evaluation of the effectiveness of strobe lights, an analysis of the benefits and an estimation of the costs of the proposed regulation, and a measure of the economic impact of the regulation on the railroad industry.

The benefits of strobe lights are measured against the accident information for 1975 and 1976 contained in the Rail-Highway Grade-Crossing Accident/Incident data base. A methodology was developed, utilizing fault tree analysis, modeling, and human factors analysis, to postulate the expected value of benefits associated with the use of strobe lights on locomotives. Fault tree analysis indicated those accidents which would be affected by the presence of strobe lights. Modeling and human factors analysis were then utilized to develop multipliers which estimated the reduction in the number of accidents for each applicable accident circumstance of the fault tree analysis.

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ANALYSIS FOR NPRM
STROBE LIGHTS ON LOCOMOTIVES
(Docket No. RSGC - 2)

GUIDEBOOK FOR THE ANALYSIS OF PROPOSED REGULATIONS ISSUED BY THE FEDERAL RAILROAD ADMINISTRATION

by

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May 26, 1978

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INTRODUCTION

This analysis for NPRM of STROBE LIGHTS ON LOCOMOTIVES (Docket No. RSGC - 2) is prepared using the procedures developed for the GUIDEBOOK FOR THE ANALYSIS OF PROPOSED REGULATIONS ISSUED BY THE FEDERAL RAILROAD ADMINISTRATION.

The analysis includes an examination of the Effectiveness of strobe lights in preventing accidents, an estimate of the Benefits and an evaluation of the Costs of the proposed regulation and a measure of the Economic Impact of the regulation on the railroad industry.

Where current sources were not readily available and research was unable to provide current information, estimates were derived from an evaluation of the best sources of information.

The application of strobe lights is measured against the accident information for 1975 and 1976 contained in the Rail-Highway Grade-Crossing Accident/Incident data base.

The effectiveness, expected value of benefits and costs were analyzed for two strobe light specifications - the TSC recommendation* and currently available equipment**.

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* Hopkins, John B. and A. T. Newfell. Guidelines for Enhancement of Visual Conspicuity of Trains at Grade Crossings, Cambridge, MA: Transportation Systems Center, 1975. (DOT/FRA)

** per Whalen Engineering, Deep River, Connecticut.

SUMMARY

Based on the analysis of STROBE LIGHTS ON LOCOMOTIVES for Notice of Proposed Rule Making:

- Effectiveness -- of the 24,250 records for rail-highway motor vehicle grade-crossing accidents on the data base, 13,572 accidents are of a nature where strobe lights could be effective to some degree. Effectiveness, as evaluated by a fault tree analysis, is estimated as the avoidance of 149 fatalities, 680 injuries and 1,697 accidents on an annual basis, for the TSC recommendation and 124 fatalities, 566 injuries and 1,414 accidents for the currently available equipment.
- Benefits -- the average societal cost of a rail highway crossing accident, based on available data, is $318,740 per fatality, $35,845 per injury and $3,695 per accident. The annual expected value (benefit) of the regulation is estimated as $78,137,275 for the TSC system and $65,036,760 for the currently available equipment. The present value * benefit of strobe lights is $558.6 million and $464.9 million, respectively.

* All present value calculations are based on a 20 year project evaluation and a 10 percent discount rate.

- Costs -- the present value cost of application and subsequent maintenance of strobe lights is $70,600,000 for the TSC system and $32,300,000 for the currently available equipment.
- The net present value of the use of strobe lights is $488.0 million for the TSC system and $432.6 million for the currently available equipment.
- Economic impact for the systems are a benefit of $41.7 million to the railroads for the TSC system and $61.4 million for the currently available equipment.

BENEFITS OF STROBE LIGHTS

The benefits of the use of strobe lights are calculated as the cost of accidents avoided - the average cost of crossing accidents times the estimated number of accidents avoided.

Base Alternative -- are the accidents recorded on the FRA Rail-Highway Grade-Crossing Accident data base for 1975 and 1976.

Base Alternative Projection -- a projection of future rail-highway crossing accidents is particularly complex because of the uncertainty of the effect of increasing traffic and the potential influence of various alternate approaches to rail-highway crossing safety.

A study by the California Public Utilities Commission * stated that "The correlation between accident rates and various independent variables listed was just not there, possibly because of the few number of accidents occurring." A correlation between vehicle registrations and accidents, and train-miles and accidents was not possible from FRA accident data.

There are other rail-highway grade-crossing safety programs in progress, whose purpose is to reduce crossing accidents. Some of these are Operation Lifesaver, which stresses education, engineering and enforcement; Amtrak's program to either upgrade or close high-accident crossings in Florida where a high portion of passenger train accidents occur; the FHWA analysis of strobe lights on safety gate arms; and

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* California Public Utilities Commission. The Effectiveness of Automatic Protection in Reducing Accident Frequency and Severity of Public Grade Crossing in California, June, 1974. (NTIS No. PB-254 799).

various Federal-State programs to identify hazardous crossings and upgrade their warning devices.

The elimination of branchlines and consolidation of main-lines may also reduce the number of crossings and have at least some effect on crossing accidents.

The evaluation of other programs may be beyond the scope of the analysis of strobe lights under the existing manual guidelines. An approach between the projection of accidents as a function of increased traffic on the one hand and increased warning measures and reduced number of crossings on the other would be the use of the present data as the projection for future years.

Cost Categories -- average cost in 1977 dollars has been calculated for rail-highway grade-crossing accidents:

- Fatalities -- NHTSA 1975 * societal cost less legal, administration, property damage and traffic delay costs - $280,540 inflated to 1977 prices $315,900.
- Injuries -- A search was unsuccessful in locating current injury severity data for rail-highway crossing accidents. The 1972 FRA Report to Congress: Rail-Highway Safety Part II ** contained societal costs

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* Faigin, Barbara Moyer. 1975 Societal Cost of Motor Vehicle Accidents, Washington, DC: Planning and Evaluation, NHTSA/DOT, December 1976.

** Federal Highway Administration. Report to Congress. Railroad-Highway Safety Part II: Recommendations for Resolving the Problem, Washington, DC: FHA/DOT, August 1972, pp. 77. (NTIS No. PB-213 115).

of $22,000 and $29,000 for injuries incurred in urban and rural grade-crossing accidents. These figures were prorated by the number of urban and rural crossings *; property damage, legal, administrative and miscellaneous costs were deducted and the remaining figure was adjusted to reflect an average injury cost figure of $34,700.

- Railroad Property -- damage figures for collisions at grade crossings were obtained for 1975 and 1976 from the FRA Accident/Incident Bulletin. After adjustments were made to reflect damages below the reporting threshold and for inflation, the average cost per accident in 1977 was $800.00.
- Wreck Clearing -- the total dollars from ICC account 415 ** for 1975 (the latest year available) were prorated on the ratio of railroad property damage for collisions at grade crossings to the total railroad property

* Hitz, John S., Editor. Summary Statistics of the National Railroad-Highway Crossing Inventory for Public At Grade Crossings, Cambridge, MA: Transportation Systems Center, 1977. (DOT/FRA).

** Interstate Commerce Commission. Eighty-Ninth Annual Report on Transport Statistics in the United States for the Year Ended December 31, 1975, Washington, DC: ICC, 1975 damage (.043), divided by the total number of crossing accidents and adjusted for an average cost of $335.00.

- Loss and Damage -- AAR statistics for loss and damage attributable to Train Accidents in 1975 ($60,705,703) * were prorated and adjusted as above (Wreck Clearing) for an average of $265.00.
- Non-Railroad Property -- the program retrieval of the FRA Rail-Highway Grade-Crossing Accident/Incident data base, 1975 and 1976, provided the total dollars for motor vehicle property damage. This figure was divided by the number of accidents, and adjusted for inflation for an average cost per accident of $1,755.00.
- Railroad Administrative and Legal Expenses -- In lieu of data not available from the railroads, legal and court and insurance administration data were utilized from NHTSA 1975 for fatality, injury (AIS 3) ** and property damage. The

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* Association of American Railroads. Freight Loss and Damage, Chicago, IL: Freight Claim and Damage Prevention Division, Operations and Maintenance Department, AAR, 1975.
** Abbreviated Injury Scale -- A consistent scale for collecting and analyzing injury severity data utilized by NHTSA and other agencies.

The property damage figure was subtracted from the fatality and injury figures, allowing property damage to apply to all accidents. The resulting average costs per occurrence are $2,760.00, $1,100.00 and $45.00 for fatalities, injuries, and accidents, respectively.

- Lost Utilization and Productivity -- for equipment, personnel and cargo, at an average two-hour delay per accident, is estimated as $310/accident.
- Societal Services -- most commonly provided would be accident investigation by the police. From NHTSA 1975 the respective adjusted net values are $80.00, $45.00 and $5.00 for fatalities, injuries and accidents.
- Inconvenience Cost -- is the estimated value attached to traffic delay based on an adjusted value from NHTSA 1975 - $180.00.

The reduction in crossing accidents was calculated by analyzing the causes of rail grade-crossing accidents and calculating the impact of strobe lights. The detail of this analysis is attached as an appendix.

By listing out the causes of grade-crossing accidents, certain factors were determined to relate to the effectiveness of strobe lights. These were:

- Speed of the motor vehicle
- Speed of the locomotive
- Awareness of the locomotives
    - Obstruction of view
    - Weather
    - Lighting on the locomotive
    - Lighting at the grade crossing
    - Warning devices at the grade crossing
- Presence of the strobe light on the leading part of the train

The typical accident prevention event was judged to be where the motorist becomes aware of the locomotive and stops the vehicle, in time, to avoid collision. It was assumed that the strobe light would be mostly effective in alerting the motorist while the motorist was in motion towards the tracks. Therefore, the obstructions of view of the locomotive and braking distances for the vehicle to avoid collision were considered.

The 24,250 accident records for the 1975 and 1976 period were analyzed for accidents that would not be prevented with a strobe light on the locomotive. Accidents attributed to vehicles stopped or stalled on tracks (6,094 of the accidents) were omitted. Also omitted were accidents involving locomotives pushing a train and those involving freight cars moving and standing (2,342 accidents). * If the motor vehicle struck the train past the 20th rail car these were removed since the effect of even a 360 degree strobe would be minimal (567 accidents). If the view of the tracks was obstructed as indicated by the FRA accident statistics, these

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* See Data fields 15 and 16 of the Rail-Highway Grade Crossing Accident/Incident Report — copy in appendix attached.

accidents were removed since a strobe light would not provide warning in time for a moving vehicle (1,733 accidents). Pedestrian accidents were removed since these usually occur for reasons that a strobe light cannot much impact (989 accidents).

For the remaining accidents, the effectiveness of strobe lights was estimated under varying conditions. These conditions were:

- Visibility
  - Day
  - Night
  - Dusk/Dawn
- Crossing Illumination
- Weather
  - Clear/Cloudy
  - Rain/Sleet
  - Fog
- Presence of grade crossing devices
- Speed of train
- Speed of vehicle

By calculating whether the strobe light was alerting the motorist for different distances from the track, different vehicle and train speeds, and under different driving conditions, a percentage of accidents occurring under these different circumstances were determined to be preventable.

These preventable accidents depend upon every motorist's averting the accident when sufficient time and strobe light alerting is present. It is extremely unlikely that every motorist would react effectively in these circumstances. It is judged that between 25 and 75 percent of the motorists would react effectively. Final calculation of benefits resulting from reduced accidents are based on 50 percent of the motorists reacting effectively when a 1100 candela strobe is used and 60 percent when a 4000 candela strobe is used.*

As a result of this analysis it was found that 1,414 (to 1,697 for the higher intensity strobe) accidents would be prevented for each year that every locomotive was equipped with strobe lights, and that the reduction in injuries per year would be 566 (680) and the reduction in fatalities would be 124 (149). Motorist vehicle damage would be reduced by $2,132,084 ($2,558,502) per year. Reduced damage to railroad property, wreck clearing and loss and damage would be $2,022,377 ($2,426,853) per year. Reduced lost utilization and productivity would be $438,340 ($526,070).

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* See pages 38 and 48 regarding the basis for this assumption.

Benefits Summary Form

Regulation Strobe Lights on Locomotives - TSC Recommendation (4000 candela)

Cost Category	Number	Cost/Source*	Total Cost
Fatalities	149	$ 315,900 (F)	$ 47,069,100
Injuries	680	34,700 (I)	23,596,000
Societal		—	
Railroad Medical		—	
Railroad Property	1,697	800 (A)	1,357,600
Wreck Clearing	1,697	335 (A)	568,495
Loss & Damage	1,697	265 (A)	449,705
Non Railroad Property	1,697	1,755 (A)	2,978,235
Administrative Railroad	149	2,760 (F)	411,240
and Legal Expenses	680	1,100 (I)	748,000
	1,697	45 (A)	76,365
Lost Utilization and Productivity	1,697	310 (A)	526,070
Passenger Service			
Societal Services	149	80 (F)	11,920
Position Costs	680	45 (I)	30,600
	1,697	5 (A)	8,485
Inconvenience Cost	1,697	180 (A)	305,460
Railroad Viability		—	
Health and Productivity		—	
TOTAL			$78,137,275

* F - Fatalities
I - Injuries
A - Accident

Benefits Summary Form

Regulation Strobe Lights on Locomotives - Currently Available System (1100 candela)

Cost Category	Number	Cost/Source*	Total Cost
Fatalities	124	$ 315,900 (F)	$ 39,171,600
Injuries	566	34,700 (I)	19,640,200
Societal		—	
Railroad Medical		—	
Railroad Property	1,414	800 (A)	1,131,200
Wreck Clearing	1,414	335 (A)	473,690
Loss & Damage	1,414	265 (A)	374,710
Non Railroad Property	1,414	1,755 (A)	2,481,570
Administrative Railroad	124	2,760 (F)	342,240
and Legal Expenses	566	1,100 (I)	622,600
	1,414	45 (A)	63,630
Lost Utilization and Productivity	1,414	310 (A)	438,340
Passenger Service			
Societal Services	124	80 (F)	9,920
Position Costs	566	45 (I)	25,470
	1,414	5 (A)	7,070
Inconvenience Cost	1,414	180 (A)	254,520
Railroad Viability		—	
Health and Productivity		—	
TOTAL			$ 65,036,760

* F - Fatalities
I - Injuries
A - Accident

EXPECTED VALUE OF BENEFITS PROJECTION

REGULATION Strobe Lights   LEAD TIME ½ year   ($ Millions)

ALTERNATIVE TSC Recommendation (4000 candela)   IMPLEMENTATION SCHEDULE 3 years   (# Units M)

Base Alternative	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of Units	29*	29	29	29. . .																	
Costs		78.1	78.1	78.1 . . .																	
Expected Value of Benefits																					
Number of Units PRE	0	20	10	0	0	0 . . .															
POST		9	19	29	29	29 . . .															
Average POST Units		.15	.46	.81	1.0	1.0 . . .															
Effectiveness Multiplier	(included elsewhere)																				
Combined Probability																					
Costs		78.1	78.1	78.1	78.1 . . .																
Expected Value of Benefits		11.7	35.9	63.3	78.1	78.1 . . .															

* Number of locomotives based on Yearbook of Railroad Facts, 1977 Edition, Association of American Railroads, Washington, DC; plus an adjustment for Class II and commuter railroad authority locomotives.

