U.S. Department of Transportation
Federal Railroad Administration

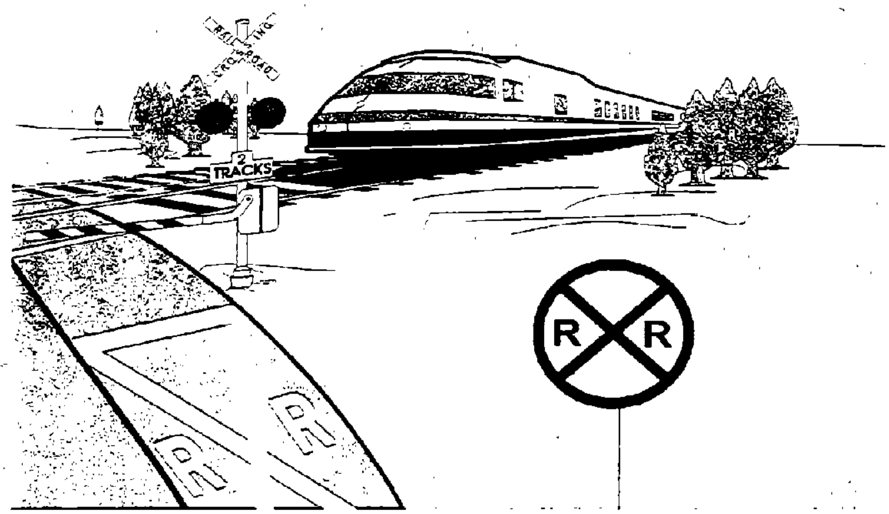
Safety of Highway-Railroad Grade Crossings

Research Needs Workshop
Volume II - Appendices

PB96-183256

Office of Research and Development
Washington, DC 20590

U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142



DOT/FRA/ORD-95/14.2
DOT-VNTSC-FRA-95-12.2

Final Report
January 1996

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

PB96-183256

2. REPORT DATE
January 1996

3. REPORT TYPE AND DATES COVERED
Final Report
October 1994 - August 1995

4. TITLE AND SUBTITLE
Safety of Highway-Railroad Grade Crossings Research Needs Workshop, Volume II

5. FUNDING NUMBERS
RR597/R5042

6. AUTHOR(S) Anya A. Carroll and Janelle L. Helser

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Kendall Square, Cambridge, MA 02142

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FRA-95-12.2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Research and Development
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FRA/ORD-95/14.2

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the National Technical Information Service, Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Federal Railroad Administration (FRA) recently developed the U.S. Department of Transportation's (U.S. DOT) Action Plan for Rail-Highway Grade Crossing Safety. The objective is to achieve at least a fifty-percent reduction in accidents and fatalities at grade crossings over the next ten years. The Action Plan identifies the need for a workshop to develop an intermodal consensus on projected research needs.

The John A. Volpe National Transportation Systems Center hosted and conducted the Highway-Railroad Grade Crossing Safety Research Needs Workshop on April 10 - 13, 1995. Seventy-five delegates participated in the workshop and identified ninety-two (92) crossing safety related research needs.

This document contains results of analyses of the research needs. The results suggest that cost-effective research can be conducted without large expenditures of public funds. Results also indicate most research needs apply to high speed rail and the area of human response to grade crossing applications should receive increased emphasis in the future. Results address relationships among the identified research needs, the Action Plan and current research being conducted.

The workshop delegates' consensus is that the workshop was a worthwhile first step in developing an intermodal approach to improving highway-railroad grade crossing safety and the process should continue.

14. SUBJECT TERMS
Federal Railroad Administration, highway-railroad grade crossing safety, railroad safety research, U.S. DOT Action Plan

15. NUMBER OF PAGES
440

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unclassified

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC	METRIC TO ENGLISH
LENGTH (APPROXIMATE)	**LENGTH** (APPROXIMATE)
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA** (APPROXIMATE)
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT** (APPROXIMATE)
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = .45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME** (APPROXIMATE)
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 quart (qt) = 0.96 liter (l)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	
TEMPERATURE (EXACT)	**TEMPERATURE** (EXACT)
$[(x - 32)(5/9)]$°F = y°C	$[(9/5)(y + 32)]$°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0			1			2			3			4			5
CENTIMETERS	0	1	2		3	4	5	6	7		8	9	10	11	12	13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 9/29/95

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List of Attendees

Rick Bartoskewitz
Transportation Systems Division
Texas A&M
Texas Transportation Institute
College Station, TX 77843

Lt. Ron Beck
Public Information Division
MO State Highway Patrol
PO Box 568
Jefferson City, MO 65102

Kenneth W. Beljen
Police and Safety
NYS&W Railway
One Railroad Ave.
Cooperstown, NY 13325

Frann Bell
IDEA Program
Transportation Research Board
2001 Wisconsin Avenue, N.W., Green Bldg, 2nd F
Washington, D. C. 20007

Bill Berg
University of Wisconsin
2206 Engineering Hall
Madison, WI 53706

Brian Bowman
TRB, Grade Crossing Chairman
c/o Auburn University
Harbert Engineering Center
Auburn University, AL 36849

Barbara Brody
Department of Education
120 State Street
Montpelier, VT 05602

Matt Brooks
Intermodal Transportation Division
Indiana DOT
100 N. Senate Ave. Rm. N901
Indianapolis, IN 46204

Richard Brown
Iowa DOT
800 Lincoln Way
Ames, IA 50010

Dennis Burkheimer
Rail & Water Division
Iowa DOT
800 West Lincoln Way
Ames, IA 50010

Preceding page blank

Ellen Canter
UNISYS Corporation
VNTSC
4 Cambridge Center
Cambridge MA 02142

Rick J. Cantwell
ConRail
PO Box 41412
2001 Market St. - 12B
Philadelphia, PA 19101

Anya Carroll
DTS-73
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Fred Coleman
1203 Newmark C.E, Bldg., MC -250
University of Illinois
205 N. Mathews Ave.
Urbana, IL 61801

Jim Curry
Engineering Management Consultants
707 Wilshire Blvd
Los Angeles, CA 90017

David Daley
DTS-801
US DOT/RSPA/Volpe
55 Broadway
Cambridge, MA 02142

R Andrew Davis
Sales & Marketing
OMNI Products Inc.
PO Box 15319
Portland, OR 97215

Randall L. Dickinson
Region I, Crossing & Trespasser Manager
US DOT/FRA
258 Ushers Road, Suite 203
Clifton Park, New York 12065

Thomas Donahey
Maintenance Division
Iowa DOT
800 Lincoln Way
Ames, IA 50010

Mahmood Fateh
Research & Development, RDV 31
US DOT/FRA
400 Seventh St. SW
Washington, DC 20590

Bruce George
Safety, RRS - 21
US DOT/FRA
400 7th St. SW
Washington, D.C. 20590

Dan Gilbert
Norfolk Southern
110 Franklin Rd.
Roanoke, VA 24042 - 0021

Jeff Gordon
DTS-76
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Bernardine Hayes
Unisys Corporation
Systems Support Group
55 Broadway
Cambridge Center
Cambridge, MA 02142

Hugh Henry
Association of American Railroads
50 F Street, NW
Washington, D.C. 20001

John Hitz
DTS-73
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Lou Hubbaud
Manager, Safety & Security
LA County MTA
818 West Seventh Street
Los Angeles, CA 90017

Lawerence Jackson
National Resource Specialist
National Transportation Safety Board
490 L'Enfant Plaza East, SW - Rm 6223
Washington, D.C. 20594

John W. Johnson
Domestic Sales
Harmon Industries, Inc.
1300 Jefferson Court
Blue Springs, MO 64015

John Killpack
Director, Client Services
Global Exchange
7910 Woodmont Avenue, Suite 400
Bethesda, Maryland 20814-3015

Susan Kirkland
Rail Highway Safety Section
Ohio DOT
50 W. Broad St. Rm. 1520
Columbus, OH 43215

Terry Klein
US DOT/NHTSA
NRD-31, Room 6125
400 Seventh Street, SW
Washington, DC 20590

Andrew Kleine
Office of Programs & Evaluation, B-10
US DOT/Office of the Secretary of Transportation
400 Seventh Street, SW
Washington, DC 20590

Norman Knable
DTS-73
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Hans Korve
President
Korve Engineering
155 Grand Avenue, Suite 94612
Oakland, CA 94612

Donald Laschkewitsch
Rail Program Planning Division
608 East Boulevard Ave
Bismarck, ND 58505

Neil Lerner
Manager, Human Factors
COMSIS
8737 Colesville Road, Suite 1100
Silver Spring, MD 20910

Herbert S. Levinson
Transportation Consultant
40 Hemlock Rd.
New Haven, CT 06515

W.C. Liddell
Regulatory Affairs - Engineering
Suite E-209 Windsor Station
P.O. Box 6042
Station Centre Ville
Montreal, Quebec H3C3E4

Fred Loehfelm
Wireless Technology
112 Stillwater Rd.
Mahopac, NY 10541

Elaine Lyte
DTS-82
US DOT/RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Ron Madigan
DTS-70
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Jerry Masters
14th Floor
Burlington Northern
9401 Indian Crk. Parkway
Overland Park, KS 66210

Richard Mather
Railroad Crossing Signal Specialist
Oregon PUC
1485 Ammon St. NW
Salem, OR 97304

Dr. David Mayer
Office of the Chairman
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594

Linda Meadow
Manager, System Safety
LA County MTA
818 West Seventh Street
Los Angeles, CA 90017

Leroy Meisel
MO Division of Economic Development
Missouri DOT
PO Box 1216
Jefferson City, MO 65102

Mark Mironer
DTS-73
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Marilyn Mullane
DTS-801
US DOT/RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Jordan Multer
DTS-45
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Joe Noffsinger
ConRail
PO Box 41410
2001 Market St. -10C
Philidelphia, PA 19101 - 1410

William T. O'Brien
Ohio State Legislative Board
Brotherhood of Locomotive Engineers
PO Box 20189
Columbus, OH 43220

Phil Olekszyk
Safety, RRS - 2
US DOT/FRA
400 Seventh Street, SW
Washington, DC 20590

Ernie Oliphant
Highway & Rail Consulting Services
3008 North 16th Drive
Phoenix, AZ 85015

Ed Pederson
Safety
S. CA Regional Rail Authority
818 West 7th St.
Los Angeles, CA 90017

Phil Poichuk
ASREA
Transport Canada
344 Slater Street, 15 Floor
Ottawa, Ontario, Canada K1A0N5

Tom Raslear
Research & Development, RDV-32
US DOT/FRA
400 7th Street, SW
Washington, DC 20590

Capt. Les Reel
Executive Officer, Operations Department
Ohio Highway Patrol
660 East Main Street
Columbus, OH 43205

Donald F. Remaley
Gov't & Industry Relations
Safetran Systems Corporation
1044 East Chestnut St.
Louisville, KY 40204

Hoy Richards
Transportation Specialist
Richards and Associates
PO Box 10305
College Station, TX 77842

Steve Richards
Director, Transportation Center
University of Tennessee
357 South Stadium Hall
Knoxville, TN 37996

Dr. Eugene Russell
Department of Civil Engineering
Kansas State University
119 Seation Hall
Manhattan, KS 66506

Jeff Schultz
Rail Office
Washington State DOT
P.O. Box 7387
Olympia, Washington 98504-7387

John Sharkey
Communications & Signal Division
Illinois Central Railroad
17641 Ashland Avenue
Homewood, IL 60430

Cliff Shoemaker
Director, Industry & Public Projects
Union Pacific Railroad
1416 Dodge St.
Omaha, NE 68179

Yvonne Shull
NTS-40
US/DOT/NHTSA, Room 5119
400 7th Street, SW
Washington, DC 20590

Tom Simpson
Railway Progress Institute/Operation Lifesaver Inc.
700 North Fairfax Street, Suite 6
Alexandria, VA 22314

John Smith
DTS-73
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Mike Smith
US DOT/NHTSA, NTS-30
400 7th St. SW
Washington, D.C 20590

John Smith
Norfolk Southern
99 Spring St.
Atlanta, GA 30303

Jim Sotille
Safety, Region I
US DOT/FRA, DTS-906
55 Broadway, 10th Floor
Cambridge, MA 02142

Debbie Swanson
DTS-74
US DOT/ RSPA/Volpe
55 Broadway
Cambridge, MA 02142

Chuck Taylor
Association of American Railroads
4th Floor
50 F Street, NW
Washington, DC 20001

Garold Thomas
Research & Development, RDV-32
US DOT/FRA
400 7th Street, SW
Washington, DC 20590

John Tolman
Chairman
Brotherhood of Locomotive Engineers
80 Sheffield Street
Melrose, MA 02176

Francis G. Welsh
Wayside Ground Equipment
Union Switch & Signal Inc.
5800 Corporate Dr.
Pittsburgh, PA 15237

Bob Winans
HHS-22
US DOT/FHWA
400 Seventh Street, SW
Washington, DC 20590
West Trenton, NJ 08628

Capt. William Yodice
NJ State Police
Traffic Bureau
PO Box 7068

Tom Zeinz
Engineer, Public Works
Illinois Central Railroad
17641 South Ashland Avenue
Homewood, IL 60430

Appendix B

Agenda and Handouts

AGENDA

HIGHWAY-RAILROAD GRADE CROSSING SAFETY RESEARCH NEEDS WORKSHOP

APRIL 10 - 13, 1995

Sponsored by:
FEDERAL RAILROAD ADMINISTRATION
Location:
Volpe National Transportation Systems Center, Cambridge, MA

APRIL 10, 1995

REGISTRATION / RECEPTION 6:00 - 9:00 p.m.
Location: Holiday Inn, Government Center
5 Blossom St.
Boston, MA

APRIL 11, 1995

REGISTRATION 7:30 - 8:30 a.m.
Location: Volpe National Transportation System Center Auditorium

WELCOME TO VOLPE CENTER 8:30 - 8:40
Mr. Ron Madigan - Host
- *Director, Office of Systems Engineering*
- *Volpe National Transportation Systems Center*