EXPECTED VALUE OF BENEFITS PROJECTION

REGULATION: Strobe Lights — LEAD TIME: ½ year — ($ Millions)

ALTERNATIVE: Equipment Currently Available (1100 candela) — IMPLEMENTATION SCHEDULE: 3 years — (# Units M)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Base Alternative																					
Number of Units	29*	29	29	29. . .																	
Costs		65.0	65.0	65.0 . . .																	
Expected Value of Benefits																					
Number of Units PRE	0	20	10	0	0	0 . . .															
POST		9	19	29	29	29 . . .															
Average POST Units		.15	.46	.81	1.0	1.0 . . .															
Effectiveness Multiplier	(included elsewhere)																				
Combined Probability																					
Costs		65.0	65.0	65.0	65.0 . . .																
Expected Value of Benefits		9.8	29.9	52.7	65.0	65.0 . . .															

* Number of locomotives based on Yearbook of Railroad Facts, 1977 Edition, Association of American Railroads, Washington, DC; plus an adjustment for Class II and commuter railroad authority locomotives.

COSTS OF REGULATION

The costs of strobe lights are generated for two specifications. Both cases include the following considerations: three-year implementation schedule, installation during normal locomotive maintenance, subsequent maintenance required at five-year intervals, and no cleaning aside from regular locomotive washing.

TSC Recommendation - (4000 candela) *

DAY 800-4000 candela
NIGHT 100-400 candela
DIM 50-100 candela
DAY/NIGHT transition automatic - photocell
automatic hookup to horn and/or whistle
ON/OFF manual override

Though this specification is not in production, an approximate quote of $1,750 was provided. **

Currently Available Equipment - (1100 candela) **

Standard 1500 candela
3 level option 100/550/1100 candela
automatic transition - photocell
automatic hookup to horn and/or whistle
manual override

An approximate figure of $555.00 was given.**

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* Hopkins, John B. and A. T. Newfell. Guidelines for Enhancement of Visual Conspicuity of Trains at Grade Crossings, Cambridge, MA: Transportation Systems Center, 1975. (DOT/FRA)
** per Whalen Engineering, Deep River, Connecticut.

COST CALCULATION FORM

REGULATION Strobe Lights

TSC Recommendation
(4000 candela)

NEW EQUIPMENT 2050 PROPOSED ______ EXISTING ______ INCREMENTAL ______

CONVERSION	LOST UTILIZATION	MATERIAL	LABOR INSTALL	LABOR MODIFY	TOTAL
REPLACE TO EXISTING STANDARD					______
REPLACE TO PROPOSED STANDARD					______
RETROFIT	$54.00 (4 hrs.)	$1,750	$306.00 (3 men X 4 hrs.)		$2,110
SUBSEQUENT MAINTENANCE Every 5 years	Rebuild $80.00 Labor remove/replace 2 hrs. x $25.00 = $50.00 3 sets bulbs = $130.00 1/3 hr. replace a set - $25.00				285
ADMINISTRATION					______
INSPECTION					______
OPERATING COSTS					______
______					______
______					______
FRA COSTS					______
TOTAL					______

COST CALCULATION FORM

REGULATION Strobe Lights
Equipment Current Available (1100 candela)

NEW EQUIPMENT 860 PROPOSED ____ EXISTING ____ INCREMENTAL ____

CONVERSION	LOST UTILIZATION	MATERIAL	LABOR INSTALL	LABOR MODIFY	TOTAL
REPLACE TO EXISTING STANDARD					
REPLACE TO PROPOSED STANDARD					
RETROFIT	$54.00 (4 hrs.)	$555.00	$306.00 (3 men x 4 hrs.)		$ 915.
SUBSEQUENT MAINTENANCE Every 5 yrs.	Rebuild $80.00 Labor remove/replace 2 hrs. x $25.00 = $50.00 1 Bulb/per $44.00				$ 175.
ADMINISTRATION					
INSPECTION					
OPERATING COSTS					
FRA COSTS					
TOTAL					

FLEET AND COST PROJECTION

Regulation: Strobe Lights   Lead Time: ½ year   ($M)

Alternative: TSC Recommendation (4000 candela)   Implementation Schedule: 3 yrs.   (# Units M)

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fleet Composition END OF PRE		29 *	20	10	0																	
POST			9	19	29																	
New Units	#		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Additions ____																						
Retirements ____																						
$2,050	$		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Replacement	#																					
____	$																					
Retrofit	#		8	9	9																	
$2,110	$		16.9	19	19																	
Subsequent Maintenance	#					0	0	8	9	9	1	1	8	9	9	1	1	8	9	9	1	1
$286.00	$							2.3	2.6	2.6	.3	.3	2.3	2.6	2.6	.3	.3	2.3	2.6	2.6	.3	.3
Admin. & Inspection																						
Operating Costs																						
____	$																					
____	$																					
FRA Costs																						
TOTAL			18.9	21	21	2	2	4.3	4.6	4.6	2.3	2.3	4.3	4.6	4.6	2.3	2.3	4.3	4.6	4.6	2.3	2.3

* Number of locomotives based on Yearbook of Railroad Facts, 1977 Edition, Association of American Railroads, Washington, DC; plus an adjustment for Class II and commuter railroad authority locomotives.

FLEET AND COST PROJECTION

Regulation: Strobe Lights — Lead Time: ½ year — ($M̄)

Alternative: Equipment Currently Available (1100 Candela) — Implementation Schedule: 3 years — (# Units M)

		END OF 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fleet Composition	PRE	29*	20	10	0																	
	POST		9	19	29																	
New Units	#		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Additions ___																						
Retirements $860.00	$		.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Replacement	#																					
___	$																					
Retrofit	#		8	9	9																	
$915.00			7.3	8.2	8.2																	
Subsequent Maintenance	#					0	0	8	9	9	1	1	8	9	9	1	1	8	9	9	1	1
$175.00 / $175.00	$							1.4	1.6	1.6	.2	.2	1.4	1.6	1.6	.2	.2	1.4	1.6	1.6	.2	.2
Admin. & Inspection																						
Operating Costs																						
___	$																					
___	$																					
FRA Costs																						
TOTAL			8.2	9.1	9.1	.9	.9	2.3	2.5	2.5	1.1	1.1	2.3	2.5	2.5	1.1	1.1	2.3	2.5	2.5	1.1	1.1

* Number of locomotives based on Yearbook of Railroad Facts, 1977 Edition, Association of American Railroads, Washington, DC; plus an adjustment for Class II and commuter railroad authority locomotives.

ECONOMIC IMPACT

To develop an estimate of the economic impact of this regulation on the railroad industry, those costs borne by the railroads are separated from the societal cost of accidents.

Railroad Property, Wreck Clearing, Loss and Damage to Freight, Railroad Administrative and Legal Expenses and Lost Utilization and Productivity are railroad expenses.

Societal Services and Inconvenience costs are societal costs.

The cost of fatalities and injuries are both railroad and societal costs. They are railroad costs to the degree that the railroads pay for them by means of settlements and litigation awards.

Settlements for damage to non-railroad property -- without additional data, it is estimated that the average cost developed for the societal cost would also be the amount paid by the railroads.

Economic Impact

Regulation Strobe Lights on Locomotives TSC Recommendation (4000 candela system)

Summary of Actual Costs of Grade-Crossing Accidents to the Industry

Accident Cost Category	Number	Cost**/Source*	Total Cost
Settlements - Fatalities	148	$ 26,900 (F)	$ 4,008,100
- Injuries	680	6,750 (I)	4,590,000
- Non Railroad Property	1,697	1,755 (A)	2,978,235
Railroad Property	1,697	800 (A)	1,357,600
Wreck Clearing	1,697	335 (A)	568,495
Loss & Damage	1,697	265 (A)	449,705
Railroad Administrative and Legal Expenses	149	2,760 (F)	411,240
	680	1,100 (I)	748,000
	1,697	45 (A)	76,365
Lost Utilization & Productivity	1,697	310 (A)	526,070
TOTAL			$15,713,810

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* F - Fatalities; I - Injuries; A - Accident

** These are actual costs of rail crossing accidents to the industry as opposed to the "societal" costs.

Economic Impact

Regulation Strobe Lights on Locomotives — Currently Available Equipment (1100 candela system)

Summary of Actual Costs of Grade-Crossing Accidents to the Industry

Accident Cost Category	Number	Cost**/Source*	Total Cost
Settlements - Fatalities	124	$ 26,900 (F)	$ 3,335,600
- Injuries	566	6,750 (I)	3,820,500
- Non Railroad Property	1,414	1,755 (A)	2,481,570
Railroad Property	1,414	800 (A)	1,131,200
Wreck Clearing	1,414	335 (A)	473,690
Loss and Damage	1,414	265 (A)	347,710
Railroad Administrative and Legal Expenses	124 566 1,414	2,760 (F) 1,100 (I) 45 (A)	342,240 622,600 63,630
Lost Utilziation & Productivity	1,414	310 (A)	438,340
TOTAL			$13,084,080

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* F - Fatalities; I - Injuries; A - Accident

** These are
ndustry as opposed to

APPENDIX A

EFFECTIVENESS ANALYSIS

The detail enclosed here is provided to substantiate the estimates of effectiveness of strobe lights to reduce grade-crossing accidents. The approach used to obtain the estimates is based upon the techniques of fault tree analysis, modeling and human factors analysis.

Figure A-1 shows a fault tree diagram for a grade crossing accident. Contributory events that bring the vehicle and train to the collision point are shown on the left and right sides of the diagram, respectively. These two sets of events are shown in the diagram as "Vehicle at Crossing at Impact Time" and "Train at Crossing at Impact Time." Of these contributory events, some were found to be affected by the presence of strobe lights on the locomotive. These events relate to the motorist's awareness of the train and the time of this awareness before impact.

The "direct visibility" of the train portion of the diagram becomes the focus of the effectiveness analysis. Here obstruction to view, weather, geometry, and visual perception become key factors that determine whether a motorist is alerted to a train in time to avert an accident.

As described in the main body of this report, the 24,250 accidents occurring over the two-year period 1975-1976 were reduced to 13,752 accidents. Figure A-2 shows a tree diagram of grade-crossing accident circumstances. On this diagram are shown all combinations of grade-crossing circumstances that significantly relate to the effectiveness of strobe lights in preventing accidents. At the top, the 10,948 accidents removed from consideration are shown. These were removed because the strobe light would be essentially ineffective in these circumstances. This is: when the motor vehicle is stalled or stopped on the tracks, when the train is pushing or rail cars alone are moving or standing, when the motor vehicle hit past the 20th rail car, and when the view of the track was obstructed a very short range from the track.

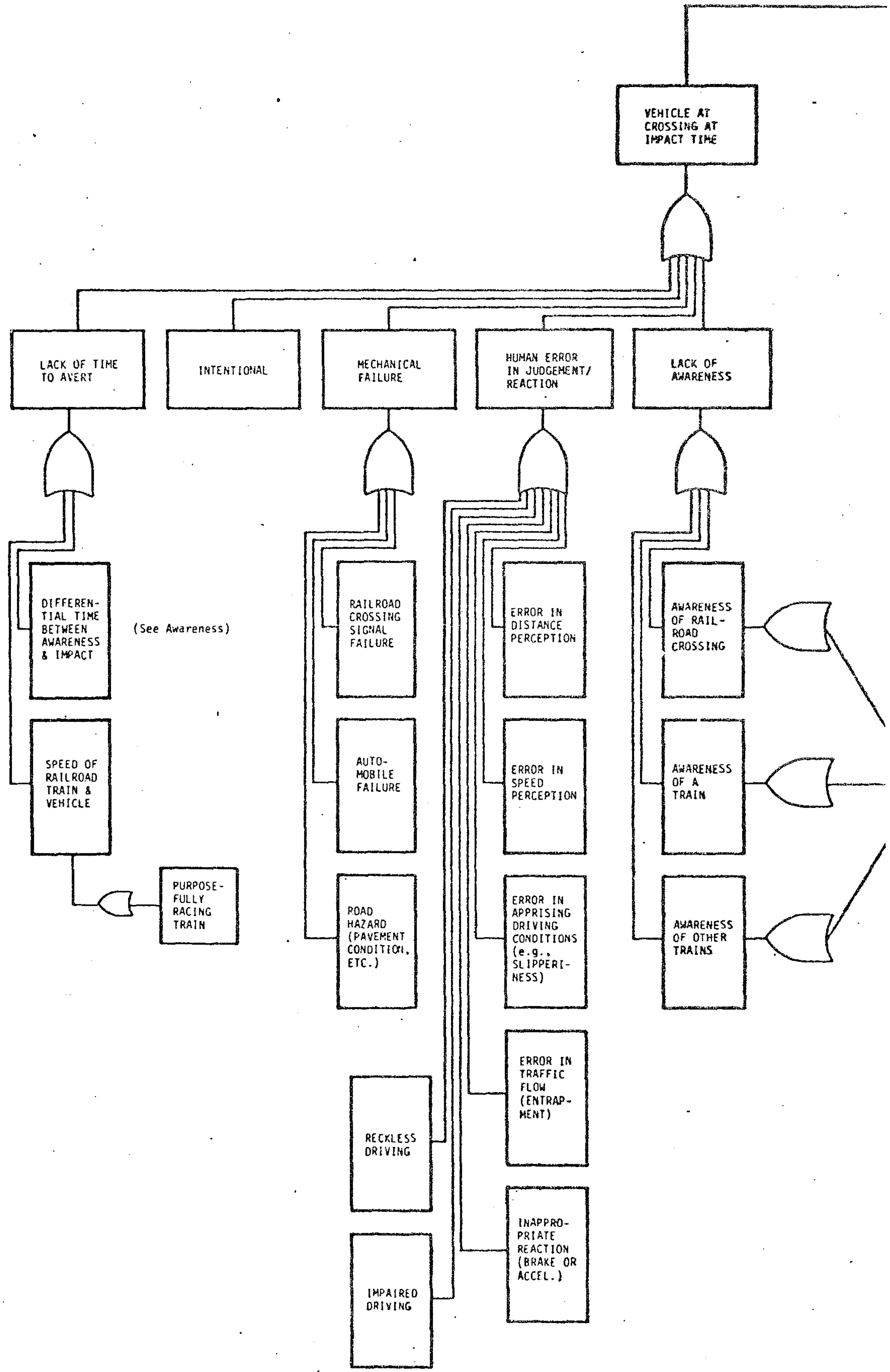
The events left are circumstances where the motor vehicle and train are in motion, and there is an opportunity for the motorist to see the train in time to avert a collision. To determine whether the motorist can see the train in time to avert a collision, two basic forms of a collision model for an accident were used.

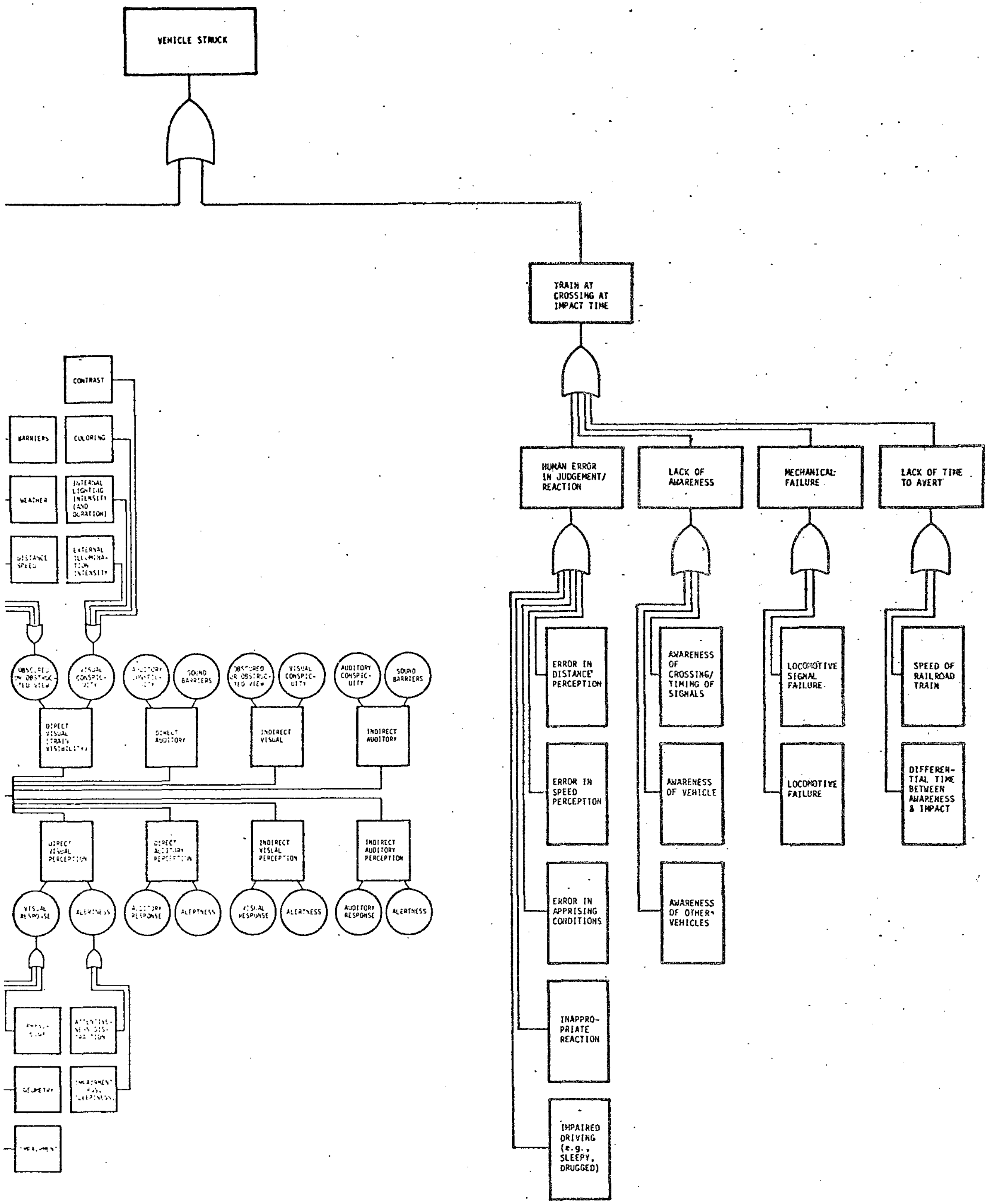
The basis of the model is the motor vehicle on a collision path with a train. If the motorist is alerted to the presence of the train -- before he has passed the point where he can successfully brake his vehicle to avoid colliding -- it is assumed the accident will not occur. To model the situation, two forms of the potential accident are used. One corresponds to an urban setting and the other to a rural setting.

In the urban setting, the average car speed is computed to be 31.4 mph (see Figure A-3 showing the results of the GM car chase study) and the average train speed is computed at 10.8 mph (obtained by separating the FRA accident data base train speeds by urban and rural, summing the train speeds and computing the average). It should be noted that vehicle speeds shown in the FRA data base were not suitable for this analysis since they are the speed upon impact, not the speed at 200-500 feet from the track when the sighting of the train is necessary.

In a rural setting, the average car speed is computed to be 49 mph (see Figure A-4 showing the distribution of car speeds in a rural setting) and the average train speed is computed at 29.5 mph (obtained as described above).

CONTRIBUTORY EVENTS TO
FAILURE AT GRADE CROSSING
FIGURE A-1

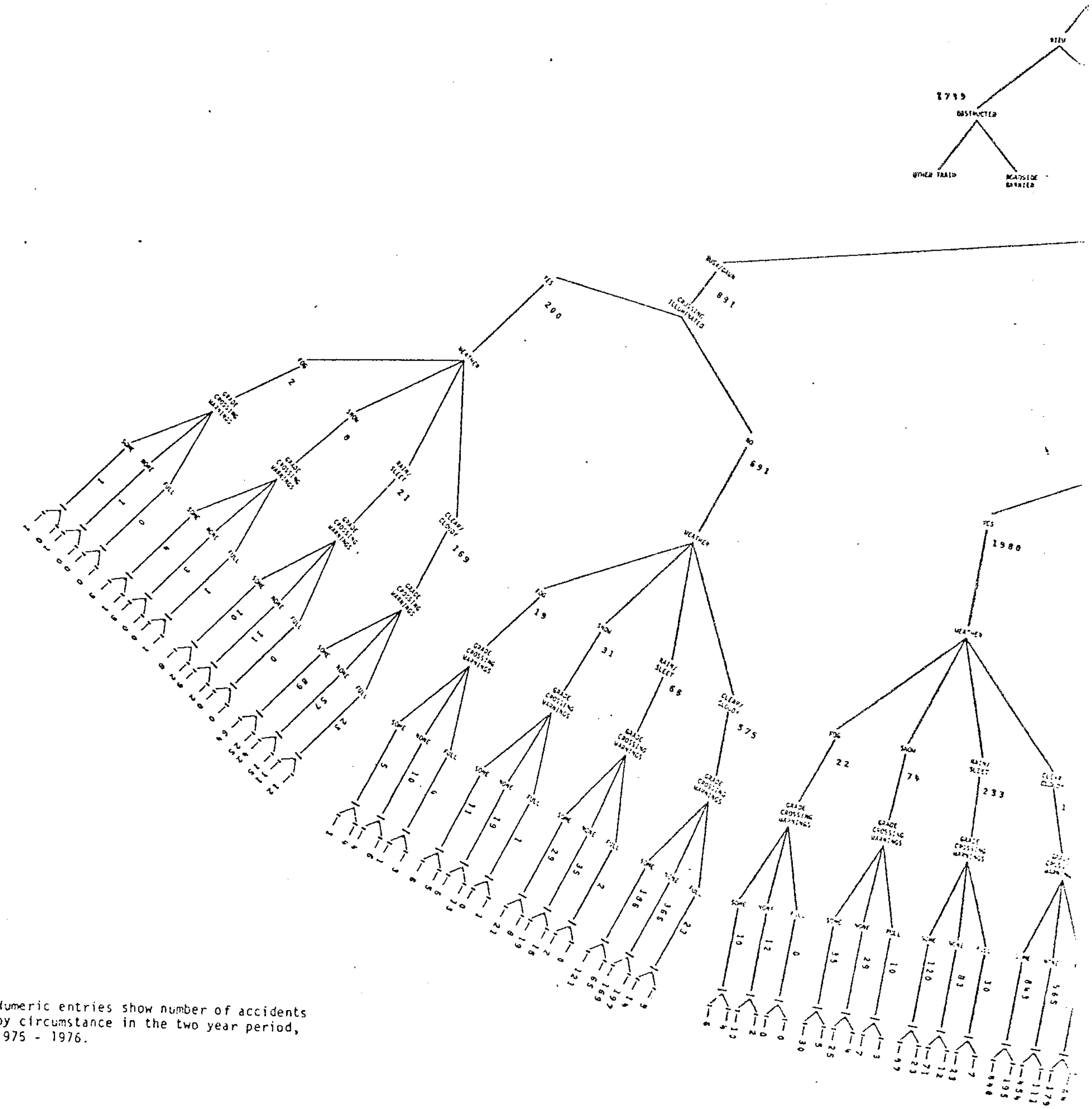



VEHICLE STRUCK
TRAIN AT CROSSING AT IMPACT TIME
HUMAN ERROR IN JUDGEMENT/ REACTION
LACK OF AWARENESS
MECHANICAL FAILURE
LACK OF TIME TO AVERT
ERROR IN DISTANCE PERCEPTION
ERROR IN SPEED PERCEPTION
ERROR IN APPRISING CONDITIONS
INAPPROPRIATE REACTION
IMPAIRED DRIVING (e.g., SLEEPY, DRUGGED)
AWARENESS OF CROSSING/ TIMING OF SIGNALS
AWARENESS OF VEHICLE
AWARENESS OF OTHER VEHICLES
LOCOMOTIVE SIGNAL FAILURE
LOCOMOTIVE FAILURE
SPEED OF RAILROAD TRAIN
DIFFERENTIAL TIME BETWEEN AWARENESS & IMPACT
CONTRAST
BARRIERS
COLORING
WEATHER
INTERNAL LIGHTING INTENSITY (AND DURATION)
EXTERNAL ILLUMINATION INTENSITY
VISUAL CONSPICUITY
SOUND BARRIERS
OBSTRUCTED OR OBSTRUCTED VIEW
AUDITORY CONSPICUITY
INDIRECT VISUAL
INDIRECT AUDITORY
ALERTNESS
INDIRECT VISUAL PERCEPTION
INDIRECT AUDITORY PERCEPTION
AUDITORY RESPONSE
VISUAL RESPONSE
GEOMETRY

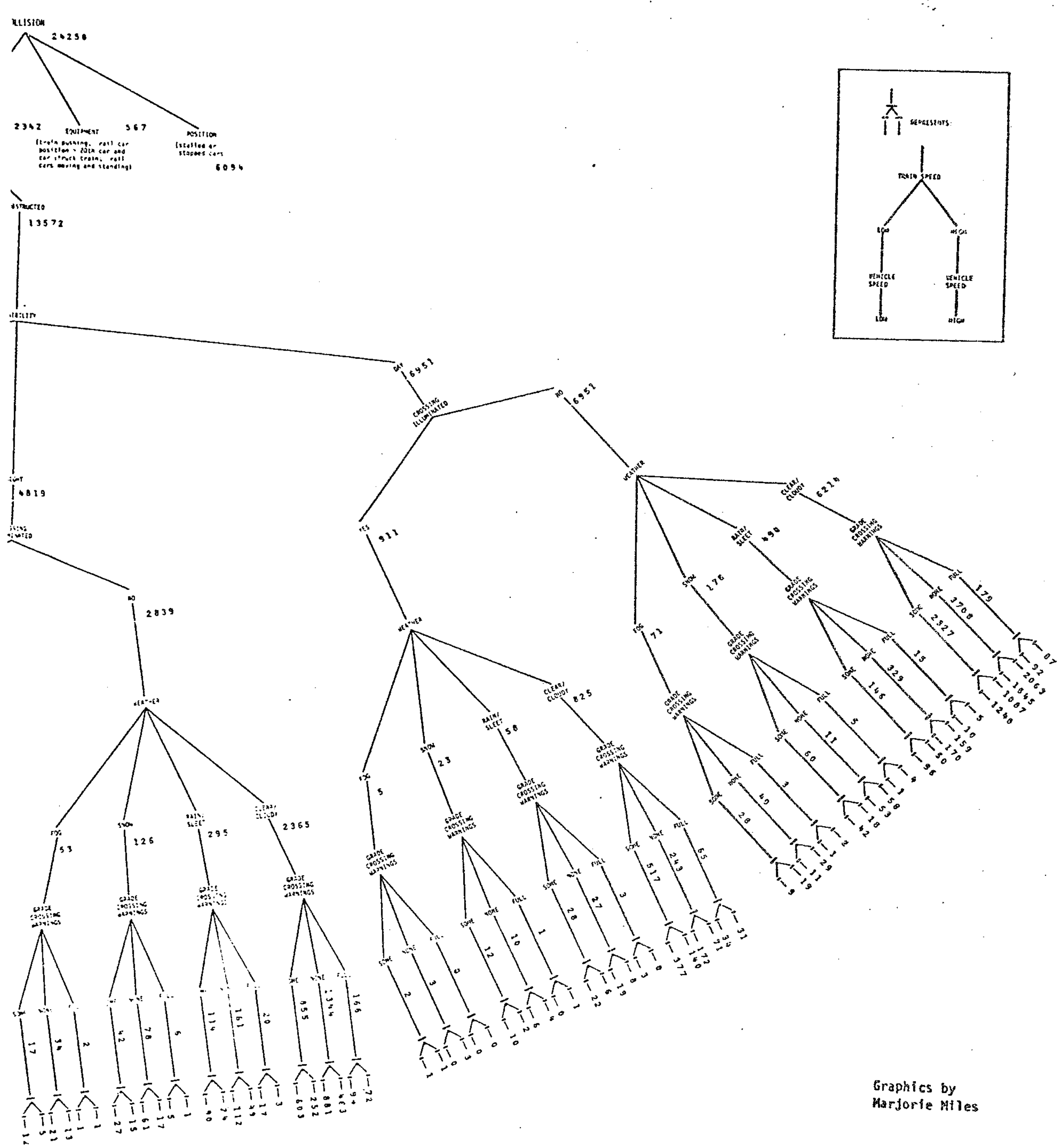
GRADE CROSSING ACCIDENT CIRCUMSTANCES

W. CURTISS PRIEST
INPUT OUTPUT COMPUTER SERVICES, INC.

FIGURE A-2



Numeric entries show number of accidents by circumstance in the two year period, 1975 - 1976.