OPENING REMARKS 8:40 - 9:00
Mr. Bruce George
- *Chief, Highway-Rail Crossing and Trespasser Division*
- *Federal Railroad Administration*

GRADE CROSSING SAFETY RESEARCH 9:00 - 9:20
IMPLICATIONS FOR HIGH SPEED RAIL
Mr. John Hitz
- *Chief, Accident Prevention Division*
- *Volpe National Transportation Systems Center*

BREAK 9:20 - 9:30

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	ENFORCEMENT - Chair, Ms. Linda Meadow	9:30 - 11:00
	1) Ms. Yvonne Shull - Historical Perspective - *National Highway Traffic Safety Administration* 2) Capt. Les Reel - Current Research - *Ohio Highway Patrol* 3) Mr. Lou Hubbaud - Innovation - *LA County Metropolitan Transit Authority* 4) Mr. Hans Korve - Innovation - *Korve Engineering*	
	DRIVER EDUCATION - Chair, Mr. Tom Simpson	11:00 - 11:50
	1) John Killpack - Historical Perspective - *Global Exchange* 2) Ms. Barbara Brody - Innovation - *Department of Education*	
LUNCH		11:50 - 1:00
	HUMAN FACTORS - Chair, Mr. Bob Winans	1:00 - 2:10
	1) Mr. Neil D. Lerner - Historical Perspective - *COMSIS* 2) Mr. Tom Raslear - Current Research - *Federal Railroad Administration* 3) Mr. John Tolman - Innovation - *Brotherhood of Locomotive Engineers*	
	CROSSING IMPROVEMENT - Chair, Chuck Taylor	2:10 - 3:20
	1) Mr. Tom Zeinz - Historical Perspective - *Illinois Central Railroad* 2) Mr. John Sharkey - Current Research - *Association of American Railroads* 3) Mr. Hoy Richards - Innovation - *Richards & Associates*	
BREAK		3:20 - 3:40
	DATA - Chair, Dr. Brian Bowman	3:40 - 4:50
	1) Mr. Bill Berg - Historical Perspective - *University of Wisconsin* 2) Mr. Terry Klein - Current Research - *National Highway Traffic Safety Administration* 3) Ms. Linda Meadow - Innovation - *LA County Metropolitan Transit Authority*	
WRAP-UP		4:50 - 5:30

April 12, 1995

GENERAL MEETING Location: Auditorium Anya Carroll - *Workshop Coordinator* - *Volpe National Transportation Systems Center* -Explanation of the days events	9:00 - 9:45
BREAK	9:45 - 10:00
ROUNDTABLE DISCUSSIONS BEGIN Location: individual breakout rooms	10:00 - 12:00
LUNCH	12:00 - 1:15
ROUNDTABLE DISCUSSIONS CONTINUE	1:15 - 3:00
BREAK	3:00 - 3:15
ROUNDTABLE WRAP-UP	3:15 - 4:15
PRIORITIZE URGENT RESEARCH NEEDS - *Within each topical area group*	4:15 - 5:00
RECONVENE Location: Auditorium - *Distribute Roundtable Results*	5:15 - 5:30

April 13, 1995

CHAIRPERSONS' PRESENTATIONS

Location: Auditorium
- *Review of Research Needs Identified per Topical Area*
- *Discussion of Urgent Research Needs Identified per Topical Area*

ENFORCEMENT Ms. Linda Meadow - *LA County Metropolitan Transit Authority*	8:30 - 9:00
DRIVER EDUCATION Mr. Thomas Simpson - *Railway Progress Institute/Operation Lifesaver*	9:00 - 9:30

<u>HUMAN FACTORS</u> Mr. Bob Winans *- Federal Highway Administration*	9:30 - 10:00
BREAK	10:00 - 10:15
<u>CROSSING IMPROVEMENT PROGRAMS</u> Mr. Chuck Taylor *- Association of American Railroads*	10:15 - 10:45
<u>DATA</u> Mr. Brian Bowman *- Transportation Research Board*	10:45 - 11:15
DISCUSS AND PRIORITIZE RESEARCH NEEDS *- Individual Participants will Prioritize All Urgent Research Needs Identified (Worksheets Provided)*	11:15 - 11:50
ADJOURNMENT	11:50 - 12:00

Opening Remarks

Presented by:
Bruce George

U.S. DOT/Office of Safety
Highway Rail Crossing and Trespasser Division

Mr. Philip Olekszyk, Ron Madigan (and others)

Thanks to John and Anya and their staff for all the work which has gone into preparing for this Workshop,

And a most sincere thanks to all of you who have taken time from busy schedules to prepare papers, to agree to moderate sessions and to just be here. Without your participation, we would have no chance of success.

This slot on the agenda, Opening Remarks, should ideally be filled by a first-rate motivational speaker to get us all "fired-up." But, on second consideration, this group is already dedicated, and I don't think motivation is what's needed. More important is recognition of the challenge we face in this Workshop, to work with each other to develop creative and innovative ideas worthy of our research investment. The **long term potential** of this Workshop is such that I believe this is probably the most important presentation I've ever been called upon to offer. I hope what I have to offer meets this need. First, I will present a little background and then some cautions which I believe we will have to observe if we are to be successful over the next couple of days.

You all remember the <u>Action Plan</u>, released 10 months ago by Secretary of Transportation Federico Peña. A copy is among your handout materials. Part V of the Plan deals with Data and Research, and calls for a Workshop regarding **research needs** to improve safety at highway-rail crossings. This Workshop is held in fulfillment of that commitment. However, it is not just another <u>Action Plan</u> commitment fulfilled, checked-off and done with. If we are successful over the next couple of days, this will be a beginning, a focusing and a targeting on those aspects of this problem which might be amenable to solution or adjustment or progress through research.

These are not decisions which we, FRA, felt comfortable, or even competent, to make by ourselves. We need the collective wisdom and real-world, outside-the-beltway experience of this group, and, most importantly, we need "buy-in" from this group. If we are successful, we will identify some "**do-able,**" **high-potential** projects. That is our first and foremost goal. Icing-on-the-cake will be coordination among us regarding <u>who</u> will address <u>which</u> issues. Achieving this second goal is not necessary for the overall success of the Workshop, but if we don't address it here, coordination will most likely occur by default which leaves a high likelihood for gaps and overlaps. So that is the challenge, **do-able high potential projects**, and who will address which. We have our work cut out for us.

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Now, I spoke of some cautions. Maybe I should call them "Rules of Engagement."

Each of you have been invited because of your recognized personal interest, your expertise and your prior contributions. Your peers, seated next to you, and behind you and in front of you, will assess your contributions over the next couple of days by your ability to divorce yourself from the interest group(s) you may represent (for many of you, from the employer who sent you here), and that is **not** easy. I'm calling on you, as the first Rule of Engagement, to apply your personal expertise, first and foremost, to the safety and convenience of the at-large public, to the public interest! In this context, the "public interest" extends well beyond the motoring public who **drives** across tracks. It includes passengers, in vehicles, in buses and in trains. It includes those who operate trains, and those who live or work near railroads. It includes taxpayer dollars and costs to **industries, States and local governments**. The public interest even includes the railroads which, though privately owned, are a national and a public resource, and a key element in this nation's transportation infrastructure.

Let me offer a case-in-point from my own experience within the Department of Transportation. Early in my FRA career, when I was even more naive than I am today (which I know is hard for some of you to believe), I would attend meetings with my associates from the FHWA. These meetings frequently led to a clear defining of our respective positions, but little progress or agreement, stand-offs which were often resolved only through the intervention of higher "authority" despite the other party's position, or the public interest. I often marveled at the unanimity, and well thought-out, persuasive, mutually supportive arguments, presented by the various FHWA offices. Only later did I learn that this unison was achieved in what FHWA staff called "pre-meetings." They would meet prior to our **inter**-agency meeting, discuss the pros and cons of the issue, settle on an FHWA position and decide who would present which arguments. In essence, they rehearsed. They then came to the inter-agency meeting with their position set and inflexible -- often those who came to the meeting were not empowered to change their position -- it was their position or no agreement at all. I'm happy to say, at least where crossing safety is concerned, that has changed. FHWA and FRA, from our respective political leadership down to our program staff, make a point of pre-decision coordination. The Action Plan is one result of this cooperative activity, and included, not two, but four DOT agencies. Another example is the FHWA's Grade Crossing Safety Team which meets weekly to review and discuss on-going crossing related staff actions. A member of my staff is an invited participant in these FHWA team meetings. The public's interest is much better served.

The point I'm making: We must begin this Workshop with an open mind, not with a pre-meeting. We must set aside baggage we may have carried into this room, and consider alternatives on the basis of the public interest.

Can we raise the concerns of the interest groups we represented until that door (in the back of the room) closed? Absolutely! It is those concerns, problems and perceptions which need to be addressed.

But when it comes time to make a decision between alternatives, we should be swayed only by the larger pubic interest, and we should reach consensus. That is the First Rule of Engagement, consensus and the public interest.

Let me say a few words about "consensus": Consensus means "general agreement" on an issue. I want to be able to say after Thursday noon that we reached "consensus" on the developed research needs. That we reached "general agreement." I ask those of you who would be inclined to dissent on one issue or another, on a need, to make yourself heard -- offer your opinion, and after you've been heard, ask yourself, "Can I live with this decision of my peers?" I'm not really asking you to agree with the decision, only to acknowledge that it is the conclusion of your peers, and, as such, that it is acceptable, that, "I can live with it." If the majority of us agree, and the remainder of us, after being heard, can accept and live with the decision, then that is consensus, that is general agreement.

The second Rule of Engagement deals with "conventions." And I don't mean annual meetings. We are to discuss possible research projects -- different procedures and innovative technologies, new participants and changed responsibilities. There is no place in these discussions for arguments based on current conventions and current standards. Objections raised based on the Manual on Uniform Traffic Control Devices, or on the Uniform Vehicle Code, or on the AAR Signal Manual, or the new Part 236 of the Code of Federal Regulations, or railroad operating rules, or labor-management agreements, or court decisions, or state and local ordinances are not relevant and are without force in these deliberations. At what cost does the MUTCD have a one-sign-per-post rule? At what cost does the CFR require back-up power? Surely, there are alternatives to track circuits for determining the whereabouts of a train! These and many other conventions are all extant: We must discuss potential. Needs, perceptions and potential are more relevant than existing conventions. The Second Rule of Engagement: For the next two and a half days, we must not be hampered by existing conventions and practices.

The third rule deals with our "mind-set." We've got to breakout of our tried and true, if it ain't broke don't fix it, mind-set. We must be creative. I would submit that what is out there today has been "tried," and it continues to be found wanting. That's why we're here. We're still experiencing nearly 5,000 collisions per year resulting in over 600 deaths, and we know exactly where and when those collisions and deaths will occur--at a crossing when a train is present. According to my home town newspaper, Annapolis' Sunday Capital, just last Saturday, in Castle Rock, Colorado, six individuals died when their two-door Volvo collided with a Santa Fe freight train at a crossing equipped with operating flashing lights. Ladies and gentlemen, it is broken, and it needs fixin'! Let me be the first to say that public understanding and acceptance are lacking, as are education and enforcement. Those may indeed be appropriate subjects for research. But also lacking, are warning device credibility, circuit design minimum standards or, if you prefer, performance specifications, the concept of "fail-safe" and even the definition of "malfunction." Those too are all on the table for discussion. **We must be open, and not defensive,** in what we are willing to discuss and creative in the solutions we are willing to consider.

Frankly, I'm concerned about one aspect of our proceedings over the next couple days. I've reviewed the lists of who wants to be in which discussion groups, and I foresee very little originality, an unfortunate potential for a lot of pre-determined agendas and maybe even a circle-the-wagons defensive mentality. If we are to generate new and original ideas, the public-project engineers must not spend all of their time in the discussion of warning devices, nor should the police officers spend all their time addressing enforcement issues. Our contributions over the next few days will be enhanced only if we apply our knowledge and experience from our own personal fields of endeavor to assisting in the definition of **needs** in other fields. Remember, we are here to define needs, not necessarily to solve the problem. Share your perceptions of needs in the other disciplines, not your own, and then let the practitioners in those fields, the experts, subsequently address the need and develop the solutions. That's where your opportunity will come to apply your expertise in your own field. No subject is taboo, no idea is silly. Third Rule of Engagement: Allow yourself to be creative.

Lastly, let me offer a couple of broad distinctions for your consideration. First, I think there are some distinctions to be made between what I'm going to define as the "soft" side **of the problem and the solutions** and the "hard" side. The soft side encompasses issues and solutions such as Federal, State, local and railroad **interactions and procedures**, education and enforcement, human factors, public behavior, operating practices, information needs, etcetera. The hard side would include visible and audible warning devices, both train borne and site specific, control circuitry, traffic control, train location and vehicle detection, crossing monitors, impact attenuation, and so forth. Among many challenges we face here today is that the identification and matching of problems and solutions often cross these soft/hard distinctions. Hard-side proponents often find fault with existing soft-side practice, and vice versa. How many times have you heard a public projects engineer lament the inadequacy of driver education or enforcement. Today, tomorrow and the next day are going to provide you with an opportunity to turn that grousing into a needs statement. A soft-side problem may often be solved by the offering of a hard-side solution, and vice-versa. The implication for us, is that the electrical or mechanical or civil engineers here today, the hard-side proponents, must listen to and be receptive to the ideas and suggestions, needs and perceptions, of the human factors, education and enforcement specialists, the soft-side proponents, who are also here. And, of course, the reverse is also true.

Let me give one example I'm sure you've all heard. It's classic and unproductive, and I want to stress that word, unproductive. The classic unproductive exchange too often heard, more often than not initiated by the "soft-side," is: "The warning device was broken," to which the "hard-side" apologist responds, "It functioned as designed!" Ladies and gentlemen, the message in this exchange, and there is a message, was either not heard or was intentionally ignored! The Fourth Rule of Engagement during this Workshop: Listen with respect, not just toleration. Look for the message, don't just tolerate the speaker.

So, let me sum up:

I propose four Rules of Engagement:

First, Public interest as we reach consensus is paramount;

Second, Current conventions and practices are not relevant;

Third, Allow yourself, give yourself the opportunity, to be creative, and it's not likely you can do that while defining needs which apply to your own discipline; and,

Fourth, Listen with respect, not just toleration, with the emphasis on "listen."

Only if we follow these Rules can we be successful, and if we are successful, our success will out live us -- we will have made a difference.

Thank you.
Let's get started.

U.S. Department
of Transportation

Research and
Special Programs
Administration

John A. Volpe
National Transportation
Systems Center

Kendall Square
Cambridge Massachusetts 02142

Reply to: DTS-73

March 30, 1995

Dear Attendee:

The intermodal Highway-railroad Grade Crossing Safety Research Needs Workshop is bringing together representatives of Federal transportation agencies, industry and academia to develop a global view of research needs for highway-railroad at-grade crossing safety research. To enhance productivity at the upcoming intermodal workshop, we wish to provide you with as much information as possible. Therefore, please find the enclosed copies of all currently available papers written for the workshop. It is recommended that you review these papers before you attend the workshop. All other papers will be available at the workshop registration desk for review during the workshop.

Also, please find the preliminary agenda attached. Note that a new speaker has been added to the opening session of the workshop to address highway-railroad grade crossing safety research implications for high speed rail service.

Sincerely yours,

Anya A. Carroll

Ms. Anya A. Carroll, Workshop Coordinator

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{TOPICAL AREA}

Research Need #______ TITLE____

Problem Statement:

Research Objective:

Relationship to Current Research (circle one): Supplemental New

Organization conducting current research__________________________________
Title of Current Research____

Potential Benefits of Identified Research Need:

Urgency of Research Need (circle one): HIGH MEDIUM LOW

Cost to conduct Research Need (circle one):

HIGH	MEDIUM	LOW
> $500,000	$500,000 - $100,000	< $100,000

Possible Responsible Organization to conduct Research Need:____________________

Other Comments: **Applicable to High Speed Rail Service**(check here)____________

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HIGHWAY-RAILROAD GRADE CROSSING SAFETY

RESEARCH NEEDS WORKSHOP

April 12, 1995

Working Group Topical Area
Breakout Room Assignments

TOPICAL AREA	CHAIR	FACILITATOR	ROOM ASSIGNMENT	DESIGNATED COLOR
ENFORCEMENT	Linda Meadow LAC MTA	Marilyn Mullane Volpe	Room 11-20	**RED**
DRIVER EDUCATION	Tom Simpson RPI/OLI	Elaine Lyte Volpe	Room - 7-29A	**GREEN**
HUMAN FACTORS	Bob Winans FHWA	David Daley Volpe	Room 12-61	**GOLD**
CROSSING IMPROVEMENT	Chuck Taylor AAR	Ellen Canter Unisys	Reserved Dining Bay #1 and #2	**BLUE**
DATA	Brian Bowman TRB	Bernadine Hayes Unisys	Room 6-25	**SILVER**

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PRIORITIZATION OPINION SURVEY

DATA

Priority	Research Needs #	Title
	D-1.A	Data Requirements for Highway-railroad Grade Crossing Safety
	D-2.A	Data Integration Working Group
	D-3.A	Update Crossing Inventory and Include Sight Distance Data Collection
	D-4.A	Exposure Measures

HUMAN FACTORS

Priority	Research Needs #	Title
	HF-1	Effects of Sight Distance on Driver Behavior
	HF-2	Effectiveness of Low Cost Countermeasures for Passive Crossings
	HF-4	Unique Advance Warning signs for Active & Passive Crossings
	HF-6	Causal Analysis of Accidents Involving Grade Crossings
	HF-9	Vehicle Activated Strobe
	HF-10	Applicability of Highway Traffic Control Devices at Railroad Crossings
	HF-11	Interim Improvements at Grade Crossings
	HF-12	Rail Car Conspicuity
	HF-14A	Train Horns
	HF-14B	Way-side Horns
	HF-15	Factors Affecting Credibility of Grade Crossing Warning Devices
	HF-22	Institutional Issues; Technology Transfer
	HF-23	Driver Perception of Risk
	HF-25	Warning Time Trade-offs
	HF-28	In-Train Warning Devices
	HF-29	Post Train Accident Effects
	HF-37	ITS and its Relationship to Driver and Rail Operators Information

PRIORITIZATION OPINION SURVEY (cont)

ENFORCEMENT

Priority	Research Needs #	Title
	E-1	Training and Model Policies
	E-2	Photo Enforcement

DRIVER (public) EDUCATION

Priority	Research Needs #	Title
	DE-1	Determining Target Audiences
	DE-2	Survey of Current & Completed Research
	DE-3A	Survey of Existing programs
	DE-3B	Funding Sources

CROSSING IMPROVEMENT (engineering) PROGRAMS

Priority	Research Needs #	Title
	CIP-1	Highway Traffic Control Engineering Technology Transfer
	CIP-2	Highway Median Barriers
	CIP-3	Four-Quadrant Gate Systems
	CIP-4	Standard Crossbuck Applications
	CIP-5	Low-Cost Alternatives to Conventional Warning Devices
	CIP-6	Proper Warning Time With Credibility
	CIP-7	Intelligent Highway-Rail Intersection
	CIP-8	Proposed National Warrants For Selection of Warning Devices
	CIP-9	Off - Track Train Detection
	CIP-21	Advance Warning Messages

DRIVER EDUCATION WORKING GROUP

Chair - Tom Simpson
Facilitator - Elaine Lyte

Number in Group	Name	Organization
1	Lt. Ron Beck	MO State Highway Patrol
2	Bruce George	FRA/Safety
3	John Killpack*	Global Exchange
4	Elaine Lyte	Volpe/Facilitator
5	Stephanie Markos	Volpe
6	Ernie Oliphant	Highway & Rail Consulting Services
7	Phil Poichuk	Transport Canada
8	Cliff Shoemaker	Union Pacific RR
9	Tom Simpson**	RPI/OLI
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** - Chair   * - Speaker

ENFORCEMENT WORKING GROUP

Chair - Linda Meadow
Facilitator - Marilyn Mullane

Number in Group	Name	Organization
1	Kenneth Beljen	NYS&W Railway
2	Randy Dickinson	FRA/Safety
3	Lou Hubbaud	LA County MTA
4	John Johnson	Harmon Industries Inc.
5	Hans Krove*	Krove Engineering
6	Linda Meadow**	LA County MTA
7	Marilyn Mullane	Volpe/Facilitator
8	Capt. Les Reel*	Ohio Highway Patrol
9	Yvonne Shull*	NHTSA
10	Mike Smith	NHTSA
11	Capt. William Yodice	NJ Traffic Bureau
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** - Chair * - Speaker

HUMAN FACTORS
WORKING GROUP

Chair - Bob Winans
Facilitator - David Daley

Number in Group	Name	Organization
1	Rick Bartoskewitz	Texas A&M
2	David Daley	Volpe/Facilitator
3	Neil Lerner*	COMSIS
4	Herbert Levinson	Transportation Consultant
5	Jerry Masters	Burlington Northern
6	Dr. David Mayer	NTSB
7	Mark Mironer	Volpe
8	Jordan Multer	Volpe
9	Phil Olekszyk	FRA/Safety
10	Tom Raslear*	FRA/R&D
11	Bucky Remaley	Safetran Systems Corporation
12	Steve Richards	University of TN Trans. Center
13	Gene Russell	Kansas State University
14	Garold Thomas	FRA/R&D
15	John Tolman*	BLE
16	Bob Winans**	FHWA
17		
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** - Chair * - Speaker

CROSSING IMPROVEMENT PROGRAM WORKING GROUP

Chair - Chuck Taylor
Facilitator - Ellen Canter

Number in Group	Name	Organization
1	Ellen Canter	UNISYS/Facilitator
2	Rick Cantwell	ConRail
3	R. Andrew Davis	OMNI Products Inc.
4	Thomas Donahey	Iowa DOT
5	Dennis Gilbert	Norfolk Southern
6	Jeff Gordon	Volpe
7	Hugh Henry	AAR
8	John Hitz	Volpe
9	Lawerence Jackson	NTSB
10	Donald Laschkewitsch	Rail Program Planning Division
11	Bill Liddell	Canadian Pacific Rail System
12	Dick Mather	Oregon Public Utilities Commission
13	Leroy Meisel	Missouri DOT
14	Rex Nichelson	TransTech Group
15	Bill O'Brien	Ohio - BLE
16	Hoy Richards*	Richards and Associates
17	Jeff Schultz	Washington State DOT
18	John Sharkey*	Illinios Central Railroad
19	John W. Smith	Norfolk Southern
20	Debbie Swanson	Volpe
21	Chuck Taylor**	AAR
22	Fran Welsh	Union Switch & Signal Inc.
23	Tom Zeinz*	Illinios Central Railroad

** - Chair * - Speaker

DATA
WORKING GROUP

Chair - Brian Bowman
Facilitator - Bernadine Hayes

Number in Group	Name	Organization
1	Frann Bell	Transportation Research Board
2	Bill Berg*	University of Wisconsin
3	Brian Bowman**	TRB
4	Matt Brooks	Indiana DOT
5	Richard Brown	Iowa DOT
6	Dennis Burkheimer	Iowa DOT
7	Fred Coleman	University of Illinios
8	Jim Curry	Engineering Management Consultants
9	Mahmood Fateh	FRA/R&D
10	Bernadine Hayes	UNISYS/Facilitator
11	Susan Kirkland	Ohio DOT
12	Terry Klein*	NHTSA
13	Andrew Kleine	US DOT/OST
14	Norman Knable	Volpe
15	Fred Loehfelm	Wireless Technology
16	Joe Noffsinger	ConRail
17	Ed Pederson	SCRRA
18	John Smith	Volpe
19	Jim Sotille	FRA/Safety
20		
21		

** - Chair * - Speaker

United States
Architectural and Transportation Barriers Compliance Board

1331 F Street, NW • Washington, DC 20004-1111 • 202-272-5434 (Voice) • 202-272-5449 (TDD) • 202-272-5447 (FAX)

DATE: 6 April 1995

TO: Anya A. Carroll, Workshop Coordinator
John A. Volpe National Transportation Systems Center
USDOT/Research and Special Programs Administration

FROM: Lois E.L. Thibault (x32)
US Architectural and Transportation Barriers Compliance Board

SUBJECT: *Highway-railroad Grade Crossing Safety Research Needs Workshop*

ATTACHMENT: Proposed Research Problem Statement

The US Architectural and Transportation Barriers Compliance Board (the Access Board) is an independent Federal agency charged with developing guidelines for the accessibility of newly-constructed and altered buildings and facilities under the Americans with Disabilities Act of 1990. In 1991, the Board issued--and the Departments of Justice and Transportation adopted--the *ADA Accessibility Guidelines (ADAAG)*. In 1992, the Board proposed amendments to *ADAAG* to include coverage of new construction and alterations in the public right-of-way; adoption of this and other sections is pending. The Access Board also has enforcement responsibilities under the Architectural Barriers Act of 1968, which generally applies the *Uniform Federal Accessibility Guidelines (UFAS)* to work funded with Federal monies, such as that supported under the Highway-aid Act.

Amendments to *ADAAG* proposed in December 1992 (revised and republished in June 1994) as *Section 14 Public Rights-of-Way* included a 2-1/2-inch maximum width for the flangeway gap at pedestrian-railroad grade crossings. This requirement is already contained in *ADAAG Section 10 Transportation Facilities*. Comments from public works and railway interests suggest that a flangeway gap of almost 4 inches is in fact required at some pedestrian crossings on freight lines. This is a substantial barrier to use by persons in wheelchairs.

Please consider the attached Research Problem Statement in your workshop. The Access Board would be pleased to support a research project in this area with its technical expertise in the design and construction of accessible buildings, facilities, and transportation systems. Thank you.

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PROPOSED RESEARCH PROBLEM STATEMENT

USDOT/Research and Special Programs Administration
John A. Volpe National Transportation Systems Serninar

Title: Technology Applications for Accessible At-Grade Rail Crossings

Problem: Horizontal flangeway gaps at pedestrian/rail crossings may be as wide as 4 inches where heavy freight must be accommodated; light rail requires as much as 2-1/2 inches of clearance. There have been several reports of wheelchair entrapment at such crossings. The ADA Accessibility Guidelines (ADAAG) limit horizontal gaps in the accessible route to 1/2 inch. New, highly maneuverable wheelchairs may have front wheels with a diameter of 3 inches or less. Wheels of any diameter may swivel and drop into the flangeway when they hit an obstruction. Although gap fillers are available for locations where railcars travel at very low speeds, as in railyards, no products are manufactured for more demanding environments characterized by heavy freight loadings and moderate to high speeds. As light rail systems, transit malls, and transit-oriented development expand, there will be a great increase in pedestrian crossings of rail lines.

Objective: This project should 1) identify and assess the most promising technologies or research directions for the development of a product or system to render at-grade rail crossings accessible for persons using wheelchairs and 2) formulate a plan for research, development, testing, and demonstration.

Key Words: Flangeway, at grade-crossings, rail, ADA, accessibility, wheelchairs

Related Work: None known

Urgency/Priority: High. A guideline proposing technical specifications for the accessibility of public rights-of-way has been proposed by the Access Board and will be considered next year for adoption by the Department of Justice as the standard for regulations implementing title II of the ADA.

Cost: $150,000

User Community: Grade crossing manufacturers, FRA, AMTRAK, railroads and transit agencies, state public utility commissions, state highway engineers

Implementation: This study should be used to program and fund [a] research and development project[s].

Effectiveness: An accessible at-grade crossing product would eliminate the need for overpass/underpass construction or alternative routings where public sidewalks are interrupted by rail lines.

Submitted by: Lois E.L. Thibault, US Architectural and Transportation Barriers Compliance Board

RAIL-HIGHWAY CROSSING REPORTS, 1969-1993

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

Ordering Information:

Reports having an NTIS Order Number may be ordered from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. Enclose check or money order. Add $3.00 "Handling Charge" per order. Telephone number (Sales Desk: (703) 487-4650). Prices are effective as of January 1, 1994 and are subject to change thereafter. For other reports, a more comprehensive listing may be found in Bibliographies 57 and 58, published by and available through the Transportation Research Board, Washington, D.C. 20418.