Graphics by
Marjorie Miles

TABLE A-3: Distribution of Normal Passenger Car Speeds

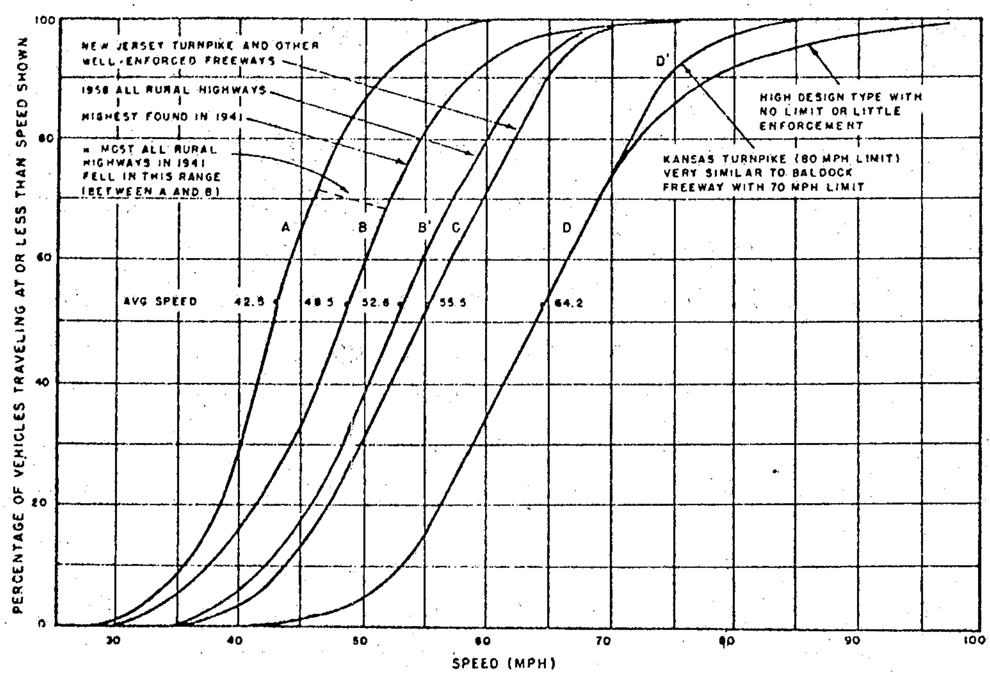
CONSERVATIVES ======== I ======== OUTLAWS

RATIO OF ACTUAL SPEED/POSTED SPEED LIMIT

POSTED SPEED LIMIT	0.0 – 0.2	0.2 – 0.4	0.4 – 0.6	0.6 – 0.8	0.8 – 1.0	1.0 – 1.2	1.2 – 1.4	1.4 – 1.6	1.6 – 1.8	1.8 – 2.0	
	% DIST	% DIST	% DIST	% DIST	% DIST	% DIST	% DIST	% DIST	% DIST	% DIST	TOTAL %
15	0.00	0.01	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.19
20	0.00	0.01	0.01	0.01	0.02	0.03	0.04	0.03	0.02	0.01	0.17
25	0.11	0.40	0.73	1.13	1.34	1.72	1.15	0.52	0.11	0.04	7.25
30	0.19	0.56	1.09	1.73	2.71	2.92	1.32	0.41	0.10	0.03	11.07
35	0.17	0.44	0.92	2.00	3.77	3.80	1.32	0.33	0.09	0.02	12.87
40	0.08	0.23	0.45	1.10	2.46	2.48	0.81	0.22	0.01	0.0	7.85
45	0.07	0.23	0.52	1.36	3.45	3.49	0.68	0.05	0.01	0.0	9.85
50	0.04	0.13	0.32	0.75	2.86	4.26	0.79	0.00	0.0	0.0	9.15
55	0.05	0.23	0.74	2.43	10.63	20.27	6.78	0.18	0.0	0.0	41.30
60	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.01
65	0.00	0.01	0.03	0.03	0.18	0.03	0.0	0.0	0.0	0.0	0.29
70	0.0	0.0	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.71	2.25	4.84	10.57	27.45	39.03	12.91	1.78	0.36	0.11	100.00

(Source: T.M. Johnson, et. al. Measurement of Motor Vehicle Operation Pertinent to Fuel Economy, SAE Paper 750003)

HIGHWAY CAPACITY



(Source: *Freeway Operations*, Inst. of Traffic Eng., 1960)

FIGURE A-4: Distribution of Normal Passenger Car Speeds

On the tree diagram, the accident circumstance is divided into slow train, slow vehicle and fast train, fast vehicle - to dichotomize the urban and rural forms of the accident model.

Using braking distances required under various weather conditions -- viewing distances, sighting distances and sight angles were computed for various circumstances. These are shown in Figures A-5 to A-9. (See Figure A-10 for braking distances.)

From these figures, several key factors were computed. The angle of sighting determines the angle of peripheral vision required of the motorist. Figure A-11 shows how the relative intensity of a light must vary to compensate for decreased eye sensitivity to a peripheral stimulus. This compensation factor is then used in the calculations for minimum detection threshholds of light to alert the motorist. Also, the percentage of grade crossings that afford a sight angle required was computed.

To obtain a distribution of sight distances (the distance one can see along the track a specified distance from the track), the Department of Highway Safety of Ohio was consulted. Ohio is one of the few states that collects sight distance for their grade crossings for an appreciable distance from the crossing. The State of Ohio has over 9,000 grade crossings which provide over 36,000 sighting angles (4 x 9,000). The technical services group performed a computer run and provided sight distance distribution data from 300 feet back from the crossing for the 36,000 sighting angles -- divided by rural and urban. Figures A-12 and A-13 show the percentage of grade crossings by the distribution of sight distances in 25-foot intervals. Since the State of Ohio is fairly representative of the U. S., these sighting distance distributions were used to calculate the percentage of accidents that could be prevented for each given model circumstance. These percentages

CIRCUMSTANCE:

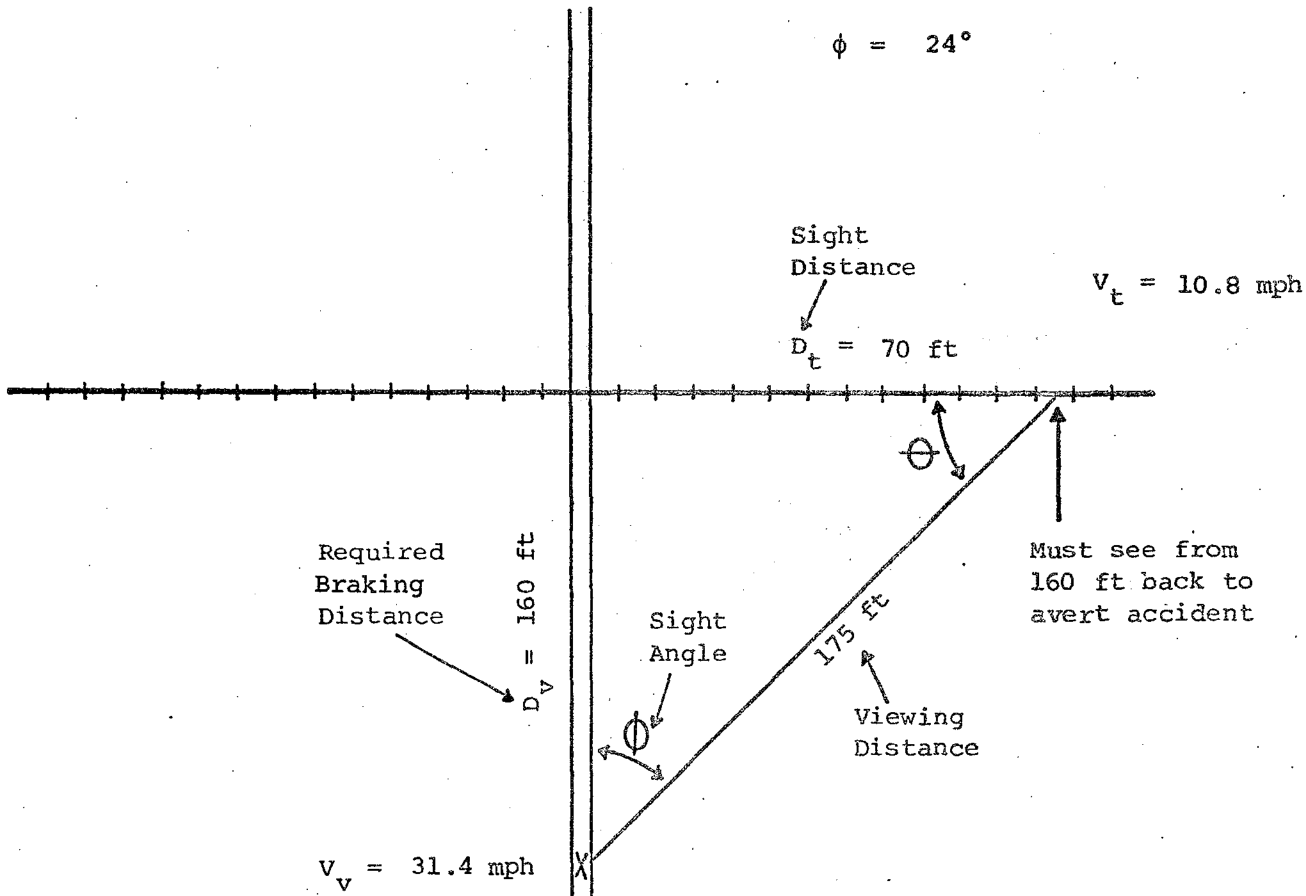
SLOW/DRY

CALCULATION OF PERIPHERAL VISION ANGLE:

$$\tan \theta = \frac{160}{70}$$

$$\theta = 66°$$

$$\phi = 24°$$



CALCULATION OF PERCENTAGE CROSSINGS UNOBSTRUCTED AT SIGHT DISTANCE OF 70 FEET:*

If Rural:

90.7% x 1.07 = 97%

If Urban:

84% x 1.07 = 89.9%

CALCULATION OF TIME TO TRAVEL 185 FEET AT 31.4 mph:

(D = VT)

$$T_v = \frac{(185)(3600)}{(31.4)(5280)}$$

$$T_v = 4.02 \text{ sec}$$

$$D_t = \frac{(10.8)(4.02)(5280)}{3600}$$

$$= 63.8 \text{ ft} + \Delta$$

$$\cong 70 \text{ ft}$$

*Adjust sight distance distribution by 160/300; equivalent to going out to 30 feet in the distribution table.

FIGURE A-5: Collision Model Geometry

CIRCUMSTANCE:

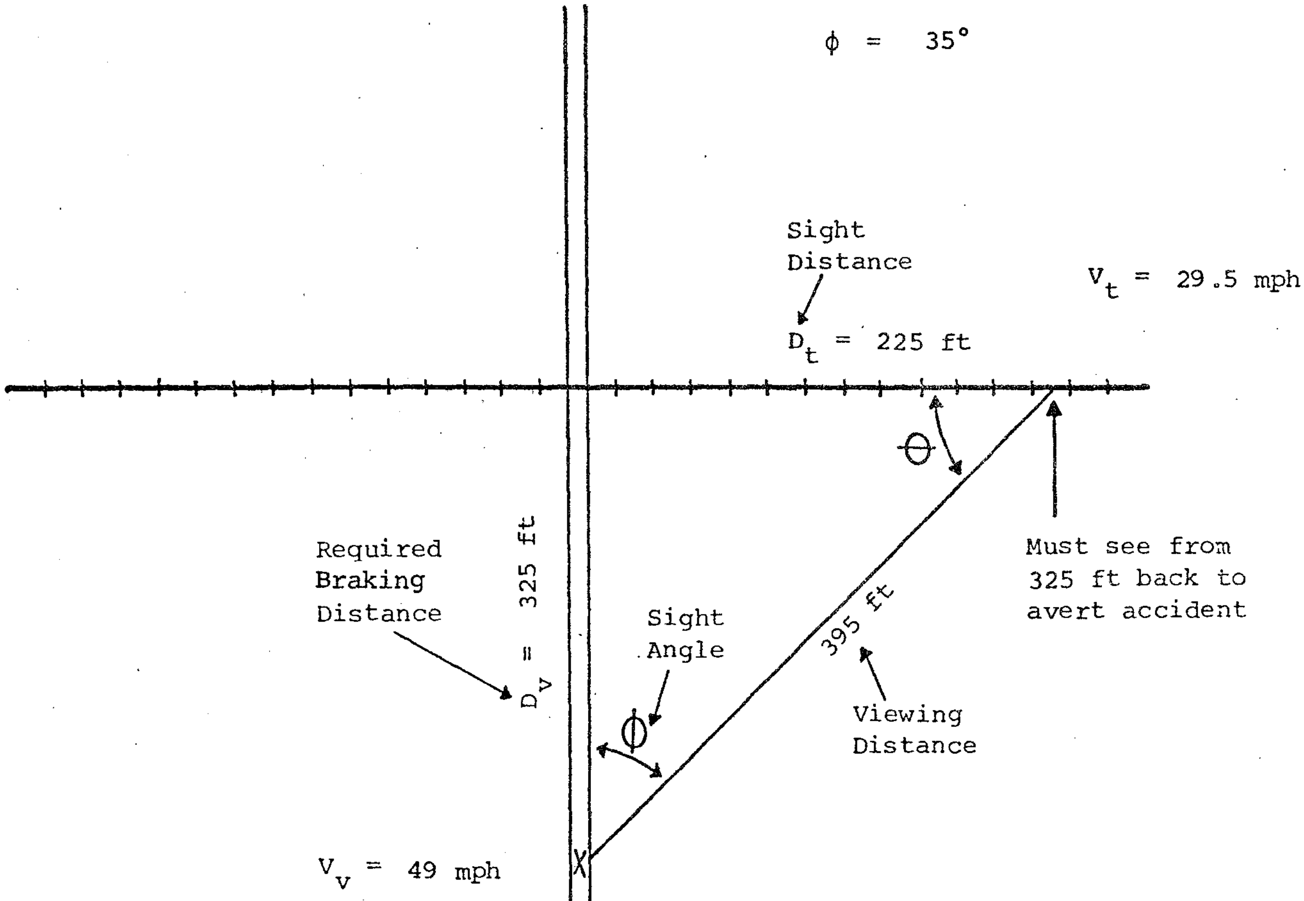
FAST/DRY

CALCULATION OF PERIPHERAL VISION ANGLE:

$$\tan\theta = \frac{325}{225}$$

$$\theta = 50°$$

$$\phi = 35°$$



CALCULATION OF PERCENTAGE CROSSINGS UNOBSTRUCTED AT SIGHT DISTANCE OF 225 FEET:

If Rural:

56.3% x 1.07 = 60.2%

If Urban:

28.7% x 1.07 = 30.7%

CALCULATION OF TIME TO TRAVEL 350 FEET AT 49 mph:

(D = VT)

$$T_v = \frac{(350)(3600)}{(49)(5280)}$$

$$T_v = 4.9 \text{ sec}$$

$$D_t = \frac{(29.5)(4.9)(5280)}{3600}$$

$$= 212 \text{ ft} + \Delta$$

$$\cong 225 \text{ ft}$$

FIGURE A-6: Collision Model Geometry

CIRCUMSTANCE:

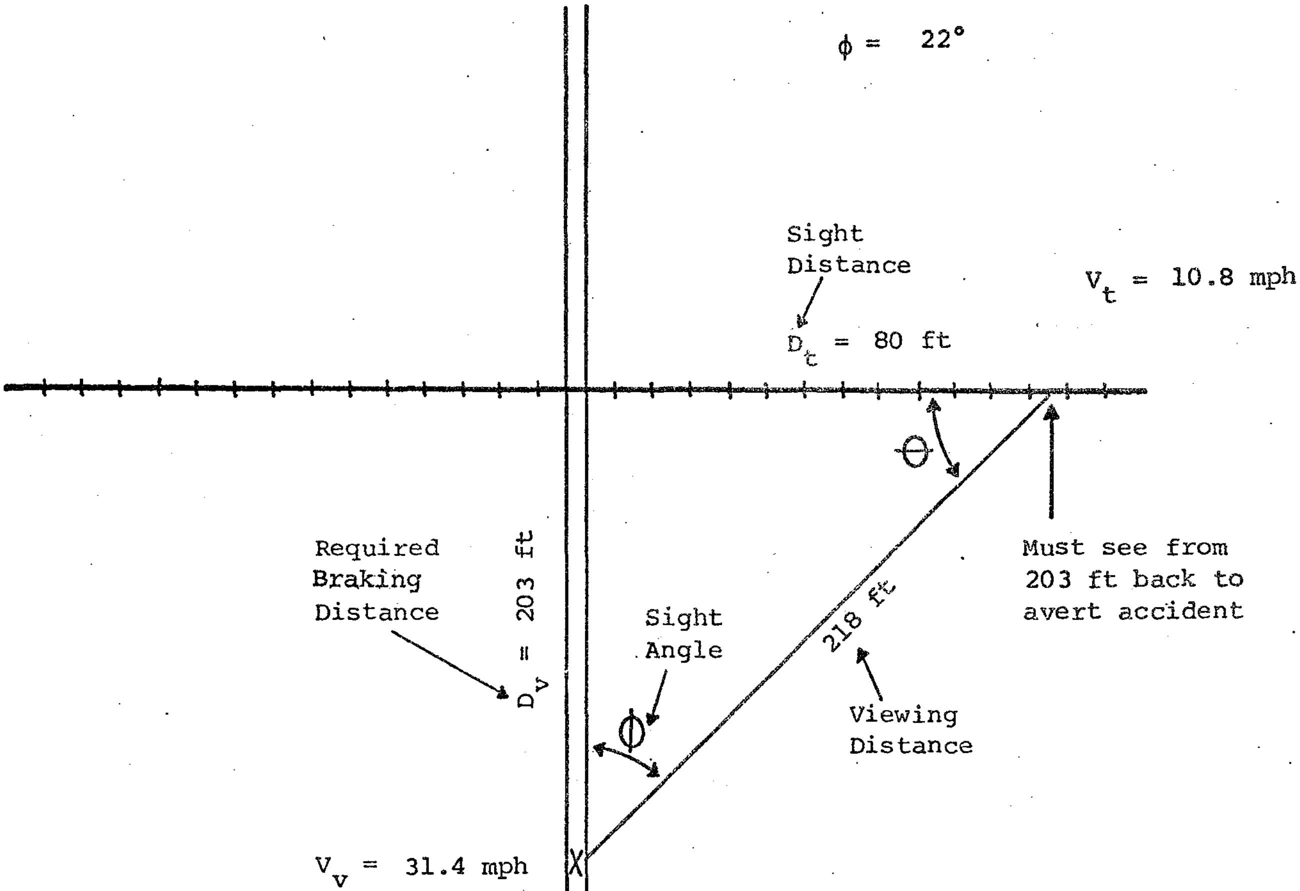
SLOW/WET

CALCULATION OF PERIPHERAL VISION ANGLE:

$$\tan \theta = \frac{203}{80}$$

$$\theta = 68^\circ$$

$$\phi = 22^\circ$$



CALCULATION OF PERCENTAGE CROSSINGS UNOBSTRUCTED AT SIGHT DISTANCE OF 203 FEET:*

If Rural:

83.1 x 1.07 = 88.9%

If Urban:

71.6 x 1.07 = 76.6%

* Adjust sight distance distribution by 203/300; equivalent to going out to 202 feet in the distribution table.