Published FRA Reports in Chronological Order:

		NTIS ORDER NO.	PRICE CODE*
1.	A Program Definition Study for Rail-Highway Grade Crossing Improvement. Prepared by Alan M. Voorhees and Associates, Inc., for FRA, Report FRA-RP-70-2, October 1969.	PB 190401	A08
2.	The Visibility and Audibility of Trains Approaching Rail-Highway Grade Crossings. Prepared by Systems Consultants, Inc. for FRA, Report FRA-RP-71-1, May 1971.	PB 202668	A08
3.	Technological Innovation in Grade Crossing Protective Systems. Prepared by TSC for FRA, Report DOT-TSC-71-3, June 1971.	PB 201624	A05
4.	Report to Congress. Railroad-Highway Safety. Part I: A Comprehensive Statement of the problem. Part II: Recommendations for Resolving the Problem. Prepared jointly by the Staffs of FRA and FHWA. November 1971 and August 1972.	PB 206792 PB 213115	A07 A06

*See last page for prices.

R.C. WINANS

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1945-1976

TRB

TRANSPORTATION RESEARCH BOARD
NATIONAL ACADEMY OF SCIENCES

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HNG-12

J P Carney
R.C. Winans

BIBLIOGRAPHY 58

48 NEW ENTRIES

Railroad-Highway Grade Crossings: Update

(1972)
1976-1979

TRB
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NATIONAL ACADEMY OF SCIENCES

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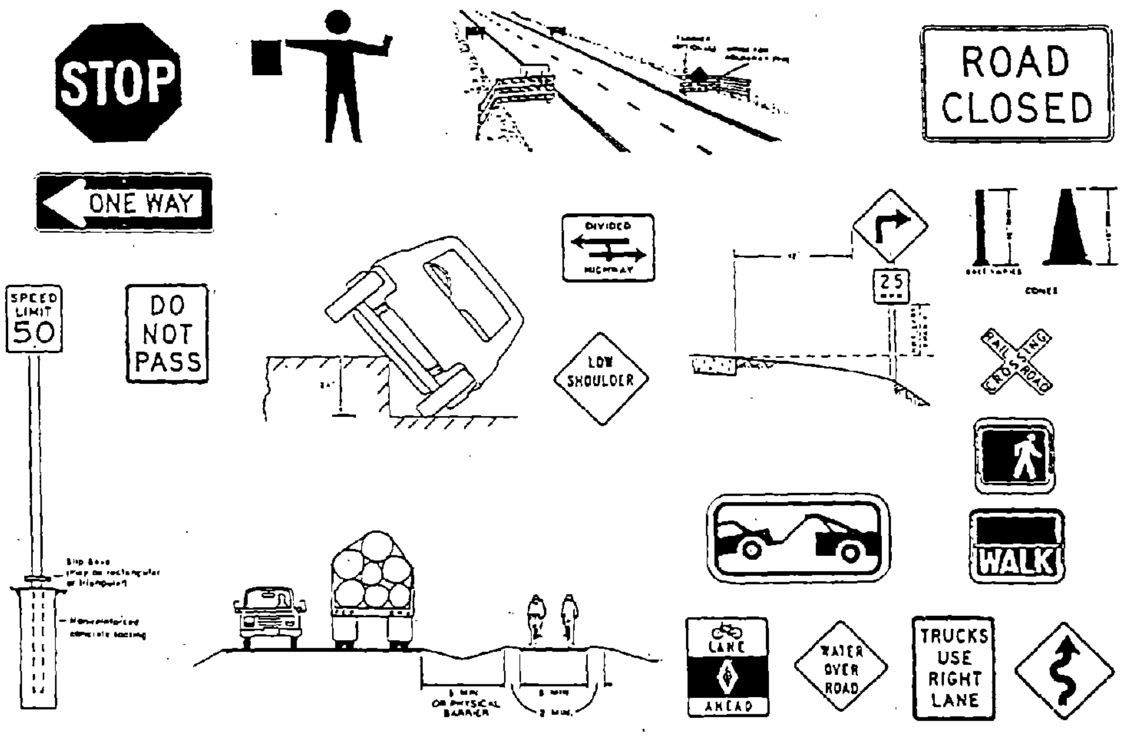
TranSafety, Inc.

ROBERT C. WINANS
HIGHWAY ENGINEER
FHWA HNG-12
202-366-4656



HIGHWAY SAFETY PUBLICATIONS CATALOG

January, 1992

Accidents
Bridges
Drainage Structures
Environmental Factors
Geometric Design
Grade Crossings p.15
Hazardous Materials
Human Factors
- Operators
- Pedestrians

Lighting and Visibility
Maintenance
Management
Noise Control
Pavement
Risk Management and Liability
Roadside Safety:
- Barriers
- Safety Appurtenances
- Poles (Utility & Light)
- Sign Supports

Snow and Ice Control
Standards
Traffic & Operations
Traffic Control Devices
Vehicles:
- Automobiles
- Trucks
- Motorcycles
- Bicycles
- Trains

Work Zones

Railroad Grade Crossings: Human Factors — 1985-1995

MARCH 1995

TRANSPORTATION RESEARCH INFORMATION SERVICE

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

B-37

Appendix C

Action Plan Support Proposals

Rail-Highway
Crossing Safety

Action Plan
Support Proposals

Federal Highway Administration

Federal Railroad Administration

Federal Transit Administration

National Highway Traffic Safety Administration

June 13, 1994

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ACTION PLAN

Highway-Rail Crossing Safety

Contents Page

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Appendices

Executive Summary

This Action Plan presents a multi-faceted, multi-modal approach for improving safety at our Nation's highway-rail crossings and for the prevention of trespassing on the rights-of-way of our Nation's railroads. It is multi-faceted in that it presents enforcement, engineering, education, research, promotional and legislative initiatives addressing crossings of both light and conventional rail rights-of-way by public and private streets and highways. It is multi-modal in that contributions to its preparation have been made by four U.S. Department of Transportation (DOT) administrations, i.e., the National Highway Traffic Safety Administration (NHTSA), the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA) and the Federal Railroad Administration (FRA), working together with the same interest, safety at crossings. We have also received, considered and often incorporated or adapted, in whole or in part, ideas from many outside sources, individuals, railroads and States.

The Action Plan identifies six major initiatives encompassing 55 individual proposals. The major initiatives are:

I Increased Enforcement of Traffic Laws at Crossings
II Rail Corridor Crossing Safety Improvement Reviews
III Increased Public Education and Operation Lifesaver
IV Safety at Private Crossings
V Data and Research
VI Trespass Prevention

These are followed by Recommendations and a Goal and two Appendixes.

The essence of the Action Plan lies in fifty-five proposals. They can generally be divided into two groups: 1) Those which describe programs targeting individual needs; and 2) Those which will enable or provide incentives for a program's advancement.

Of those in the first category, highlights would include initiatives to:

- Establish the goal of eventual crossing elimination or warning device upgrades at all National Highway System crossings.

- Increase truck and bus driver awareness of crossing safety through education and consideration of revocation of the Commercial Driver's License for crossing violations.

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- Emphasize state traffic law enforcement programs through NHTSA Section 402 funds, as well as police and judicial education and outreach on crossing safety.

- Consolidate state crossing safety assessments to emphasize corridor review, and integrate intermodal planning to bring together railroads, MPOs and state DOTs to insure emphasis on crossing issues.

- Expand Operation Lifesaver (OL) through new community assistants sponsored by the Corporation for National Service, upgrade OL advertising and public awareness efforts and implement new regional trespass prevention programs.

- Enhance research and data collection in such areas as accident severity, prediction formulas, crossing inventories, reporting requirements, and safety and demographic data.

- Demonstrate and encourage new technologies, such as vehicle detection and four quadrant gates, automated malfunction report handling, and new lighting and marking systems.

- Work with States to develop model codes for state laws for crossing and trespass prevention, along with information package on rules of evidence.

Taken together, these initiatives represent a comprehensive Departmental effort, elevating highway-rail crossing safety, and adopting a uniform strategy across the modal administrations to deal with this important issue.

The <u>Action Plan</u> proposes some major legislative initiatives. These proposals include:

- Establishing fiscal incentives to states for crossing consolidations.

- Establishing fiscal incentives to states for participating in corridor reviews and projects.

- Increase Operation Lifesaver funding from the Department to $600,000 per year.

- Include trespass prevention programs within the scope of Operation Lifesaver funding.

In 1972, then Secretary of Transportation John A. Volpe declared a goal of reducing the number of highway-rail crossing accidents and fatalities by one third within ten years. The meeting of that goal was clearly attributable to Congress' endorsement and support in the establishment in 1973 of the Highway-Rail Crossing Safety Improvement program, a program which has been continuously funded and supported (by Congress, States and industry) to this day. Concurrently, Operation Lifesaver made its debut in Idaho, also in 1972. Its programs and effectiveness have grown and matured over the same period, are also now partially underwritten by Congress and have also made significant contributions.

The continuation and renewal of this partnership, between Congress, the Department of Transportation and the modal administrations, the States, the industry and Operation Lifesaver, as proposed in this <u>Action Plan</u>, will produce similar results, i.e., a further reduction in accidents and fatalities at highway-rail crossings of at least fifty percent over the next ten years. Before the year 2004, accidents per year should be less than 2,500 and fatalities less than 300.

Objectives

Develop an action plan to reduce the number of highway-rail crossing accidents and casualties while not impeding, but facilitating, the contribution potential of the highway and rail infrastructure on the Nation's economy. The plan must consider the need for, and the crossing safety implications of, high speed inter-city, intermodal freight and passenger service as well as single-city commuter and intra-urban service.

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Current Statistics

Crossing statistics include all conventional rail and "some" light rail. Accident and fatality data is for conventional rail only. See Figures 1 and 2.

At-Grade Crossings

	Active	Passive	Total
Public[1]	59,182	111,440	170,622
Private	923	108,958	109,881
Total	60,105	220,398	280,503

1993 Accidents

	Active	Passive	Total
Public	2,207	2,230	4,437
Private	32	423	455
Total	2,239	2,653	4,892

1993 Fatalities

	Active	Passive	Total
Public	320	264	584
Private	2	40	42
Total	322	304	626

---

1 **Active** crossings are those equipped with motorist warning devices automatically activated by approaching trains, i.e., flashing lights or flashing lights with gates. **Passive** crossings are provided with signs only and occasionally with continuously flashing lights.

Public crossings are generally defined as those for which the roadway approaches are open to public travel and are maintained by a public highway authority. Many exceptions exist.

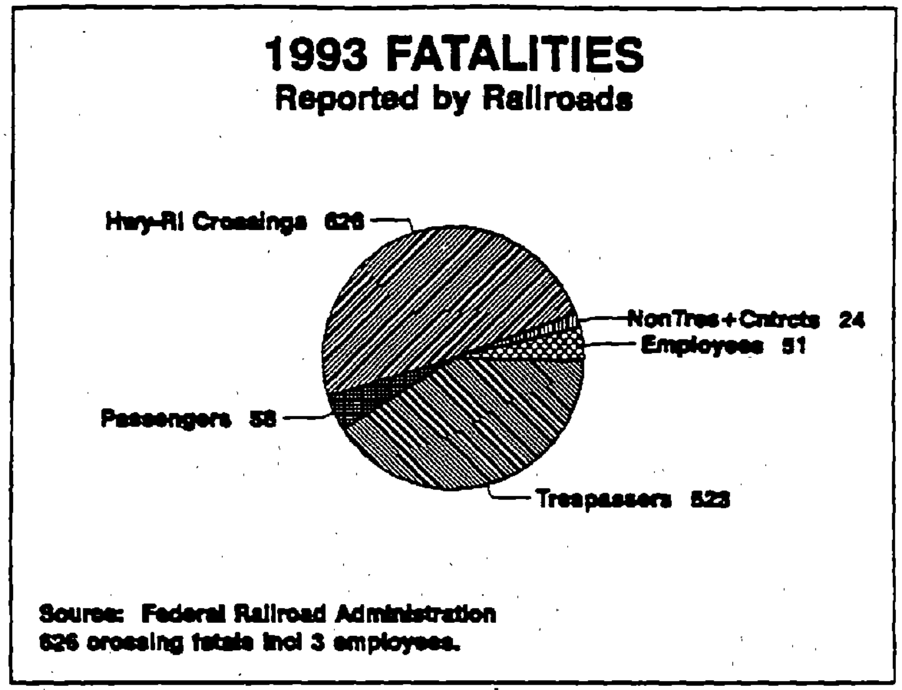

Figure 1

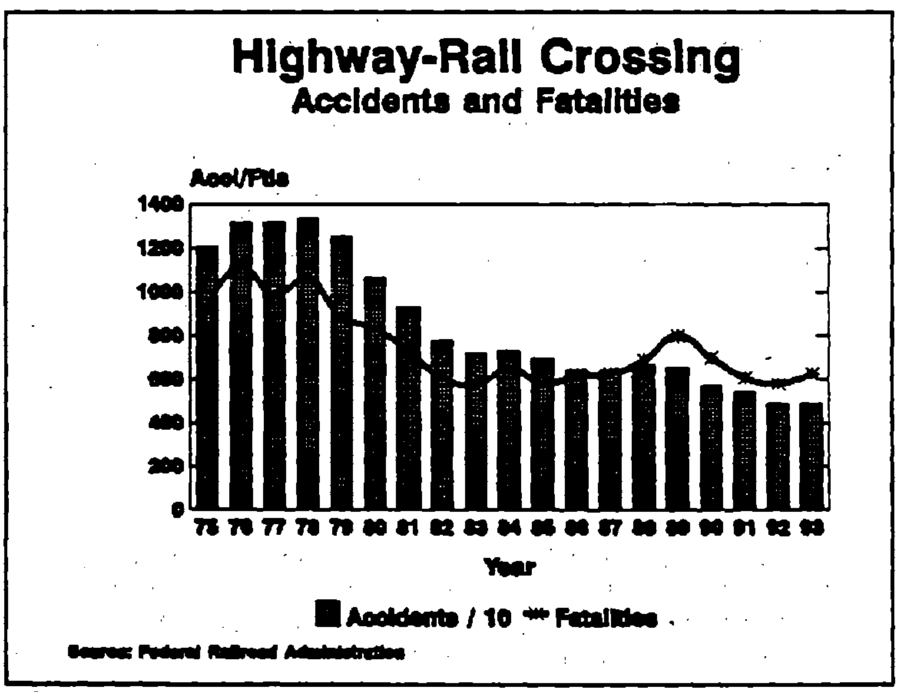

Figure 2

Initiatives

Six major initiatives are detailed on this and the following pages. These proposals constitute the Department's Action Plan for addressing highway-rail crossing safety and trespass prevention for the remainder of the decade. The Department and four modal administrations within the Department -- the Federal Highway Administration, the Federal Transit Administration, the Federal Railroad Administration and the National Highway Traffic Safety Administration -- will target these initiatives as resources permit. A joint task force will promote and coordinate these initiatives and will oversee the progress of individual projects.