CALCULATION OF TIME TO TRAVEL 218 FEET AT 31.4 mph:

(D = VT)

$$T_v = \frac{(218)(3600)}{(31.4)(5280)}$$

$$T_v = 4.73$$

$$D_t = \frac{(10.8)(4.73)(5280)}{3600}$$

$$= 75 \text{ ft} \quad + \Delta$$

$$\cong 80 \text{ ft}$$

FIGURE A-7: Collision Model Geometry

CIRCUMSTANCE:

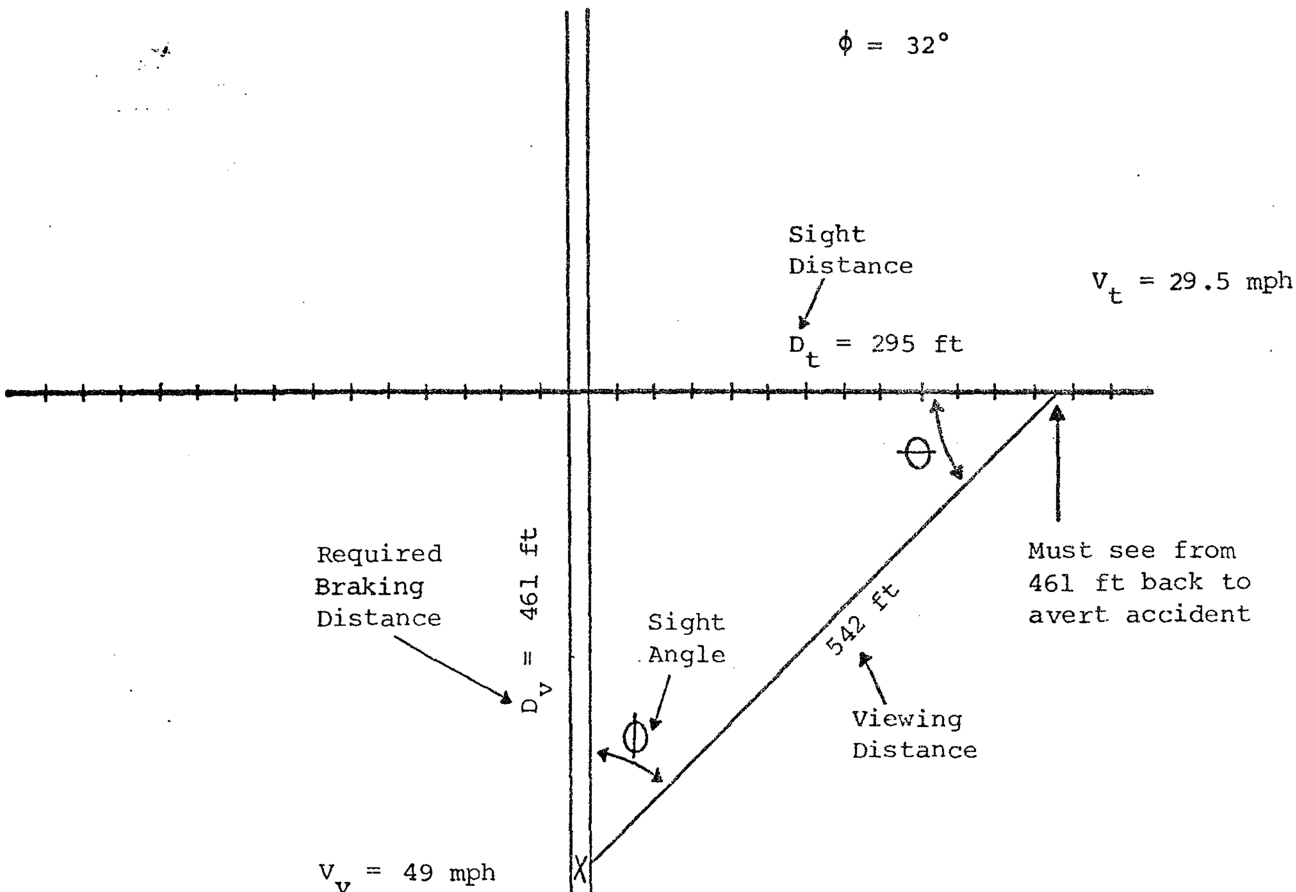
FAST/WET

CALCULATION OF PERIPHERAL VISION ANGLE:

$$\tan \theta = \frac{461}{285}$$

$$\theta = 58°$$

$$\phi = 32°$$



CALCULATION OF PERCENTAGE CROSSINGS UNOBSTRUCTED AT SIGHT DISTANCE OF 285 FEET:*

If Rural:

38.2% x 1.07 = 40.8%

If Urban:

16.4% x 1.07 = 17.5%

* Adjust sight distance distribution by 461/300; equivalent to going out to 438 feet in the distribution table.

CALCULATION OF TIME TO TRAVEL 475 FEET AT 49 mph:

(D = VT)

$$T_v = \frac{(475)(3600)}{(49)(5280)}$$

$$T_v = 6.6$$

$$D_t = \frac{(29.5)(6.6)(5280)}{3600}$$

$$= 285 \text{ ft} \quad + \Delta$$

$$\cong 295 \text{ ft}$$

FIGURE A-8: Collision Model Geometry

CIRCUMSTANCE:

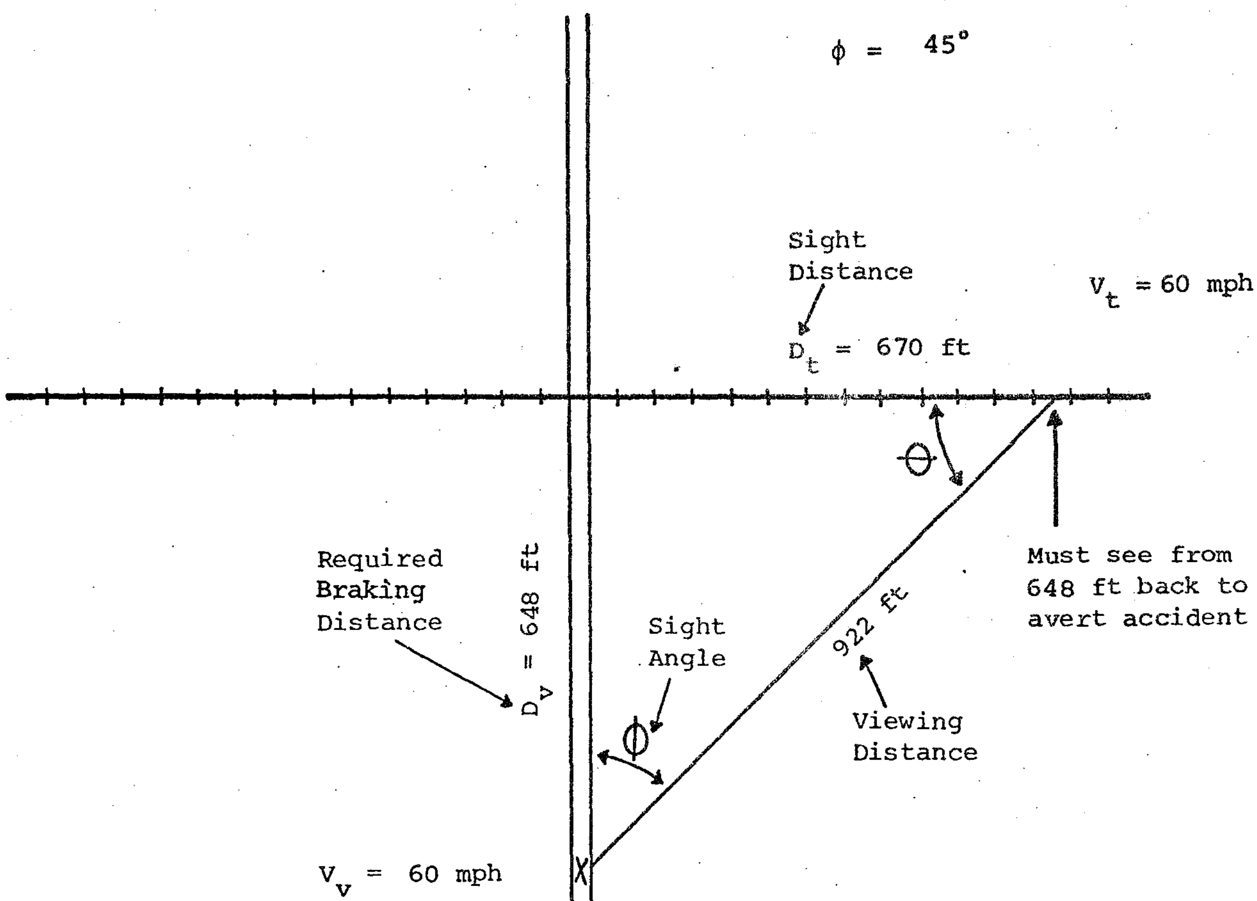
EXTRA FAST/WET

CALCULATION OF PERIPHERAL VISION ANGLE:

$$\tan\theta = \frac{665}{670}$$

$$\theta = 45^\circ$$

$$\phi = 45^\circ$$



CALCULATION OF PERCENTAGE CROSSINGS UNOBSTRUCTED AT SIGHT DISTANCE OF 660 FEET:*

If Rural:

15% x 1.07 = 16%

If Urban:

4.21% x 1.07 = 4.5%

* Adjust sight distance distribution by 648/300; equivalent to going out to 652 feet in the distribution table.

CALCULATION OF TIME TO TRAVEL 665 FEET AT 60 mph:

(D = VT)

$$T_v = \frac{(665)(3600)}{(60)(5280)}$$

$$T_v = 7.5 \text{ sec}$$

$$D_t = \frac{(60)(7.5)(5280)}{3600}$$

$$= 660 \text{ ft} \quad + \Delta$$

$$\cong 670 \text{ ft}$$

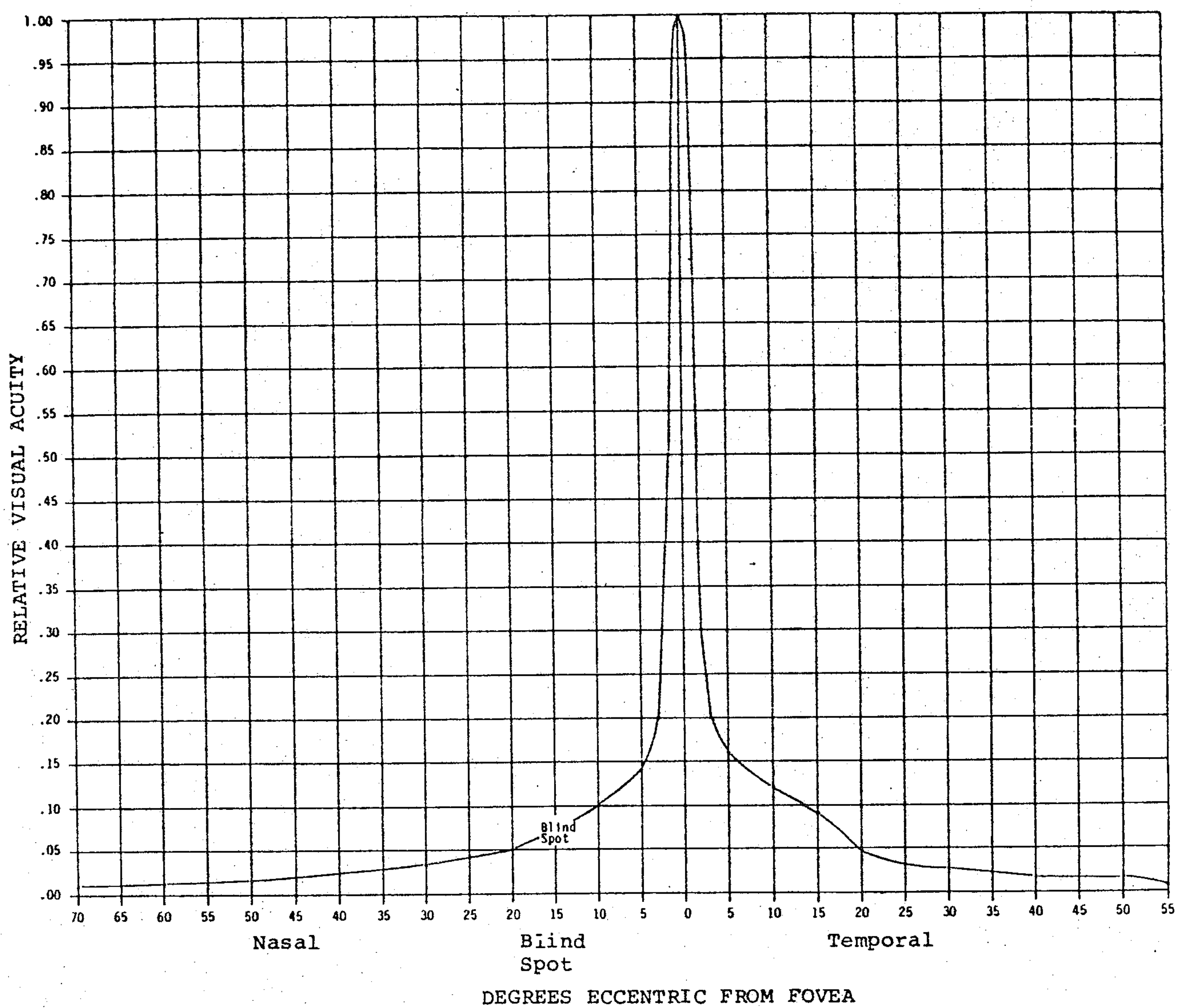
FIGURE A-9: Collision Model Geometry

TABLE A-10: Stopping Distances

Stopping Distance in Feet
(Reaction & Perception Time = 2.5 sec.)

Approach Speed mph	(kph)*	Dry		Wet		Ice	
10	(16)	42	(13)	46	(14)	70	(21)
20	(32)	94	(29)	110	(33)	207	(63)
30	(48)	158	(48)	198	(60)	410	(125)
40	(64)	236	(72)	313	(95)	680	(207)
50	(80)	327	(99)	461	(140)	1017	(309)
60	(97)	434	(132)	648	(197)	1420	(432)
70	(113)	559	(170)	884	(269)	1890	(575)

* kilometers per hour



(Flashing white light; Eye in adapted state; Horizontal plane)

FIGURE A-11: Sensitivity and Cone Density Across Human Retina

(Source: Douglas, 1950; Wertheim, 1894.)

TABLE A-12: Distribution of Sight Distances for 9212 Grade Crossings in the State of Ohio* at a Distance 300 feet from the Track (Urban)

SIGHT DISTANCE RANGE** (ft)	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED
0 - 25	6.00	500 - 525	.94	1000 - 1025	.66	1500 - 1525	0.00
25 - 50	19.40	525 - 550	.47	1025 - 1050	.19	1525 - 1550	.20
50 - 75	18.10	550 - 575	.60	1050 - 1075	.09	1550 - 1575	.09
75 - 100	9.90	575 - 600	.28	1075 - 1100	.06	1575 - 1600	.12
100 - 125	6.00	600 - 625	1.10	1100 - 1125	.10	1600 - 1625	.03
125 - 150	3.60	625 - 650	.22	1125 - 1150	.03	1625 - 1650	0.00
150 - 175	3.50	650 - 675	.22	1150 - 1175	.19	1650 - 1675	0.00
175 - 200	2.00	675 - 700	.25	1175 - 1200	.18	1675 - 1700	.09
200 - 225	2.80	700 - 725	.57	1200 - 1225	.41	1700 - 1725	.06
225 - 250	1.20	725 - 750	.35	1225 - 1250	.09	1725 - 1750	.19
250 - 275	1.70	750 - 775	.19	1250 - 1275	0.00	1750 - 1775	0.00
275 - 300	1.30	775 - 800	.06	1275 - 1300	.09	1775 - 1800	.13
300 - 325	2.60	800 - 825	.50	1300 - 1325	.06	1800 - 1825	.03
325 - 350	2.10	825 - 850	.38	1325 - 1350	.09	1825 - 1850	.13
350 - 375	1.50	850 - 875	.25	1350 - 1375	.09	1850 - 1875	.06
375 - 400	1.40	875 - 900	.22	1375 - 1400	.03	1875 - 1900	.03
400 - 425	1.40	900 - 925	.50	1400 - 1425	.30	1900 - 1925	.09
425 - 450	1.10	925 - 950	.16	1425 - 1450	.09	1925 - 1950	.16
450 - 475	1.00	950 - 975	.19	1450 - 1475	.03	1950 - 1975	.09
475 - 500	.57	975 - 1000	.09	1475 - 1500	0.00	1975 - 2000	0.00
						2000 - ∞	2.17

* Courtesy of the Department of Highway Safety, State of Ohio

** Pages 29-33 contain visual presentations of Sight and Viewing Distance

TABLE A-13: Distribution of Sight Distances for 9212 Grade Crossings in the State of Ohio* at a Distance 300 feet from the Track (Rural)

SIGHT DISTANCE RANGE (ft) **	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED	SIGHT DISTANCE RANGE (ft)	PERCENT OBSTRUCTED
0 - 25	4.3	500 - 525	1.6	1000 - 1025	.68	1500 - 1525	.35
25 - 50	11.1	525 - 550	.75	1025 - 1050	.53	1525 - 1550	.48
50 - 75	9.6	550 - 575	1.2	1050 - 1075	.26	1550 - 1575	.45
75 - 100	5.3	575 - 600	.66	1075 - 1100	.41	1575 - 1600	.02
100 - 125	4.2	600 - 625	1.31	1100 - 1125	.38	1600 - 1625	.42
125 - 150	2.5	625 - 650	.78	1125 - 1150	.13	1625 - 1650	.07
150 - 175	2.9	650 - 675	.70	1150 - 1175	.30	1650 - 1675	.08
175 - 200	1.8	675 - 700	.56	1175 - 1200	.33	1675 - 1700	.17
200 - 225	2.0	700 - 725	1.1	1200 - 1225	.63	1700 - 1725	.50
225 - 250	1.1	725 - 750	.90	1225 - 1250	.27	1725 - 1750	.20
250 - 275	2.0	750 - 775	.61	1250 - 1275	.10	1750 - 1775	.08
275 - 300	2.3	775 - 800	.42	1275 - 1300	.28	1775 - 1800	.07
300 - 325	3.1	800 - 825	.0	1300 - 1325	.27	1800 - 1825	.28
325 - 350	2.5	825 - 850	.40	1325 - 1350	.28	1825 - 1850	.03
350 - 375	2.4	850 - 875	.40	1350 - 1375	.07	1850 - 1875	.12
375 - 400	1.7	875 - 900	.71	1375 - 1400	.15	1875 - 1900	.55
400 - 425	2.0	900 - 925	1.1	1400 - 1425	.60	1900 - 1925	.43
425 - 450	1.0	925 - 950	.27	1425 - 1450	.63	1925 - 1950	.03
450 - 475	1.7	950 - 975	.38	1450 - 1475	.15	1950 - 1975	.13
475 - 500	1.1	975 - 1000	.35	1475 - 1500	.03	1975 - 2000	.15
						2000 - ∞	9.08

* Courtesy of the Department of Highway Safety, State of Ohio

** Pages 29-33 contain visual presentations of Sight and Viewing Distance are shown as "if rural" and "if urban" on the left side of the model geometry forms.* This data is summarized in Figure A-14. Figure A-15 shows a sample Ohio grade crossing inventory form with the geometry of how sight distances are measured.

An extreme case, under wet driving conditions, was also evaluated. This calculation was made for a train moving at 60 mph and a car moving above 55 mph. This was useful in determining the severe sighting case for establishing whether the motorist could sight the train in time.

Once sighting distances, viewing distances (the direct distance from the motor vehicle to the locomotive at the time of sighting), and angles were determined, it was necessary to compute how alerting the strobe light would be to the motorist. To calculate this, figures were used from the National National Bureau of Standards on Visual Range (monograph 159) and estimates provided by a leading researcher in flashing lights and perception -- Mr. Charles Douglas. Figure A-16 shows the visual detection threshold under various cases of ambient light and viewing angle. The angles shown correspond to the angles computed for the accident models described above. Factors for windshield attenuation and motorist attentiveness were included.

In parallel, the illuminance of strobe lights at varying intensities, under different weather conditions, and at various viewing distances were computed. The viewing distances, again, correspond to distances computed for the accident models. See Figures A-17, A-18, and A-19.

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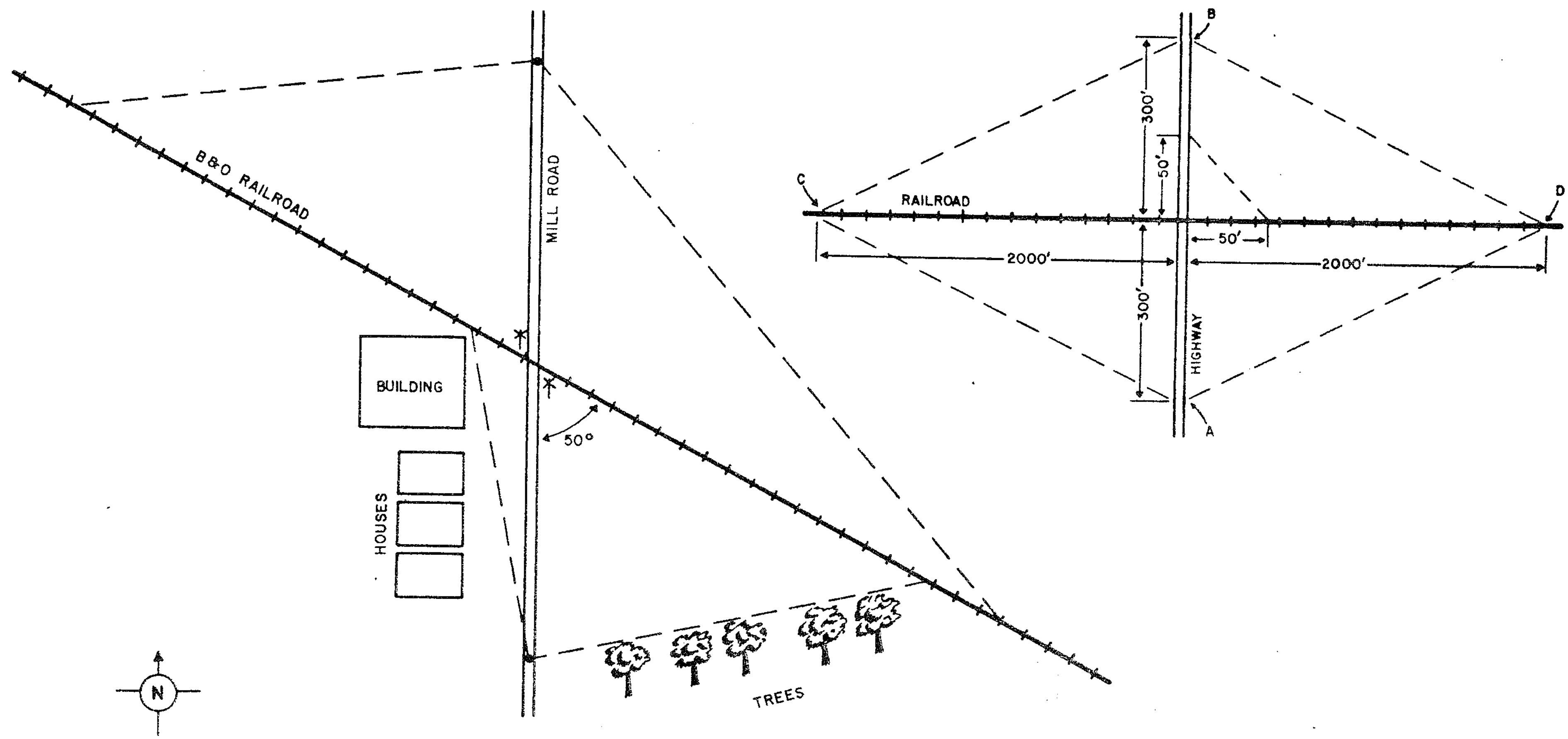
* These percentages are adjusted by 1.07 times to compensate for the initial removal of 6% of the accident cases due to obstruction at close range. This is based upon the FRA accident statistics. (Consult tree diagram)

TABLE A-14: Percentage of Accidents with Sufficient Unobstructed View to Stop in Time

	Percentage of Total Accidents	Percentage of Accidents Left After 6.8% Obstructed Initially Removed.
RURAL		
Dry:		
Slow	90.7	97.0
Fast	56.3	60.2
Wet:		
Slow	83.1	88.9
Fast	38.2	40.8
URBAN		
Dry:		
Slow	84.0	89.9
Fast	28.7	30.7
Wet:		
Slow	71.6	76.6
Fast	16.4	17.5



Sample Ohio Grade Crossing Inventory Form
FIGURE A-15

TABLE A-16: Motorist Illumination Detection Thresholds for Locomotive Strobelight at Various Angles from the Direction of View

	MINIMUM DETECTION THRESHOLD (in lux)		WIND-SHIELD GLASS LOSS	WIND-SHIELD GLASS ANGLE LOSS	STROBE GLASS LOSS	ATTENTIVE-NESS LOSS	PERIPHERAL VISION LOSS*			COMPOSITE DETECTION THRESHOLD (in lux)		
	At 50% Probability of Detection	At 98% Probability of Detection					AT 22-24°	AT 32-35°	AT 70°	AT 22-24°	AT 32-35°	AT 70°
NIGHT	8×10^{-7}	x 2	x 2	x 2	x 2	1 to 10	x 25	x 40	x 83	= .00032 - .0032	.00051 - .0051	.0011 - .011
DUSK/DAWN	10^{-5}	x 2	x 2	x 2	x 2	1 to 10	x 25	x 40	x 83	= .004 - .04	.0064 - .064	.013 - 1.3
DAY	4.2×10^{-5}	x 2	x 2	x 2	x 2	1 to 10	x 25	x 40	x 83	= .017 - .17	.027 - .27	.056 - .56

* Angles chosen for:

- Average low speed case (175 ft view of train to stop when dry; 218 when wet)
- Average high speed case (395 ft dry; 542 feet wet)
- Extreme angle case (922 ft wet)

SOURCE: NBS Monograph 159, J. W. Sparke (relative sensitivity of light adapted eye to flashing white lights); and discussions with Charles Douglas (attentiveness factors).

TABLE A-17: Illuminance of Strobe Lights Under Consideration (in lux)

EFFECTIVE INTENSITY* (in Candela)	ILLUMINANCE				
	at 175 ft (53.3m)	at 218 ft (66.4m)	at 395 ft (120.4m)	at 542 ft (165m)	at 922 ft (281m)
4000	1.4	.91	.28	.15	.050
1100	.39	.25	.076	.04	.014
550	.19	.12	.038	.02	.0070
100	.039	.022	.0076	.004	.0014

*Calculations do not include background illumination. A background sky illumination will reduce the effective intensity by ~100 candela at a sky illumination of 1000 candela (for a strobe cross sectional area of 1/10 ft^2). If the strobe is a 360° type, then sky illumination passing through the light will decrease the effect of background illumination, reducing the effective intensity. It is assumed the 550 and 1 0 levels will be used only at dusk or at night. (Consult the Blondel-Ray equation for computation of the effective intensity of a flashing light.)

TABLE A-18: Multiplier for Decrease of Illuminance of Strobe Lights Under Adverse Weather

	218 ft.	542 ft.	922 ft.
CLEAR	.98	.97	.92
HAZE	.94	.86	.78
THIN FOG	.88	.74	.60
LIGHT FOG & TYPICAL RAIN	.79	.55	.36
MODERATE FOG & TYPICAL SNOW	.62	.30	.13
THICK FOG	.38	.09	.02
DENSE FOG	.15	.008	.003

TABLE A-19: Illuminance of Strobe Lights Corrected for Weather (in lux)

	Rain*			Snow**			Fog**		
	218 ft	542 ft	922 ft	218 ft	542 ft	922 ft	218 ft	542 ft	922 ft
4000 Candela	.36	.041	.009	.56 / .28	.045 / .022	.0065 / .0032	.56 / .28	.045 / .022	.0065 / .0032
1100 Candela	.10	.011	.0025	.15 / .078	.012 / .0060	.0018 / .00091	.15 / .078	.012 / .0060	.0018 / .00091
550 Candela	.0475	.005	.0012	.075 / .037	.0060 / .0030	.00091 / .00045	.075 / .037	.0060 / .0030	.00091 / .00045
110 Candela	.0085	.001	.00025	.014 / .007	.0012 / .00060	.00018 / .000091	.014 / .007	.0012 / .00060	.00018 / .000091

*Additional correction for poorer windshield visibility estimated at .5 times normal conditions.