To be successfully implemented, the Action Plan initiatives will require the active involvement, oversight, support and endorsement of the United States Congress, state and local governments and the railroad and transit industries.

I. Increased Enforcement of Traffic Laws at Crossings

Experience has shown that visible, high profile, law enforcement programs reduce the numbers of highway traffic violations. Programs targeting traffic violators at highway-rail crossings are also effective. The media has shown a willingness in the past to report on such programs.

The need is to develop small and large package programs (to include such milestones as officer-on-the-train, roll-call videos, railroad training, dispatcher coordination, etc.) and then to convince and encourage police and civic officials to adopt the programs. They must be convinced of the programs' relevance in their communities and of the potential effectiveness of the recommended programs. They need to be encouraged to program resources for the effort.

Such an effort will be more easily promoted if police and local officials (and the public) are already familiar with the problem and with available programs. In addition to a national program for the general public, an effort must be made to reach local civic and police officials where they work and meet, and in what they read, view and hear. Print materials for their "trade" periodicals, direct mailings, presentations and displays where they meet, nationally, regionally and locally, all would make some contribution.

In order to be successful, judicial officials must not be overlooked. They too must be convinced of the programs' relevance and seriousness. An enforcement program will end quickly if judges do not understand and support it.

A serious impediment exists to expanding programs such as the photo-enforcement program currently being demonstrated in Los Angeles and previously demonstrated in Jonesboro, Arkansas by the Burlington Northern Railroad (and in common use in Europe). Rules of evidence in most states disallow the introduction of photo-evidence not corroborated by a police officer eye witness. (This also impedes the expansion of unmanned photo-radar enforcement.) In this era of limited law enforcement resources such a restriction on the application of proven technology appears unreasonably narrow. State legislatures need to be encouraged to review the rules of evidence for traffic law enforcement.

By increasing enforcement and judicial support, the number of traffic law and warning device violations at highway-rail crossings will decrease. The Department proposes to establish an expanded and pro-active outreach program to our Nation's traffic law enforcement community, from the patrol officer to the judges who enforce our traffic laws. The following actions will be initiated:

A. Section 402 Funds

NHTSA/FHWA will advise states that where problem identification data indicate that highway-rail crossings are a significant local problem, Section 402 funds could be requested to promote targeted public education, engineering and law enforcement strategies within a comprehensive program approach to the problem. By August 1994, the NHTSA and FHWA will meet to develop a joint directive for their grant approving officials (NHTSA Regional Administrators, FHWA Division and Regional Administrators) to support this approach. Before December 1994, NHTSA and FHWA field offices will contact the states and will support this approach in discussions on development of Highway Safety Plans (HSP) for FY 1996.

B. Police Officer Detail

NHTSA will assist FRA in identifying and detailing a police officer with training background interested in working on a year detail with FRA and OLI in developing an outreach to the enforcement community. A search will be initiated this Summer, procurement action in the Fall, and assignment should begin in April 1995.

C. Outreach to Judiciary

As part of an outreach to judicial officials NHTSA and FHWA will prepare and publish an article in the National Traffic Law Center (NTLC) newsletter by August 1994. NTLC staff will assemble materials obtained from DOT to answer questions from prosecutors and judges. NTLC staff will provide technical assistance as requested from judicial officials beginning no later than August.

D. Rules of Evidence

An information package will be developed to assist states in redefining their rules of evidence for traffic cases. The package will provide model rules, with annotations, that would allow traffic citations to be issued and enforced based on photographs or video images obtained from unmanned cameras. Research will be conducted, and a first draft of model rules of evidence should be available in 1995.

E. Commercial Driver's License

FHWA will: Meet with the American Association of Motor Vehicle Administrators (AAMVA) to discuss making grade crossing violations a serious traffic violation on a driver's Commercial Driver's License (CDL); Conduct a survey of state traffic laws to document how states treat this offense now; Propose, through the AAMVA committee structure, making grade crossing offenses a serious traffic violation; Evaluate the need for rulemaking on CDL serious traffic violations.

The FHWA met with the AAMVA Executive Board in January 1994. The AAMVA in cooperation with FHWA will complete a survey of state practices in Summer 1994. A decision from the AAMVA committee on CDL serious violations will be reached at the AAMVA International meeting August 1994. The FHWA will evaluate the need for rulemaking in the Fall of 1994.

F. Compilation of State Laws and Regulations on Matters Affecting Highway-Rail Crossings

FRA, with the cooperation of FTA, NHTSA and FHWA, will initiate an effort in 1995 to update the Compilation of State Laws and Regulations On Matters Affecting Rail-Highway Crossings, last published by FHWA in 1983.

G. Safety Inquiry

The FRA will hold an informal safety inquiry (meeting) to discuss issues, ways and means to enforce railroad operating rules regarding trains, locomotives or cars standing within a specified distance of a multi-track passive crossing or on warning device track circuits not equipped with time-out equipment. (The latter situation, i.e., spotting cars on active warning device track circuits, is addressed in the just published NPRM regarding warning device Inspection, Testing, Maintenance and Timely Response. See Section 234.209 of the NPRM.) (Also, see Safety Inquiry in sections on Private Crossings and Data and Research (the Inventory).)

II. Rail Corridor Crossing Safety Improvement Reviews

The most efficient way to accomplish a comprehensive engineering review of highway-rail crossings is to examine all crossings, public and private, in a corridor or jurisdiction with a multi-disciplinary team, i.e., a diagnostic team. This has been called the "systems approach." This process is currently underway where the Intermodal Surface Transportation Efficiency Act (ISTEA) Section 1010 corridors are concerned, but in these efforts the goal is far more than crossing safety improvements, but rather the realization of high speed rail operations (necessitating significant safety improvements at crossings, often elimination). These Section 1010 corridors address only a very small part of the problem, i.e., not quite 2,800 crossings on only 4,200 km (2,600 mi) of track right-of-way. The total rail system in this country is comprised of over 273,000 km (160,000 mi) of right-of-way which is crossed at-grade nearly 283,000 times by public and private roads and designated pedestrian pathways.

Obviously, addressing just the 1010 corridors (less than two percent of the total right-of-way or crossings) is not adequate. Attempting to target the whole system is too ambitious. However, a core exists, defined by reviewing current Amtrak, intermodal (trailer or container on flat car) freight and coal and grain flow maps. These are the more heavily used freight and passenger routes. These are the routes where a thorough analysis of crossings along designated segments (corridors) has the potential of rendering maximum safety return (i.e., frequent fast trains, high passenger exposure). These are the routes where a corridor analysis will allow a credible review of crossing consolidation or elimination possibilities, of track circuit improvement needs (to include constant warning time equipment (in order to accommodate variable speed trains) and signal event recorders (to facilitate rapid response to and diagnosis of signal malfunctions)), as well as signs, signals, surfaces, sight distance improvements and illumination possibilities, etc.

In the absence of a corridor or systems approach, highway-rail crossings are selected by highway authorities for safety improvements one at a time based on the crossing's accident experience and highway and rail traffic counts. This fosters a bias toward urban areas and main roads where traffic densities are high. This process currently excludes all private crossings, most low density crossings and often those already equipped with automatic devices. In many cases, the excluded crossings are those that would benefit from low cost improvement or could be consolidated.

Crossing consolidation is the surest way to reduce the potential for highway-rail crossing collisions. Although crossing consolidation is an effective and low cost method to improve crossing safety, this option has not been widely utilized. Closing a crossing generally requires affirmation from the local political subdivision (if public) or concurrence of the easement holder (if private). The difficulty of securing approval to consolidate crossings has discouraged pursuit of this option for improving crossing safety.

Railroad and state officials, who are responsible for crossing projects and who recently participated an FRA case study project, repeatedly emphasized the need for Federal guidelines for closing crossings. In order to be an effective adjunct to the closing process, the Federal guidelines would have to be visible and definitive. That is, guidelines should unequivocally represent Federal policy and provide an objective standard for judging the need for a specific crossing.

Interest in high-speed trains, increased emphasis on crossing safety, the limits of available resources and the signalization of many high volume crossings have led many state transportation agencies and railroads to assign crossing consolidation and closure a higher priority than it has received in the past. However, the number of crossings closed, public or private, on active rail lines remains relatively small and well below the number of unnecessary crossings that are candidates for closure. Federal and state leadership is required to give consolidation the priority it warrants. Otherwise, consolidation will remain a minor factor in crossing safety improvements.

In this context (i.e., the need for a Federal initiative), the concluding observation of the Missouri Executive Summary[2] is particularly pertinent: "If in fact this is a national initiative, then there must be participation on the part of the 'national government.'"

A nationwide effort to review crossings in corridor groups is needed. The Department will promote comprehensive and systematic corridor reviews of highway-rail crossings, especially those over our nation's Principal Railroad Lines[3] (PRLs), and

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[2] Executive Summary of the Missouri Grade Crossing Closure Study, Missouri Division of Transportation Staff, January 1994, page 5.

[3] The FRA has defined a core railroad system of approximately 80,000 miles known as the Principal Railroad Lines. These lines have one or more of the following attributes: Amtrak service; defense essential; or, annual freight volume exceeding 20 million gross tons.

will encourage the elimination of little used and redundant crossings within corridors where alternatives exist, especially

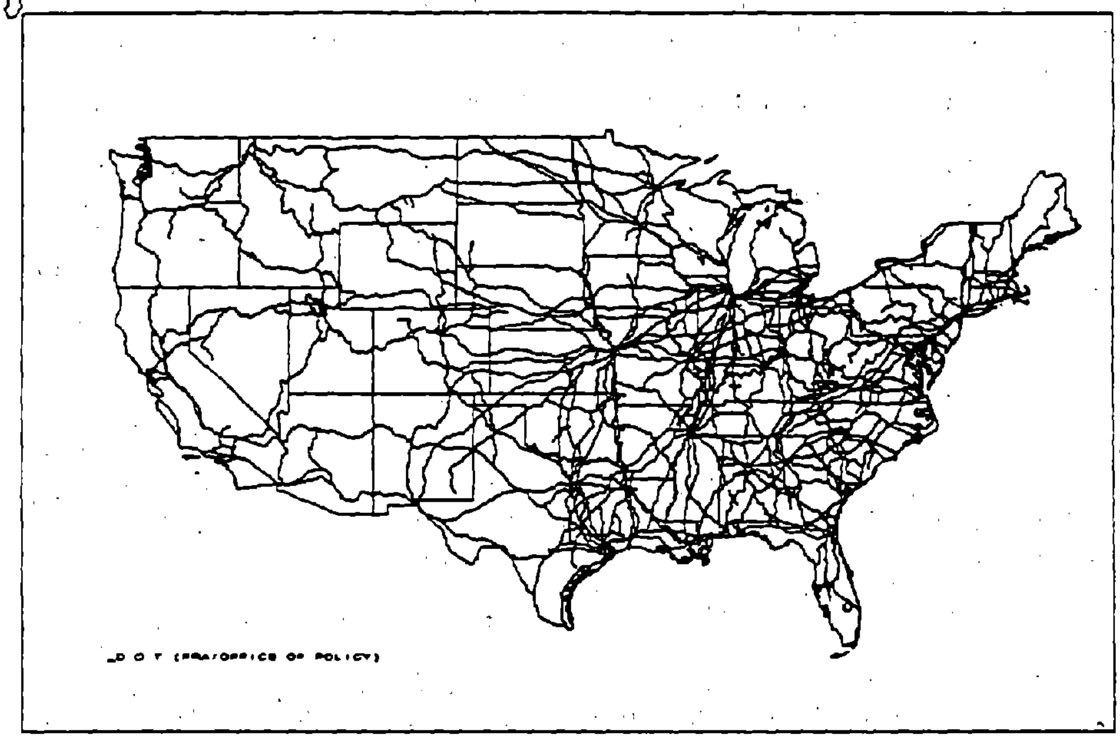

Figure 3

those on the National Highway System[4] (NHS). It is estimated there will be approximately 4,500 at-grade crossings on the NHS, about half of which will be at intersections with the PRLs. State and local highway authorities will be encouraged to upgrade signs and signals at all crossings, taking full advantage of available state-of-the-art technology. The following initiatives will be established:

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[4] The National Highway System will consist of an interconnected system of principal arterial routes to serve major population centers, intermodal transportation facilities and other major travel destinations; meet national defense requirements; and serve interstate and interregional travel.

A. Principal Railroad Lines

Principal Railroad Line corridors will be nominated for review by considering current and projected highway and rail traffic densities and accident experience. Facilitated by FRA's new Regional Program Managers, these corridor reviews should begin no later than the last quarter of 1994.

B. The National Highway System (NHS)

The FHWA will encourage that Statewide Transportation Improvement Programs and Safety Management Systems fully address the upgrading or elimination of at-grade crossings on the NHS, and give priority to the long-term goal of eliminating NHS intersections with the PRLs.

C. Upgrade Signing and Marking

The FHWA will work with FRA and the states to increase the conspicuity of signs and markings at highway-rail crossings by encouraging the widespread use of high-grade, long-lasting reflective materials. This promotion will be initiated immediately.

D. Responsibilities for Selection and Installation

The Department will review the present system of allocating responsibility for selection and installation of signal devices at public highway-rail grade crossings. The Department will review the need for nationally uniform standards for establishing the need for, and appropriate type of, warning devices at all public highway-rail grade crossings.

E. STOP Signs

In response to Section 1077 of ISTEA, the MUTCD was revised to grant states and local governments discretionary authority to install STOP or YIELD signs at highway-rail crossings that do not have active warning devices and where two or more trains operate daily. On July 8, 1993, the FHWA and FRA issued a joint memorandum to their respective field offices offering guidance for installing STOP signs and encouraging cooperation among states, communities and the railroads for the development of programs to install these signs. FHWA and FRA will work together to insure that state and local governments consider the installation of STOP signs at highway-rail crossings where warranted.

Listings produced from the Inventory which select and categorize crossings most likely to fit established criteria and to benefit from STOP sign installation will be provided to states and railroads. FHWA will issue a clarification to current

Federal regulations indicating that Federal funds are eligible to install traffic control devices, including STOP signs, at multi-track crossings.

F. Incentives for Crossing Consolidation

1. Legislation will be proposed to allow, under certain conditions and at a state's discretion, cash payments from the STP set-aside funds reserved for carrying out 23 U.S.C. 130 (the crossing safety improvement program) to local jurisdictions for the permanent surrendering of a crossing easement, i.e., the state could use Federal funds to pay for a crossing closure. The amounts paid would be limited to $7,500 and the amount paid would have to be matched by the railroad(s) involved. The Federal funds could only be used for other transportation safety improvements. Such a program could be implemented only after a state has established a state-wide procedure for reviewing the need for any new public at-grade crossings. This would be in accord with a recently adopted resolution of the National Conference of State Rail Officials (NCSRO) and the American Association of State Highway and Transportation Officials (AASHTO).

2. Legislation will be proposed to modify 23 U.S.C. 120(c) to include crossing closure projects among those STP projects which are eligible for 100 percent Federal funding, i.e., along with signs, signals and pavement markings. (The current situation, where a state or local match is required for a closure project, but not for warning devices, amounts to a disincentive to close.)

G. Crossing Consolidation and Closure Case Studies

Based on the case studies conducted by FRA, FRA is now preparing three reports on crossing consolidation and closure. The first report, to be available this Spring, will be a "how-to" guide on closing crossings for state and railroad officials. The guide will be a composite of the successful strategies for closing crossings and rules of thumb derived from the case studies. The second report, also available this Spring, will consist of a limited number of case studies that would demonstrate the consolidation process through the example of actual projects. A third report will recommend options to increase the rate of crossing consolidation, based on analysis of the case studies and suggestions of railroad and state officials who have been actively involved in crossing consolidation projects. The recommendations will be completed by early Summer.

H. Integrated Intermodal Transportation Planning

The Department of Transportation is sponsoring a number of outreach efforts to assist those implementing ISTEA. Of particular interest to those concerned with highway-rail crossing safety is the series of meetings FRA and FHWA are sponsoring between State Departments of Transportation, MPOs and the railroad industry. This series of seven meetings, begun in Arlington, Texas (March 30 -- April 1), encourages cooperation between the transportation planning community and the railroads by addressing issues of mutual interest, including grade crossings.

I. Check List

FRA and FHWA will develop a "check list" of items to be considered in a corridor analysis. This will include warning device and site improvement options (e.g., adequacy of warning devices and circuits, horizontal and vertical approach angles, surfaces, volume, type and flow of rail and highway traffic, etc.) as well as the consolidation of crossings. The check list should be developed and distributed during the last quarter of 1994.

J. Highway-Rail Crossing Handbook

FHWA, with the cooperation of FTA, NHTSA and FRA, will initiate an effort in 1995 to update the Railroad-Highway Crossing Handbook, last published by FHWA in 1986.

K. Vegetation Clearance

FRA's NPRM on track standards will contain a provision addressing the need to maintain rail rights-of-way adjacent to highway-rail crossings free of sight-obstructing vegetation. The FHWA will explore ways and means through the SMS to encourage that vegetation on highway rights-of-way be kept cleared.

L. Corridor Review Participation

Legislation will be proposed to established a jointly administered incentive program for state and local governments to participate in reviews and safety improvements on a corridor basis. One possible scenario would set aside $15,000,000 of STP funds each year (from an STP program of $23.9 billion), **in addition to the existing Section 130 program funds,** as an incentive fund pool. This pool fund would be distributed to states with aggressive corridor programs to off-set corridor improvement costs either on a first come/first served basis or in amounts proportional to total corridor improvement costs incurred by the participating governmental entities.

M. Distribution of Funds

FHWA and FRA will initiate a study of the formulas used to distribute to states the crossing safety improvement funds authorized in Section 1007 of ISTEA. An assessment will be made to define a more appropriate method of distributing improvement funds, possibly on the basis of the number of crossings and accidents in each state.

III. Increased Public Education and Operation Lifesaver

Since 1973, more than $2.8 billion of Federal-aid funds has been spent by states for safety improvements at highway-rail crossings. Over half of this was for automated warning devices. However, half of all collisions occur at crossings so equipped. To realize full benefit from the public investment in these devices, motorists must be educated in their responsibilities at all types of crossings.

Operation Lifesaver (OL) is an active, continuing public information and education program to help prevent and reduce crashes, injuries and fatalities and improve driver performance at our Nation's 280,000 public and private highway-rail crossings. Operation Lifesaver, Inc. (OLI) is a tax exempt, non-profit corporation which coordinates and facilitates state and local OL programs nationwide.

OLI needs to supplement its Federal funds with funds from other sources. This would serve the dual purpose of providing additional funds in the near term for the promotion of the OL message and would establish a cushion should Federal funding be reduced or eliminated in the future.

The success and effectiveness of OL state programs at getting the OL message out is directly dependent on the capabilities of the OL State Coordinator. In some cases this individual is a state employee, sometimes a railroad, railroad association or railroad supply industry employee (ranging from executive to locomotive engineer), sometimes a local or state police officer or official and sometimes an employee of a safety or highway oriented group (e.g., American Automobile Association, a state safety council, a school bus driver, etc.). Many carry out the function of State Coordinator as an "additional duty." Many are volunteers, receiving no remuneration for their effort, and little support. Many of the State Coordinators need assistance, i.e., considerable additional man-hours. The credibility of the program suffers when the public reaches only a message machine at the State Coordinator's office. Scheduling, coordination, support and material functions must often wait until the weekend or until the State Coordinator returns. If an assistant were available, their involvement would expand the presence, visibility and outreach of the program in communities throughout the U.S.

The Department proposes to work with Operation Lifesaver, states and industry advocates to facilitate delivery of the OL message at the state and local levels and thus to increase public awareness of hazards at crossings and of motorist responsibilities.

A. Marketing Materials Plan

NHTSA, FHWA, FTA, FRA and possibly OLI will work together in periodic meetings to develop programs and material to promote public and youth awareness. A marketing materials plan will be developed. When products are available, NHTSA Regional staff will promote this material through Governors' Representatives to appropriate organizations and officials. States may use Section 402 funds to purchase or reproduce materials as well as to implement programs.

B. Driver Training Materials

NHTSA, working with the AAMVA, will review current driver training material relevant to highway-rail crossing safety and will determine what material(s) may need updating and where gaps exist. NHTSA, FHWA, FTA, FRA and possibly OLI, will work together to select the best of these materials, develop new and updated materials, if necessary, and disseminate this information to the states. An interagency working group will be established. Draft materials will be completed by Winter, and final products will be available by Summer 1995.

C. National and Community Service

For FY 96, pursuant to the National and Community Service Trust Act of 1993, FRA will explore the possibility of assigning national service participants to support OL State Coordinators.

D. Truck and Bus Involved Accidents

In the near-term the FHWA will take the following actions to improve highway-rail crossing programs with respect to commercial motor vehicles.

1. <u>On-Guard</u> Notice

Publish an <u>On-Guard</u> notice to alert the truck and bus industry of the dangers at crossings. This was mailed to all 270,000 interstate motor carriers on our records. The notice was written, printed and distributed in February 1994.

2. Advisory Bulletin

Send an advisory bulletin to the trade press about the danger of accidents at crossings. The bulletin was released to all motor carriers in February.

3. Public Service Print Advertisements

Prepare public service print advertisements for the trade journals on truck and bus accidents at highway-rail crossings. Attention will be given to ensuring the articles reach state and local trucking association newsletters. The public service messages will be published and distributed to 4,500 potential carriers in June.

4. "Trucker on the Train" Program

Work with Amtrak, the American Trucking Associations (ATA), OLI and FRA to create a "Trucker on the Train" program where motor carrier executives and drivers accompany train engineers on the engine of a train to view first hand dangerous highway-rail crossings. FHWA and FRA representatives have recently begun meeting with the ATA and Amtrak officials on this program.

5. Operation Lifesaver

Encourage OLI staff to meet with trucking companies and associations regarding this problem. An OL spokesperson addressed the ATA Safety Management Council in February. The ATA Safety Management Council reminded their members and drivers in a January letter of crossing dangers.

6. National Safety Organizations

Address the issue at meetings of national safety organizations such as the International Association of Chiefs of Police (IACP). Discuss the issue with industry executives at the next National Motor Carrier Advisory Committee meeting.

7. On-Site Compliance Reviews

Ensure that at each on-site compliance review conducted by the Office of Motor Carriers field staff and state personnel, the motor carrier is informed of the risks at highway-rail crossings.

E. Operation Lifesaver Matching Funds

Legislation will be proposed to increase the FHWA grant to OLI to an amount not to exceed $500,000 annually, but any portion of the funding in excess of the current grant of $300,000 (and $100,000 from FRA) would be available to OL only if OLI matches the increased amount through its own fund raising mechanisms outside of the public sector. The entire amount of the FHWA funding would come from a draw-down of the STP funds set aside for highway-rail crossing safety.

Failure to secure additional funding for OL will hamper the organization's ability to expand its activities to adequately support the Federal effort in this area.

IV. Safety at Private Crossings

There are 110,000 private highway-rail crossings in the United States. More than 400 accidents and 40 deaths occur at these crossings every year. In most years, the number of deaths which occur at private crossings exceeds the number of on-duty deaths among railroad employees in all rail operations.

Private crossings are categorized as either farm, residential, recreational or industrial. Nearly two-thirds are farm crossings. However, most accidents occur at industrial crossings.

Type Private Crossing	Crossings	1993 Accidents	Accident Rate	Killed	Injured
Farm	66,725	142	.002128	23	32
Residential	12,876	74	.005747	13	21
Recreational	1,649	11	.006671	0	3
Industrial	25,703	157	.006108	10	23
Unknown	2,928	19	n.a.	1	6

FRA has traditionally taken the position that private crossing matters should be settled by the private parties involved. However, from a safety perspective, this approach has proven inadequate. A few states, including Alaska and California, have also reached this conclusion and have acted to standardize responsibilities and treatments for private crossings. Despite this, the overall national result is that responsibilities are most often undefined or are inconsistently acknowledged and applied.

Similarly, traffic control or traffic warning standards have been defined in only a few instances and are not consistently applied. The FHWA lacks jurisdiction, as do most state and local highway departments. FHWA has endorsed the concept of applying MUTCD warning device standards to private highway-rail crossings, but lacks the jurisdiction to follow through.

Responsibilities and standards need to be developed and defined.

Private crossings on high speed rail lines present a special problem. And yet, most private crossings on high speed rail lines will require either safety enhancements or elimination before high speed service can be initiated. Traditional sources of public funding for safety improvements are limited to public crossings.. However, attention is beginning to be directed to private crossings on designated high speed corridors. Section 1010 of ISTEA authorizes $30 million for the elimination of grade crossing hazards at public and private crossings on the five Section 1010 corridors. Oregon has recently enacted legislation to give the state jurisdiction over private crossings on high speed rail lines. Eligible improvements under the proposed high speed rail legislation include private crossings (including payments to property owners to close such crossings where appropriate). Private crossings will be considered in the incentive/award program for state participation in corridor review programs proposed above.

There is a need to either identify a different or new source of funding, or to make private crossings (at least those on DOT designated high speed rail corridors) eligible for funding from the traditional sources. Further, there is a need to establish "condemnation" and "buy out" authority, of private crossings, at least those on DOT designated high speed rail lines. The proposed high speed rail legislation, when enacted, will address both of these needs.

The Department proposes to develop and provide national, minimum safety standards for private crossings and to eliminate the potential impediment to high speed rail operations posed by private crossings. The following actions are proposed:

A. Define Categories

Operational definitions will be developed for each of the four categories. Sub-categories may also be defined (e.g., industrial/commercial crossings open to public use; farm crossings on high speed corridors; recreational crossings in public parks; etc.), and a general approach and schedule will be developed for addressing each. As appropriate, minimum safety requirements, warning device standards and responsibilities will be defined beginning with the category(ies) with the most severe problems, i.e., probably with Private Industrial Crossings.

B. Safety Inquiry

FRA will hold an informal safety inquiry to further review the concept of defining minimum safety standards for private crossings, or for certain categories of private crossings, up to and including standards for closure and consolidation under certain conditions. The inquiry will address the allocation of responsibilities and costs associated with private crossings and the need for dispute resolution mechanisms regarding that allocation. (See also Safety Inquiry in Sections on Data and Research (the Inventory) and Enforcement.)

C. Locked Gate at Private Crossings

The feasibility of placing gates with remotely activated cipher locks at private crossings will be investigated and possibly demonstrated. In this scenario, the gate would normally be closed and locked. A potential user would call the railroad dispatcher, possibly from a special call box at the crossing. When a window of opportunity occurs, the dispatcher would enable the requestor to unlock and open the gate. The gate would be interlocked with the railroad's signal system.