**Day/Night - night values reduced by .5 to compensate for backscatter from headlamps.

With detection threshold and illuminance of the strobe lights, a comparison could then be made and a determination of whether the strobe would be visible in time to alert the driver. And with these computations performed, the variations in effectiveness by circumstance of the strobe light in preventing accidents could then be calculated.

The effectiveness of strobe lights varies as follows, under different circumstances:

Visibility -- Visibility (day, dusk/dawn, and night) circumstances are seen as a primary determinant of the effectiveness of a strobe light. Since the intensity of the strobe light will be varied according to the visibility, the relationship is not straightforward and is taken into account in the analysis by differences in detection thresholds of the motorist by visibility and the changes in illumination of the strobe light under its different settings.

Crossing Illumination -- For the day and dusk/dawn circumstances, crossing illumination is judged to have no effect on the effectiveness of the strobe light in reducing accidents. For the night case, the crossing illumination is judged to be somewhat distracting to the motorist, thereby reducing the effectiveness of the strobe light in alerting the motorist. An effectiveness reduction multiplier of .85 is used if no grade crossing devices are present and .95 with grade crossing devices.

Weather -- Weather influences the effectiveness of strobe lights in three ways. First, stopping distances under wet or icy conditions change the distance at which the motorist must see the locomotive to stop in time to avert an accident. Secondly, fog, snow and rain/sleet, affect the transmissivity of the atmosphere and decrease the illuminance of the strobe light at the vehicle. Thirdly, in the circumstance of light fog, there is an aurora effect such that the sky over the train is luminous with the flash of the strobe. Little is known about the quantitative effects of this but, qualitatively, the effect is to increase sight distance in cases where there is a physical obstruction at eye level towards the train, but a clear view to the sky above the train.

The effectiveness of strobe lights decreases under adverse weather for two reasons: first, the required sight distance needs to be greater, reducing the number of accidents that can be affected due to the distribution of obstructions by sight distance; and secondly, the transmissivity of the atmosphere is reduced, decreasing the probability that the motorist will detect the locomotive in time. Reduced sight distance is accounted for in the analysis by the introduction of the longer stopping distance required by the motorist and computing the percentage of accidents that could have been prevented, given the distribution of sight distances for these stopping distances. Reduced transmissivity is accounted for by noting the criticality of the detection threshold to the illuminance of the strobe light attenuated by the weather. If the low level of strobe intensity (100 candela) were used at night, the effect would be substantial as the detection threshold at this intensity is near criticality even in clear weather. Assuming a level closer to 550 candela were used (in poor weather), estimates of the accident cases that the strobe light could affect are shown in the figure on effectiveness of strobe lights under various visibility and weather circumstances (see Figure A-20). These were estimated by comparing the two speed cases against the detection threshold range; if a particular set of circumstances caused the estimated illuminance to fall below the lowest possible detection level, no accident reduction was attributed to the circumstance. If the illuminance fell near 5 times the

TABLE A-20: Estimated Multiplier for Decrease in Effectiveness of Strobe Lights Under Various Visibility and Weather Circumstances

	Night at 550 Candela	Day at 1100 Candela	Dusk/Dawn at 1100 Candela
Snow			
fast	.7	0.0[1]	1.0
slow	1.0	.75[2]	1.0
Rain			
fast	.8	0.0[3]	1.0
slow	1.0	.85[4]	1.0

[1] If 4000 candelas used, estimate .3

[2] If 4000 candelas used, estimate 1.0

[3] If 4000 candales used, estimate .4

[4] If 4000 candelas used, estimate 1.0

TABLE A-21: Estimated Multiplier for Decrease in Effectiveness of Strobe Lights Under Various Visibility and Warning Device Circumstances

	WARNING DEVICES		
	FULL	SOME	NONE
DAY	.1	.2	1.0
NIGHT	0.05	.5	1.0
DUSK/DAWN	.15	.3	1.0

lowest detection level, half the accidents were considered to be affectable (since half the speeds fall below the median speed value and half above). And if the illuminance was greater than the upper value detection threshold for the extreme speed and weather case, all accidents were considered affectable.

The effectiveness of strobe lights will decrease significantly with the presence of active-grade crossing warning systems. In the case of gates and lights, it is anticipated that the strobe will add very little more protection. In the calculations the effectiveness of strobe lights at crossings with active warning devices is considered as zero.

Accidents occurring due to natural causes - heart attacks, vehicle failures - caused by intoxication or involving motorists who will not respond to the strobe light even upon perceiving its presence would fall within the 50/40 percent of motorists who could or would not react effectively.

Final Calculations

Using the tree diagram of circumstances, each branch was labeled with "effectiveness decrease multipliers" corresponding to the different circumstances described above. These are the multipliers that reduce the effectiveness of the strobe light from its reducing the number of accidents in any particular circumstance by 100%.

The number of accidents that occurred by circumstance in the period 1975-1976 are labeled along the tree diagram. Table A-22 is a copy of the computer printout that shows the tally performed on the FRA data base for grade crossing accidents. Appendix B describes how the data from the data base was aggregated. To simplify the analysis, the number of entries in the data base were reduced as explained in

Appendix B. Consult the Accident Report Form provided for the meanings of the entry numbers. The tally is hierarchical from visibility, light, weather, signal to speed. The row of tabulated numbers indicates: total vehicle damage, total fatalities, total injuries and total accidents, reading from left to right.*

The tally of accidents by circumstance were entered in a separate computer program. The effectiveness decrease multipliers were also entered. The program multiplied the "decrease multiplier" by the number of fatalities, injuries, accidents, and the vehicle damage and tallied them in these four categories. Figure A-2 shows the actual coefficients used against the tallies extracted from the accident data base run. (These entries are in the same order as the entries under "SPEED" in the data base computer printout.)

At the bottom of the run are the fatalities, injuries, accidents, and the total vehicle damage attributable to being saved by strobe lights on locomotives. These numbers appear in the main body of this report.

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* To identify a particular tally row with a particular circumstance, find the accident form entry numbers for the circumstance of interest and for the level of hierarchy of interest. The next tally row, indented to the hierarchy level being consulted, is the tally row that corresponds. Check against the tally for total accidents shown on the circumstance tree, if in doubt.

TABLE A-22 Accidents and Costs Tallied by Five Major Accident Circumstances*

VISIBILITY 2			
LIGHT 1			
WEATHER 1			
SIGNAL 01			
SPEED 001			
0000030084	000002	000002	000034
SPEED 002			
0000077122	000011	000018	000065
SIGNAL 02			
0000047038	000009	000016	000031
SPEED 001			
0000542668	000003	000077	000377
SPEED 002			
0000918069	000031	000135	000517
SIGNAL 03			
0000375491	000028	000058	000140
SPEED 001			
0000203712	000001	000040	000172
SPEED 002			
0001339382	000058	000217	000825
WEATHER 3			
0000344191	000016	000064	000243
SIGNAL 01			
0000140479	000015	000024	000071
SPEED 001			
0000000500	000000	000000	000003
SIGNAL 02			
0000000500	000000	000000	000003
SPEED 001			
0000015682	000001	000009	000022
SPEED 002			
0000021668	000002	000011	000028
SIGNAL 03			
0000005986	000001	000002	000006
SPEED 001			
0000013277	000000	000004	000019
SPEED 002			
0000044081	000002	000017	000058
WEATHER 4			

* Consult text on how to read the table.

TABLE A-22 (Continued)

0000021913	000000	000006	000027
SIGNAL 02			
0000008636	000000	000002	000008
SPEED 001			
0000000450	000000	000000	000001
SPEED 002			
0000000650	000000	000001	000002
SIGNAL 03			
0000000200	000000	000001	000001
SPEED 002			
0000017150	000001	000003	000005
WEATHER 6			
0000016500	000001	000002	000003
SIGNAL 01			
0000016500	000001	000002	000003
SPEED 002			
0000003000	000001	000000	000001
SIGNAL 02			
0000003000	000001	000000	000001
SPEED 001			
0000006044	000001	000000	000010
SPEED 002			
0000014244	000001	000004	000012
SIGNAL 03			
0000008200	000000	000004	000002
SPEED 001			
0000004708	000000	000000	000006
SPEED 002			
0001434765	000063	000242	000911
LIGHT 2			
0000034152	000002	000005	000023
WEATHER 1			
0000016908	000000	000001	000010
SIGNAL 01			
0000012200	000000	000001	000004
SPEED 001			
0000094770	000003	000022	000092
SPEED 002			
0000329183	000023	000054	000179
SIGNAL 02			
0000234404	000020	000032	000087
SPEED 001			
0001503955	000037	000340	001240
SPEED 002			
0004496135	000301	000888	002327
SIGNAL 03			
0002987180	000264	000548	001087
SPEED 001			
0002032527	000035	000485	001645
SPEED 002			
0012050656	000780	002572	006214
WEATHER 3			

TABLE A-22 (Continued)

0007225338	000456	001630	003708
SIGNAL 01			
0005192811	000421	001145	002063
SPEED 001			
0000006500	000000	000003	000010
SPEED 002			
0000049550	000000	000006	000015
SIGNAL 02			
0000043050	000000	000003	000005
SPEED 001			
0000091974	000000	000021	000096
SPEED 002			
0000174212	000012	000043	000146
SIGNAL 03			
0000082238	000012	000022	000050
SPEED 001			
0000162048	000003	000064	000170
SPEED 002			
0000716229	000048	000198	000490
WEATHER 4			
0000492467	000036	000149	000329
SIGNAL 01			
0000330419	000033	000085	000159
SPEED 001			
0000003000	000000	000000	000001
SPEED 002			
0000010150	000000	000000	000003
SIGNAL 02			
0000007150	000000	000000	000002
SPEED 001			
0000006408	000000	000002	000009
SPEED 002			
0000075930	000073	000006	000028
SIGNAL 03			
0000069522	000073	000004	000019
SPEED 001			
0000007436	000000	000004	000011
SPEED 002			
0000132480	000088	000022	000071
WEATHER 6			

TABLE A-22 (Continued)

```
      0000046400     000015          000016          000040
      SIGNAL 01
        0000038064     000015          000012          000029
        SPEED 001
        0000001000     000000          000001          000001
        SPEED 002
      0000005136     000000          000003          000005
      SIGNAL 02
        0000004136     000000          000002          000004
        SPEED 001
        0000036177     000003          000010          000042
        SPEED 002
      0000062957     000004          000017          000060
      SIGNAL 03
        0000026780     000001          000007          000018
        SPEED 001
        0000042048     000000          000009          000053
        SPEED 002
0014517475     000000          003086          007862
VISIBILITY 3
  0013082710     000927          002844          006951
  LIGHT 1
    0000183345     000011          000052          000176
    WEATHER 1
      0000115252     000007          000032          000111
      SIGNAL 01
        0000073204     000007          000023          000058
        SPEED 001
        0000008930     000000          000003          000011
        SPEED 002
      0000022416     000004          000007          000023
      SIGNAL 02
        0000013486     000004          000004          000012
        SPEED 001
        0000096011     000001          000016          000064
        SPEED 002
      0000165158     000010          000031          000089
      SIGNAL 03
        0000069147     000000          000015          000025
        SPEED 001
        0000050041     000002          000008          000042
        SPEED 002
    0000257087     000017          000048          000169
    WEATHER 3
```

TABLE A-22 (Continued)

0000069513	000003	000010	000057
SIGNAL 02			
0000019472	000001	000002	000015
SPEED 001			
0000005855	000000	000001	000008
SPEED 002			
0000008541	000000	000002	000010
SIGNAL 03			
0000002686	000000	000001	000002
SPEED 001			
0000007083	000000	000000	000009
SPEED 002			
0000021124	000000	000003	000021
WEATHER 4			
0000012583	000000	000001	000011
SIGNAL 02			
0000005500	000000	000001	000002
SPEED 001			
0000000200	000000	000000	000001
SIGNAL 03			
0000000200	000000	000000	000001
SPEED 001			
0000000450	000000	000000	000002
WEATHER 6			
0000000250	000000	000000	000001
SIGNAL 01			
0000000250	000000	000000	000001
SPEED 002			
0000000550	000000	000003	000001
SIGNAL 02			
0000000550	000000	000003	000001
SPEED 001			
0000001800	000000	000000	000003
SPEED 002			
0000004000	000000	000000	000004
SIGNAL 03			
0000002200	000000	000000	000001
SPEED 001			
0000285867	000017	000054	000200
LIGHT 2			
0000007206	000000	000003	000008
WEATHER 1			

TABLE A-22 (Continued)

0000002656	000000	000000	000003
SIGNAL 01			
0000002656	000000	000000	000003
SPEED 001			
0000015408	000000	000001	000014
SPEED 002			
0000130930	000002	000004	000023
SIGNAL 02			
0000115522	000002	000003	000009
SPEED 001			
0000116809	000003	000038	000121
SPEED 002			
0000255351	000015	000079	000186
SIGNAL 03			
0000138542	000012	000041	000065
SPEED 001			
0000179338	000003	000047	000169
SPEED 002			
0000913550	000068	000242	000575
WEATHER 3			
0000527269	000051	000159	000366
SIGNAL 01			
0000347931	000048	000112	000197
SPEED 001			
0000000900	000000	000000	000002
SIGNAL 02			
0000000900	000000	000000	000002
SPEED 001			
0000012466	000002	000004	000021
SPEED 002			
0000023116	000005	000009	000029
SIGNAL 03			
0000010650	000003	000005	000008
SPEED 001			
0000023288	000000	000004	000019
SPEED 002			
0000090412	000007	000023	000066
WEATHER 4			

TABLE A-22 (Continued)

0000066396	000002	000014	000035
SIGNAL 01			
0000043108	000002	000010	000016
SPEED 001			
0000000500	000000	000000	000001
SPEED 002			
0000005400	000001	000001	000004
SIGNAL 02			
0000004900	000001	000001	000003
SPEED 001			
0000007986	000001	000005	000004
SPEED 002			
0000010986	000001	000005	000005
SIGNAL 03			
0000003000	000000	000000	000001
SPEED 001			
0000004211	000000	000000	000006
SPEED 002			
0000026597	000004	000006	000019
WEATHER 6			
0000010211	000002	000000	000010
SIGNAL 01			
0000006000	000002	000000	000004
SPEED 002			
0000000986	000000	000000	000001
SIGNAL 02			
0000000986	000000	000000	000001
SPEED 001			
0000008097	000000	000000	000006
SPEED 002			
0000012122	000000	000002	000011
SIGNAL 03			
0000004025	000000	000002	000005
SPEED 001			
0000004336	000000	000001	000006
SPEED 002			
0001359178	000098	000332	000891
VISIBILITY 4			
0001073311	000081	000278	000691
LIGHT 1			
0000042752	000002	000007	000031
WEATHER 1			

TABLE A-22 (Continued)

0000029644	000002	000005	000019
SIGNAL 01			
0000025308	000002	000004	000013
SPEED 001			
0000162730	000002	000060	000179
SPEED 002			
0000241722	000020	000104	000243
SIGNAL 02			
0000078992	000018	000044	000064
SPEED 001			
0000598225	000018	000234	000648
SPEED 002			
0000912759	000057	000361	000843
SIGNAL 03			
0000314534	000039	000127	000195
SPEED 001			
0000367286	000010	000168	000454
SPEED 002			
0001712345	000120	000708	001651
WEATHER 3			
0000557864	000043	000243	000565
SIGNAL 01			
0000190578	000033	000075	000111
SPEED 001			
0000024596	000000	000007	000023
SPEED 002			
0000030154	000001	000009	000030
SIGNAL 02			
0000005558	000001	000002	000007
SPEED 001			
0000092504	000001	000046	000097
SPEED 002			
0000120670	000008	000060	000120
SIGNAL 03			
0000028166	000007	000014	000023
SPEED 001			
0000066169	000002	000024	000071
SPEED 002			
0000234415	000012	000100	000233
WEATHER 4			