V. Data and Research

Progress towards maximizing the effectiveness of our resources is most often achieved through research and innovation. However, for highway-rail crossing issues, institutional concerns regarding costs (research and potential implementation), liability and current convention often impede progress. The Department's involvement and leadership have the potential of promoting research and championing plausible innovation while overcoming these obstacles.

Research regarding alerting lights, retro-reflective materials, illumination and horns is currently being conducted by the John A. Volpe National Transportation Systems Center (VNTSC) in Cambridge, MA, with FRA sponsorship, to enhance conspicuity of trains at or approaching crossings for highway users, especially during hours of darkness. FHWA and some state efforts are also investigating the efficacy of innovations in highway traffic signs.

Similarly, good data is also an essential ingredient to good decision making. Research and data processing and analysis must insure that timely and accurate information needed by decision makers is available.

To address these needs the Department proposes to:

A. Host Research Round Tables/Workshops

1. Research Workshop

The goals, procedures and findings of Federal crossing related research are always of interest to the industry, state officials and academia. Government sponsored research, and the researchers involved, can also benefit from an exchange of ideas, i.e., topical workshops (not just a series of briefings), with the affected industry and interest groups. A workshop will be planned to bring together highway safety, law enforcement, rail and transit industry officials, governors' highway safety representatives, academia and consultants with Federal researchers to discuss current and projected research and needs.

2. Defense Conversion Fair

Numerous contacts have been made on behalf of defense oriented research firms seeking to bring their talents and capabilities to bear on transportation related issues. A tremendous talent pool exists. However, these firms are not familiar with transportation industry needs. A fair, complete with DOT displays and seminars, could be used to focus this potential resource on transportation, on safety and on highway-rail crossing problems. Fresh thinking and new (defense developed) technology may generate some innovative solutions to old problems. An exchange program will be planned to introduce Defense oriented research firms to railroad technology and research needs.

B. Demographics

NHTSA will develop demographic data on those who die in highway-rail crossing accidents and will assist in arranging and conducting "focus group" sessions in locales with high incident rates.

C. Accident Severity

NHTSA will investigate the increasing severity of crossing accidents and attempt to determine why the trend is increasing and what countermeasures might reverse it. NHTSA will use both their Fatal Accident Reporting System (FARS) and FRA's accident and Inventory data bases.

D. Signs, Signals, Lights and Markings

The FHWA, FTA and FRA will work together to examine the potential of providing additional information to the motorist through innovative signs, signals, lights and markings.

1. Signs and Signals

The FHWA, in coordination with FRA, will initiate conceptual studies of a number of new highway-rail crossing warning devices, such as devices to inform motorists in advance whether there is an active or passive warning system at the crossing and devices that would provide positive information about the direction from which a train is approaching the crossing.

2. Train Horns

The FRA is working with the Association of American Railroads (AAR) to study the safety impact of whistle bans nationwide. This will aid FRA in determining if nationwide Federal action is required.

The FRA is also sponsoring research by the VNTSC to develop an optimal warning signal for locomotive whistles, which minimizes noise for communities while not compromising safety. VNTSC also is investigating potential alternative systems, such as audible warning devices installed directly at crossings. (A cooperative effort involving the state of Nebraska, the City of Gering, the Union Pacific Railroad and a private firm has produced some field testing of an Automated Horn System (AHS) mounted at the crossing. The Los Angeles County Transportation Commission is also considering a similar device offered by another firm.) Some Los Angeles County commuter trains have been equipped with an innovative train whistle device, somewhat toned down and mounted lower on the locomotive in order to minimize impacts on neighboring communities, but still meeting minimum FRA standards. FRA (and VNTSC) will continue to monitor these efforts.

FRA is also exploring the potential for what amounts to a noncontractual cooperative effort among interested parties. If the Union Pacific Railroad, City of Gering, the Nebraska Department of Transportation and others with a particular interest in testing a second-generation AHS can install the device(s) at highway-rail crossings selected as test sites, and conduct neighborhood surveys, FRA, through VNTSC, will make the necessary acoustical measurements and analyses, record and analyze before and after behavior of motorists, design needed surveys, train local personnel to conduct the surveys, and analyze survey results. Work may begin this Summer.

3. Light Rail Crossing Gates for Left Turn Lanes

A large number of train/vehicle collisions take place at grade crossings where there are streets running parallel to light rail transit or railroad tracks, and motorists are permitted to make left turns across the tracks. Standard railroad crossing gates are not fully effective at crossings of this type. Where the crossings are controlled by traffic signals only, some light rail transit systems have experienced numerous train-vehicle collisions.

Calgary Transit (Canada) has installed railroad crossing gates on the left turn lanes at two grade crossings where there are heavy left turn traffic volumes. The FTA proposes to investigate the application of railroad gates and other types of "pop up" barriers (for U.S. locations where there is not adequate space to install railroad crossing gates) for left turns made from streets running parallel to the tracks at grade crossings.

4. Locomotive Conspicuity:

On February 3, 1993, FRA issued interim standards regarding locomotive lighting to enhance conspicuity of trains. A second interim rule was published May 13, 1994. The Congressionally mandated schedule requires the FRA to initiate rule making for final regulations no later than June 30, 1994. Final regulations will be issued by June 30, 1995.

5. The Manual on Uniform Traffic Control Devices (MUTCD)

FHWA, FTA and FRA will begin work immediately to develop proposed changes and additions to the MUTCD dealing with each of the following. Proposals should be available in the third quarter of 1994, and changes to the MUTCD should be proposed during the fourth quarter.

a. Warrants for warning devices to be used at crossings hosting high speed rail operations;

b. New passive sign for high speed rail crossings;

c. Standards for temporary closure of road, i.e., the signing needed to accommodate the placing of a barrier in the road;

d. Supplementary multi-track plate for STOP and YIELD signs;

e. Work Zone Traffic Control standards for highway projects which include highway-rail crossings;

f. Four-quadrant gate standard;

g. Warning device standards unique to light rail operations (The National Committee on Uniform Traffic Control Devices is currently drafting proposals regarding traffic control and light rail.); and

h. A design standard for display of the Inventory number at each crossing.

E. Innovative Technology

FRA and FTA will cooperate to review available automated presence and intrusion detection hardware and the potential effectiveness of existing and proposed technology for conveying emergency messages.

1. Automated Video Image Analysis

Available technology will be explored regarding the potential use of live video images monitored by computers to detect intrusion onto the rail right-of-way at highway-rail crossings (or anywhere else) and to insure that warning devices are functioning properly. In theory, when intrusion or a warning device failure is detected, an alert, maybe an image, could be provided to the dispatcher and possibly to the locomotive.

2. Radar Actuation System for Light Rail Crossing Warning Devices

Warning equipment at grade crossings is typically activated by track circuits. For certain applications, these circuits need to be designed to detect train speed. These applications include innovative active warning signs or devices (such as horns mounted at the crossing or warning messages) that will be effective only if activated for a limited number of seconds in advance of when trains actually arrive at the crossing.

Where the rails are part of the traction power system (as is typical for light rail systems), speed detection equipment based on track circuit technology (referred to as crossing predictors or motion sensor) does not work in a reliable manner. A low cost alternative to determine the speed of trains is needed for light rail transit operations.

This project would investigate the limitations of existing speed detection equipment and evaluate the feasibility of a radar-based system. If the approach were determined to be feasible, a demonstration of the radar actuation system would also be undertaken as part of this project.

F. 1-800 Computer Answering System

In 1983, the Texas Legislature initiated (and pioneered) a statewide alert or early warning system designed to inform railroads of warning device/signal problems at crossings. Signs have been placed at each crossing equipped with an automated device instructing the reader:

TO REPORT MALFUNCTION OF
THIS RAILROAD SIGNAL
CALL TOLL FREE 1-800-772-7677
GIVE THIS LOCATION # _ _ _ _ _ _ _

An impediment to more widespread adoption of this "early warning" system is the perceived resource impact, i.e., Who will answer and forward telephone calls? An automated, pc-based computer system could receive, catalogue and forward telephone calls from the concerned "public" regarding problems with specific highway-rail crossing signals.

This concept is well within currently available "off the shelf" hardware capabilities. Preliminary discussions with individuals familiar with current procedures in Texas indicate this would be a welcome capability.

An automated telephone answering and message forwarding system will be developed for handling calls concerning malfunctions or problems at highway-rail crossings. The system will be founded on the U.S. DOT/AAR Inventory numbering system.

G. Light Rail Accident Statistics

FTA's Safety Management Information Statistics (SAMIS) was devised to reflect an accurate picture of transit safety. Casualty figures include pedestrians, people in other vehicles, employees, etc., as well as patrons. Incidents are collected during revenue and nonrevenue periods, so an all-inclusive view is provided. The FTA will investigate broadening current data reporting to include specific data on shared rights-of-way accidents involving light rail vehicles.

H. Resource Allocation Procedure

The computer model currently made available by FRA to states and railroads needs to be rebuilt in order to account for more recent realities, i.e., accident experience, available data and costs. The imbedded accident prediction formulas also need to be recalculated. Procurement action for this work has begun.

I. The Inventory

The U.S. DOT/AAR National Highway-Rail Crossing Inventory was developed to serve as a data base of all highway-rail crossings in the United States. The FRA is the custodian of this computer-based file. The FRA processes changes and updates voluntarily submitted by the states and railroads, more than 80,000 per year. Though the Inventory is the only national resource of its kind and is widely used, portions of it are not being updated.

FHWA will immediately initiate efforts to explore possibilities for encouraging updating of the Inventory on a more systematic or cyclic schedule. States will be encouraged to use the Safety Management System as a means of ensuring that Inventory data is updated. Additional methods of transmitting updates to FRA electronically will be explored.

FRA will hold an informal safety inquiry to consider requiring the display of the U.S. DOT/AAR Inventory number and a toll free phone number at all crossings to facilitate Emergency Notification. (See also Safety Inquiry under Private Crossings and Enforcement preceding.)

VI. Trespass Prevention

<u>Trespasser defined</u>: A person who is on that part of railroad property used in railroad operations and whose presence is prohibited, forbidden or unlawful. For purposes of this plan, and to avoid double counting, persons at highway-rail crossings are excluded from trespasser counts, regardless of the types of warning devices at the crossing.

The focus of the Federal effort regarding trespassing on railroad rights-of-way is to **prevent** trespassing from occurring in the first place, not to make trespassing safe. Trespassing on rail rights-of-way is illegal and dangerous and should not be condoned or facilitated.

Trespassing on rail rights-of-way results in more than 1,000 deaths and injuries each year. In 1990, (and in each year since then) the number of trespassers who died on rail rights-of-way exceeded 500 for the first time. To the industry, this presents a true Gordian knot. Trespassers are not a single, cohesive group. Their one common attribute is the illegality of their act (trespassing). Because of this diversity, it is not likely that trespassers will respond to a single national initiative. Regional programs have more promise. The Department of Transportation will target this problem. Our goal is to raise public and police awareness of the illegality of, dangers inherent in, and the extent of, trespassing on railroad right-of-way.

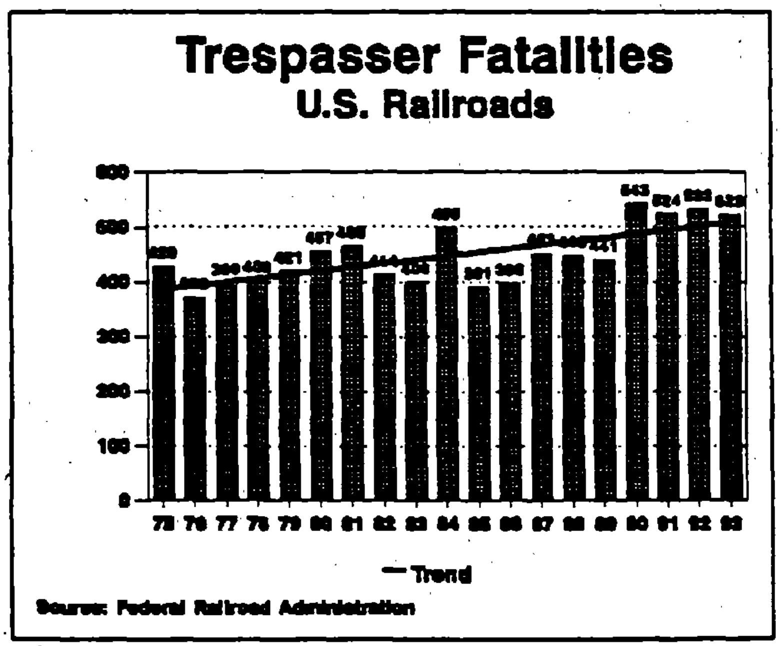

Figure 4

A related issue is vandalism. Railroads are reporting nearly 200 incidents per month of vandalism to automated warning devices at highway-rail crossings. This figure does not include vandal-caused damage to other railroad facilities, equipment and lading. Various provisions of Federal law address crimes directed at railroad equipment, passengers and employees. See 18 U.S.C. 1991 (entering a train to commit a crime), 18 U.S.C. 1992 (wrecking trains), and 15 U.S.C. 1281 (destruction of property moving in interstate commerce). While in many instances, vandalism to warning devices at highway-rail crossings may be considered to be within the scope of one of the above statutes, there is no Federal statute dealing directly with vandalism of these devices. Many states have similar statutes to the ones listed above.

The following actions are proposed:

A. Demographic Survey

FRA has requested FY 95 funds to initiate a study of trespasser problems and potential solutions. This effort will start with a survey and determination of the types of individuals and activities which are involved or result in trespasser casualties.

B. Trespasser Casualty Reporting

FRA is in the process of developing an NPRM addressing railroad accident reporting. FRA will propose gathering information from the railroads regarding the circumstances of the incident. This proposal will be published this year.

C. Workshop on Trespass Prevention

FRA will work with the railroad industry, railroad police and Operation Lifesaver to plan and host a second Workshop on Trespass Prevention. (The first was held in 1992.) The workshop will be held this year.

D. Regional Campaigns

Working with OL of Southern California, the FRA will develop a low-cost public service announcement (PSA) for television which addresses, in thirty seconds, the stark reality of trespasser casualties. FRA will work with the Congress, the Federal Highway Administration, the Association of American Railroads and OLI to clarify OLI's role in trespass prevention.