TABLE A-22(Continued)

0000083591	000003	000031	000083
SIGNAL 02			
0000017422	000001	000007	000012
SPEED 001			
0000005108	000000	000007	000006
SPEED 002			
0000009894	000001	000009	000010
SIGNAL 03			
0000004786	000001	000002	000004
SPEED 001			
0000008125	000000	000003	000010
SPEED 002			
0000018260	000001	000012	000022
WEATHER 6			
0000008375	000000	000003	000012
SIGNAL 01			
0000000250	000000	000000	000002
SPEED 001			
0000006094	000000	000001	000007
SPEED 002			
0000008280	000000	000004	000010
SIGNAL 02			
0000002186	000000	000003	000003
SPEED 001			
0000032060	000000	000010	000030
SPEED 002			
0000041996	000002	000010	000035
SIGNAL 03			
0000009936	000002	000000	000005
SPEED 001			
0000013150	000000	000010	000025
SPEED 002			
0002034841	000136	000850	001980
LIGHT 2			
0000069812	000003	000030	000074
WEATHER 1			

TABLE A-22(Continued)

0000019536	000001	000016	000029
SIGNAL 01			
0000006386	000001	000006	000004
SPEED 001			
0000115720	000003	000025	000094
SPEED 002			
0000209866	000024	000069	000166
SIGNAL 02			
0000094146	000021	000044	000072
SPEED 001			
0000668254	000014	000238	000603
SPEED 002			
0001089313	000058	000405	000855
SIGNAL 03			
0000421059	000044	000167	000252
SPEED 001			
0000863135	000038	000385	000881
SPEED 002			
0002790417	000218	001135	002365
WEATHER 3			
0001491238	000136	000661	001344
SIGNAL 01			
0000628103	000098	000276	000463
SPEED 001			
0000012952	000000	000003	000017
SPEED 002			
0000014627	000000	000004	000020
SIGNAL 02			
0000001675	000000	000001	000003
SPEED 001			
0000065424	000000	000036	000090
SPEED 002			
0000100726	000007	000060	000114
SIGNAL 03			
0000035302	000007	000024	000024
SPEED 001			
0000077835	000002	000034	000112
SPEED 002			
0000253990	000024	000124	000295
WEATHER 4			

TABLE A-22 (Continued)

0000138637	000017	000060	000161
SIGNAL 01			
0000060802	000015	000026	000049
SPEED 001			
0000001000	000000	000000	000001
SPEED 002			
0000004000	000000	000001	000002
SIGNAL 02			
0000003000	000000	000001	000001
SPEED 001			
0000043086	000000	000006	000012
SPEED 002			
0000049958	000000	000008	000017
SIGNAL 03			
0000006872	000000	000002	000005
SPEED 001			
0000023194	000001	000011	000021
SPEED 002			
0000106085	000003	000028	000053
WEATHER 6			
0000052127	000003	000019	000034
SIGNAL 01			
0000028933	000002	000008	000013
SPEED 001			
0000005758	000000	000003	000005
SPEED 002			
0000012758	000000	000003	000006
SIGNAL 02			
0000007000	000000	000000	000001
SPEED 001			
0000021740	000000	000006	000027
SPEED 002			
0000040550	000001	000010	000042
SIGNAL 03			
0000018810	000001	000004	000015
SPEED 001			
0000051478	000002	000011	000061
SPEED 002			
0005352957	000385	002172	004819
VISIBILITY			
0003318116	000249	001322	002839
LIGHT			
0000167624	000004	000035	000126
WEATHER			
0000114316	000003	000022	000078
SIGNAL			
0000062838	000001	000011	000017
SPEED			

TABLE A-23: Computation of Accident and Cost Reductions by Circumstance Using the Effectiveness Multipliers

Effectiveness Multiplier	No. of Accidents	No. of Injuries	No. of Fatalities	Vehicle Damage $'s
0.090000	34.	2.	2.	30084.
0.060000	31.	16.	9.	47038.
0.180000	377.	77.	3.	542668.
0.120000	140.	58.	28.	375401.
0.900000	172.	40.	1.	203712.
0.600000	71.	24.	15.	140479.
0.065000	3.	0.	0.	500.
0.130000	22.	9.	1.	15682.
0.000000	6.	2.	1.	5986.
0.650000	19.	4.	0.	13277.
0.000000	8.	2.	0.	8636.
0.120000	1.	0.	0.	450.
0.000000	1.	1.	0.	200.
0.000000	3.	2.	1.	16500.
0.000000	1.	0.	1.	3000.
0.120000	10.	0.	1.	6044.
0.000000	2.	4.	0.	8200.
0.600000	6.	0.	0.	4708.
0.000000	4.	1.	0.	12200.
0.090000	92.	22.	3.	94779.
0.060000	87.	32.	20.	234404.
0.180000	1240.	340.	37.	1508955.
0.120000	1087.	548.	264.	2987180.
0.900000	1645.	485.	35.	2032527.
0.600000	2063.	1145.	421.	5192811.
0.065000	10.	3.	0.	6500.
0.000000	5.	3.	0.	43050.
0.130000	96.	21.	0.	91974.
0.000000	50.	22.	12.	82238.
0.650000	170.	64.	3.	162048.
0.000000	159.	85.	33.	330419.
0.060000	1.	0.	0.	3000.
0.000000	2.	0.	0.	7150.
0.120000	9.	2.	0.	6408.
0.000000	19.	4.	73.	69522.
0.600000	11.	4.	0.	7436.
0.000000	29.	12.	15.	38964.
0.060000	1.	1.	0.	1000.

(Continued)

TABLE A-23 (Continued)

Effectiveness Multiplier	No. of Accidents	No. of Injuries	No. of Fatalities	Vehicle Damage $'s
0.000000	4.	2.	0.	4136.
0.120000	42.	10.	3.	36177.
0.000000	18.	7.	1.	26780.
0.600000	53.	9.	0.	42048.
0.000000	58.	23.	7.	73204.
0.140000	11.	3.	0.	8930.
0.090000	12.	4.	4.	13486.
0.270000	64.	16.	1.	96011.
0.180000	25.	15.	9.	69147.
0.900000	42.	8.	2.	50041.
0.600000	15.	2.	1.	19472.
0.230000	8.	1.	0.	5855.
0.120000	2.	1.	0.	2686.
0.770000	9.	0.	0.	7083.
0.410000	2.	1.	0.	5500.
0.230000	1.	0.	0.	200.
0.770000	1.	0.	0.	250.
0.060000	1.	3.	0.	550.
0.230000	3.	0.	0.	1800.
0.120000	1.	0.	0.	2200.
0.770000	3.	0.	0.	2656.
0.140000	14.	1.	0.	15408.
0.090000	9.	3.	2.	115522.
0.270000	121.	38.	3.	116809.
0.180000	65.	41.	12.	138542.
0.900000	169.	47.	3.	179338.
0.600000	197.	112.	48.	347931.
0.120000	2.	0.	0.	900.
0.230000	21.	4.	2.	12466.
0.120000	8.	5.	3.	10650.
0.770000	19.	4.	0.	23288.
0.410000	16.	10.	2.	43108.
0.120000	1.	0.	0.	500.
0.060000	3.	1.	1.	4900.
0.230000	4.	5.	1.	7986.
0.120000	1.	0.	0.	3000.
0.770000	6.	0.	0.	4211.
0.410000	4.	0.	2.	6000.
0.060000	1.	0.	0.	986.
0.230000	6.	0.	0.	8097.
0.120000	5.	2.	0.	4025.
0.770000	6.	1.	0.	4336.
0.410000	13.	4.	2.	25308.
0.028000	179.	60.	2.	162730.
0.019000	64.	44.	18.	78992.

(Continued)

TABLE A-23 (Continued)

Effectiveness Multiplier	No. of Accidents	No. of Injuries	No. of Fatalities	Vehicle Damage $'s	
0.270000	648.	234.	18.	598225.	
0.190000	195.	127.	39.	314534.	
0.500000	454.	168.	10.	367286.	
0.330000	111.	75.	33.	190578.	
0.024000	23.	7.	0.	24596.	
0.010000	7.	2.	1.	5558.	
0.240000	97.	46.	1.	92504.	
0.100000	23.	14.	7.	28166.	
0.430000	71.	24.	2.	66169.	
0.180000	12.	7.	1.	17422.	
0.240000	6.	7.	0.	5108.	
0.090000	4.	2.	1.	4786.	
0.430000	10.	3.	0.	8125.	
0.150000	2.	0.	0.	250.	
0.024000	7.	1.	0.	6094.	
0.009000	3.	3.	0.	2186.	
0.240000	30.	10.	0.	32060.	
0.090000	5.	0.	2.	9936.	
0.430000	25.	10.	0.	13150.	
0.150000	4.	6.	1.	6386.	
0.030000	94.	25.	3.	115720.	
0.020000	72.	44.	21.	94146.	
0.290000	603.	238.	14.	668254.	
0.200000	252.	167.	44.	421059.	
0.590000	881.	385.	38.	863135.	
0.390000	463.	276.	98.	628103.	
0.025000	17.	3.	0.	12952.	
0.011000	3.	1.	0.	1675.	
0.250000	90.	36.	0.	65424.	
0.110000	24.	24.	7.	35302.	
0.500000	112.	34.	2.	77835.	
0.210000	49.	26.	15.	60802.	
0.025000	1.	0.	0.	1000.	
0.010000	1.	1.	0.	3000.	
0.250000	12.	6.	0.	43086.	
0.100000	5.	2.	0.	6872.	
0.500000	21.	11.	1.	23194.	
0.180000	13.	8.	2.	28933.	
0.025000	5.	3.	0.	5758.	
0.010000	1.	0.	0.	7000.	
0.250000	27.	6.	0.	21740.	
0.100000	15.	4.	1.	18810.	
0.500000	61.	11.	2.	51478.	
0.180000	17.	11.	1.	62838.	
	5657.	2266.	496.	8528339.	TOTALS

APPENDIX B

AGGREGATION OF DATA FROM THE FRA GRADE CROSSING ACCIDENT DATA BASE, 1975 - 1976

1. Clear and Cloudy were combined (as entry 1 on accident report)
2. Rain and Sleet were combined (as entry 3 on report)
3. Full grade crossing warnings are gates only (entry 1)
4. Some grade crossing warnings are all others except: gates, crossbucks, and no markings (entries 2, 3, 4, 5, 6, 8, 9, 10, and 11 as entry 2)
5. No warnings include only: no markings and crossbucks (entries 7 and 12 as entry 3)
6. Train speed was dichotomized into those below twenty mph and those twenty and above. (This dichotomized accidents roughly in proportion to urban and rural.) (Less than twenty - as entry 1; twenty or greater as entry 2)

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

RAIL-HIGHWAY GRADE CROSSING ACCIDENT/INCIDENT REPORT

FORM APPROVED
OMB NO. 04R4033

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

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

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

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

LOCATION

7. NEAREST RAILROAD STATION
8. COUNTY
9. STATE *(two letter code)* — CODE
10. CITY *(if in a city)*
11. HIGHWAY NAME OR NUMBER *(if private crossing, so state)*

ACCIDENT/INCIDENT SITUATION

HIGHWAY USER INVOLVED

12. TYPE — 1. Auto 2. Truck 3. Truck-Trailer 4. Bus 5. School Bus 6. Motorcycle 7. Pedestrian 8. Other *(specify)* — CODE
13. SPEED *(estimated mph at impact)*
14. DIRECTION *(geographical)* — 1. North 2. South 3. East 4. West — CODE
15. POSITION — 1. Stalled on crossing 2. Stopped on crossing 3. Moving over crossing — CODE

RAILROAD EQUIPMENT INVOLVED

16. EQUIPMENT — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* — CODE
17. POSITION OF CAR/UNIT IN TRAIN — CODE
18. CIRCUMSTANCE — 1. Train struck highway user 2. Train struck by highway user — CODE

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

ENVIRONMENT

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

TRAIN AND TRACK

23. TYPE OF TRAIN — 1. Freight 2. Passenger 3. Mixed 4. Work 5. Yard/Switching 6. Light Locomotive(s) — CODE
24. TRACK TYPE USED BY TRAIN INVOLVED — 1. Main 2. Yard 3. Siding 4. Industry — CODE
25. TRACK NUMBER OR NAME
26. FRA TRACK CLASSIFICATION
27. NUMBER OF LOCOMOTIVE UNITS
28. NUMBER OF CARS
29. TRAIN SPEED *(recorded speed, if available)* SPEED MPH — Est / Recorded
30. TIME TABLE DIRECTION — 1. North 2. South 3. East 4. West — CODE

CROSSING WARNING

31. TYPE *(place X in appropriate box(es))*

1	Gates	5	Hwy. Traffic Signals	9	Watchman
2	Cantilever FLS	6	Audible	10	Flagged by crew
3	Standard FLS	7	Crossbucks	11	Other *(specify)*
4	Wig Wags	8	Stop Signs	12	None

SIGNAL

32. SIGNALED CROSSING WARNING — Was the signaled crossing warning identified in item 31 operating? 1. Yes 2. No — CODE
33. LOCATION OF WARNING — 1. Both sides 2. Side of vehicle approach 3. Opposite side of vehicle approach — CODE
34. CROSSING WARNING INTERCONNECTED WITH HIGHWAY SIGNALS — 1. Yes 2. No 3. Unknown — CODE
35. CROSSING ILLUMINATED BY STREET LIGHTS OR SPECIAL LIGHTS LIGHT — 1. Yes 2. No 3. Unknown — CODE

MOTORIST ACTION

36. MOTORIST PASSED STANDING HIGHWAY VEHICLE — 1. Yes 2. No 3. Unknown — CODE
37. MOTORIST DROVE BEHIND OR IN FRONT OF TRAIN AND STRUCK OR WAS STRUCK BY SECOND TRAIN — 1. Yes 2. No 3. Unknown — CODE
38. MOTORIST — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Other *(specify)* 5. Unknown — CODE
39. VIEW OF TRACK OBSCURED BY *(primary obstruction)* — 1. Permanent structure 2. Standing railroad equipment 3. Passing train 4. Topography 5. Vegetation 6. Highway vehicles 7. Other *(specify)* 8. Not obstructed — CODE

HIGHWAY VEHICLE PROPERTY DAMAGE/CASUALTIES

40. HIGHWAY VEHICLE PROPERTY DAMAGE *(est. dollar damage)*
41. DRIVER WAS — 1. Killed 2. Injured 3. Uninjured — CODE
42. WAS DRIVER IN THE VEHICLE? — 1. Yes 2. No — CODE
43. TOTAL NUMBER OF OCCUPANTS KILLED
44. TOTAL NUMBER OF OCCUPANTS INJURED
45. TOTAL NUMBER OF OCCUPANTS *(include driver)*

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

47. TYPED NAME AND TITLE
48. SIGNATURE
49. DATE

FORM FRA F 6180-57 (12-74) REPLACES FORM FRA F 6180-13 (10-67) WHICH IS OBSOLETE

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