E. Model Trespass Prevention Code

FRA will work with rail industry police and legal staff to synthesize existing state and Federal code regarding trespass and vandalism prevention and to develop proposed code (model legislation) for consideration by state legislatures.

Recommendations/Goals

In summary, current safety programs have resulted in a significant reduction in highway-rail crossing accidents and fatalities. In 1993, 626 people died as a result of accidents at highway-rail crossings; this is half the number of annual fatalities 20 years ago. This has occurred despite increases in rail traffic over the same period.

The development and expansion of high speed rail service on existing railroad rights-of-way will further increase the potential for, and severity of, collisions at highway-rail crossings unless mitigating steps are taken. The Department is committed to continuing the trend of reducing these collisions. Improvement funding is available under ISTEA and additional funding will be available under our high speed rail legislative proposal. We are also undertaking a program of research, development and demonstration of next generation grade crossing safety systems designed to ensure absolute protection at high speed crossings which are not closed.

This Action Plan identifies a wide variety of initiatives, beginning with efforts to reach and involve the law enforcement community. Further research is called for. Incentive programs are suggested. Special provisions are urged for the National Highway System and for the Principal Railroad Lines. Finally, a revenue neutral funding plan is proposed which could make these initiatives possible.

Only through partnership can we hope to progress these initiatives. The Department, along with the FHWA, FTA, NHTSA and FRA, the United States Congress, the railroad and transit industries, states and associations, and Operation Lifesaver, working together, can advance these recommendations and can achieve the goal.

A. Recommendations

To assure that the downward trend in crossing accidents and fatalities continues, we must work together to:

1. Establish an expanded and pro-active outreach program to our Nation's traffic law enforcement community ranging from patrol officers to judges.

2. Reduce the number of traffic law and warning device violations at highway-rail crossings by increasing enforcement and judicial support.

3. Promote comprehensive and systematic corridor reviews of highway-rail crossings, especially those over our nation's Principal Railroad Lines (PRLs).

4. Eliminate little used and redundant crossings within corridors where alternatives exist, especially those on the National Highway System (NHS).

5. Upgrade signs and signals at all crossings, taking full advantage of available state-of-the-art technologies.

6. Increase public awareness of 1) hazards at crossings and, 2) motorist responsibilities at crossings.

7. Develop and provide national, minimum safety standards for private crossings.

8. Eliminate the impediment to high speed rail operations posed by private crossings.

9. Enhance the effectiveness of our resources through research and data analysis.

10. Promote research and champion plausible innovation.

11. Insure that timely and accurate information needed by decision makers is available.

12. Raise public and police awareness of the unlawfulness of, and dangers inherent in trespassing on railroad rights-of-way.

13. Develop and make available sufficiently detailed information to prepare and focus trespass prevention campaigns.

Only if we all move forward together with these Initiatives can the Nation enjoy a balanced transportation system. Only if we move forward can we end the loss of life, health and property at highway-rail crossings.

B. Goal

We must continue the downward trend in accident and casualty trends. If current programs are continued and these recommendations are implemented, a reduction by at least 50 percent or more is possible in the decade ahead, i.e., by 2004.

Appendix I

Historical Background

In 1877, the U.S. Supreme Court discussed the duties, rights and obligations of railroad companies vis-a-vis those of the highway user at highway-rail crossings and found that they were "mutual and reciprocal." The Court went on to say that a train has preference and the right-of-way over crossings because of its "character," "momentum" and "the requirements of public travel by means thereof," but that the railroad is bound to give due, reasonable and timely warning of the train's approach. The Court stated that "those who are crossing a railroad track are bound to exercise ordinary care and diligence to ascertain whether a train is approaching." (Continental Improvement Company v. Stead, 95 U.S. 161(1877))

The Accident Reports Act of 1910 requires rail carriers to submit accident reports. Included in this requirement are those accidents which occur at grade crossings.

The Federal-Aid Road Act of 1916 made Federal funds available for "rural post roads." Crossing safety improvement projects were eligible on a 50-50 cost sharing basis.

In 1928, reported fatalities at grade crossings reached a peak of 2,568 individuals. An additional 6,666 were reportedly injured.

In 1934, Federal funds were authorized for crossing safety improvements from the National Industrial Recovery Act of 1933. No match was required, and all public crossings were eligible.

In 1935, the U.S. Supreme Court commented on changes in responsibilities regarding the funding of a grade separation (a bridge) at a crossing in order to eliminate the hazards and delay inherent at an at-grade (level) crossing: "The railroad has ceased to be the prime instrument of danger and the main cause of accidents. It is the railroad which now requires protection from dangers incident to motor transportation. Prior to the establishment of the Federal-aid [highway] system ... highways ... served in the main, local traffic. The long distance traffic was served almost wholly by the railroads and the water lines. Under those conditions the occasion for separation of grades was mainly the danger incident to rail operations; and the promotion of safety was then the main purpose of grade separations. Then, it was reasonable to impose upon the railroad a large part of the cost of eliminating grade crossings; and the imposition was rarely a hardship.... the separation of grade crossings was a normal incident of the growth of rail operations; and as the highways were then feeders of rail traffic; ... every improvement of highway facilities benefitted the railroad. The effect upon the railroad of constructing Federal-aid highways ... is entirely different. They are not feeders of rail traffic. They deplete the existing rail traffic and the revenues of the railroads. Separations of grade serves to intensify the motor competition and to further deplete rail traffic. The avoidance thereby made possible of traffic interruptions incident to crossing at grade is now of far greater importance to the highway users than it is to the railroad crossed. (Nashville, C. & St. L. Ry. v. Walters, 294 U.S. 405, 422-423)

In 1964, a "finding" of the Interstate Commerce Commission (ICC) extended the Court's 1935 rationale to warning devices: "That highway users are the principal recipients of the benefits flowing from rail-highway grade separations and from special protection at rail-highway grade crossings. For this reason the cost of installing and maintaining such separations and protective devices is a public responsibility and should be financed with public funds the same as highway traffic devices." (ICC Report No. 33440, January 22, 1964)

In 1970, Congress, counting on the cooperation of industry, Federal and state officials, included in both the Highway and Rail Safety Acts of 1970 a provision that the Secretary study the problems of highway-rail crossings and report back to the Congress with recommended solutions. A two volume Report to Congress was prepared. The first recounted the extent of the problem. The second, submitted to Congress in 1972, included recommendations which called for the Federal funding of safety improvements at highway-rail crossings, improvements in accident reporting and the establishment of a national data base of crossing information.

Also in 1972, Idaho State and Union Pacific Railroad officials cooperated in the promotion of a public education and enforcement program to reduce the number of crossing accidents in Idaho. The program was called, "Operation Lifesaver" (OL). Others states and railroads quickly followed.

Finally, in 1972, Secretary of Transportation John A. Volpe declared a goal, the reduction of 500 fatalities a year and the elimination of 4,000 accidents a year within ten years. About 12,000 accidents and 1,500 fatalities per year were then occurring.

The Highway Safety Act of 1973 funded (from the Highway Trust Fund) a $175 million dollar program over three years ($25M/$75M/$75M) for safety improvements at highway-rail crossings on the Federal-aid highway system. The Federal money was distributed to states in a fashion similar to other Federal-aid highway funds and required a 10% match. At least half the funds had to be used for the installation of warning devices at crossings. The Act also required that each state establish and maintain a survey of crossings.

A joint industry/state/Federal effort, in response to the Congressional mandate that each state establish a survey of crossings, promoted a national Inventory pointing out that the state "surveys" should be uniform. The Inventory was begun.

The Highway Safety Act of 1976 continued the Federal funding begun in 1973 by providing $250 million over 27 months for on-system crossings and $168.75 million for crossings not on the Federal-aid system, a first.

In 1977, the National Transportation Safety Board (NTSB) recommended that the National Safety Council establish a national OL program.

The Highway Safety Acts of 1978 and 1982 established and continued four-year, $190 million per year programs, dropped all distinction between crossings on and off the Federal-aid system and changed the distribution of funds to include a 50 percent consideration based on the number of crossings in each state.

In 1986, OL came out from under the auspices of the National Safety Council (NSC initiated the separation) and was incorporated as an independent entity.

The Surface Transportation and Uniform Relocation Assistance Act of 1987 continued the crossing safety improvement program at $160 million per year for five years, through FY 1991. The Act also charged the Secretary with conducting a study of national highway-railroad crossing improvement and maintenance needs. The report was due in two years, a follow-up to the 1971-72 Reports to Congress. The Act also set aside $250,000 per year for driver education (a euphemism for OL), a first.

In April 1989, the Secretary of Transportation forwarded a report to the Congress, titled: <u>Rail-Highway Crossings Study</u>. This study summarized crossing needs to the year 2005.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 continued the crossing safety program at the same funding level nationwide as the 1987 Act, but with the potential for increased funds at a state's discretion. Also, the 1991 Act significantly broadened the allowance for 100 percent financing of certain improvements under the Section 130 Program.

Appendix II

Status of Current Programs

A. Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)

Most of the funds for crossing improvements come through the Federal Highway Administration (FHWA). In 1973, Congress established and funded a categorical Highway Trust Fund program for improving highway-rail crossing safety. The crossing safety program has been funded continuously since then. Most recently, through passage of the ISTEA, the Congress authorized to states over $3.4 billion in Fiscal Year (FY) 1992 and nearly $4.1 billion per year for surface transportation programs in FYs 1993 through 1997. Of this amount, ten percent is set aside for safety programs, including crossing safety.

1. ISTEA, Section 1007

Of the ten percent set-aside for safety programs, states must spend $149 million on highway-rail crossing improvements. At least 50 percent of these funds must be spent on the installation or upgrading of warning devices, and the remainder may be spent on additional warning devices or on other means of eliminating crossing hazards. The specific amounts received by each state are determined by a Congressionally mandated formula which considers the number of crossings, highway route miles, geographical area and population. (Significantly, the numbers of crossing accidents and casualties do not enter into this formula.) States also receive over $116 million in the set-aside amount which can be spent on hazard elimination at crossings or on highways. Optional amounts for each state range from $0 to $10.6 million.

All public highway-rail crossings are eligible. Projects may include the installation of train-activated warning devices (traditional lights and/or gates), signs and pavement markings, crossing closures, signal circuit upgrades, illumination (street lights), crossing surfaces, the building of grade separations (bridges), sight-distance improvements and other highway approach modifications.

2. ISTEA, Section 1010

This section authorized $30 million over six years for the elimination of hazards at both public and private highway crossings in up to five high speed corridors. The five corridors include: The Northwest (Vancouver, British Columbia to Eugene, Oregon via Seattle and Portland); California (San Diego to the Bay Area via Los Angeles and the San Joaquin Valley with a connection to Sacramento); Chicago (with spokes to Milwaukee, St. Louis and Detroit); Florida (Tampa to Miami via Orlando); and the Mid-Atlantic (Washington to Charlotte, North Carolina via Richmond).

Corridor	Length in Kilometers (miles)	Estimated Number of Crossings
California	1,054 (655)	600
Chicago Hub	1,041 (647)	815
MidAtlantic	769 (478)	585
Northwest	747 (464)	475
Florida	576 (358)	315

The initial $5 million has been obligated and the second year funding requests are under review by FRA and FHWA. States are developing long range plans for treatment of corridor crossings and initiating projects to specific crossings. Projects being undertaken involve both existing and advanced technologies. For example, four quadrant gates will be installed and evaluated, as will an arrestor net system designed to safely restrain vehicles from entering the crossing when a train is approaching.

Two other high speed rail corridors exist or are being developed under other authorities. These include completion of the Northeast Corridor from New York City to Boston, MA and the Empire Corridor from New York City to Schenectady, NY via Albany, NY.

3. ISTEA, Section 1036

Section 1036(c) calls for a technology demonstration program which will facilitate the establishment of high-speed rail service. Of four projects selected for demonstration to-date, three address highway-rail crossings. These are:

Installation of an obstacle detection system with four-quadrant gates at a highway-rail crossing. The Connecticut Department of Transportation will demonstrate an advanced crossing protection system using four-quadrant gates with a transponder-based system which will detect an obstacle between the gates and will notify the locomotive engineer should the warning devices not work or if the crossing is blocked, enabling the train to stop in time to avoid an accident. Two or three Amtrak locomotives will be retro-fitted with the necessary cab signals to receive signals from the new vehicle detection system. The new system will overlay the existing warning system and will relay information to the engineer via cab signals.

A consortium of four firms, a university and Virginia's Center for Innovative Technology will demonstrate a "friendly mobile barrier" (FMB). The FMB is a crash attenuation device that rises from a vault in the roadway behind crossing gates after the gates have come down. The FMB will block access to the tracks for approaching highway vehicles and will stop a passenger car or light truck while averting both fatal injury to occupants and damage to the barrier. The FMB will also prevent a large truck from gaining access to the tracks at truck speeds up to 80 kph (50 mph), though damage to both the truck and barrier could be severe.

The Florida Department of Transportation (FL DOT) will demonstrate a low cost grade separation structure and process. Total cost and time of construction is expected to be approximately fifty percent less than the time and cost of a traditional pile supported, concrete wall and beamed structure. The proposed structure will use either a culvert style approach or "two vertical walls of reinforced concrete covered by a deck (to be designed by the FL DOT)." The FL DOT will "compete" the options.

4. ISTEA, Section 1072

Section 1072 requires the Department to coordinate field testing of a Vehicle Proximity Alert System (VPAS) to determine feasibility for use by priority vehicles (emergency, police, school buses, hazmat) as an effective highway-rail grade crossing safety device. A special public announcement on 26 July 1993 solicited information for any existing designs for possible test and evaluation (T&E). Eleven formal responses involving different technologies were received and evaluated. Four systems, representing three basic design concepts, were tentatively selected.

The current program effort is to provide a test site(s) (currently the Pueblo Transportation Test Center), test plan, data collection and evaluation for the selected systems that have operational prototypes. The test and evaluation will include a representative design from each of the three design concepts. Those systems that successfully pass initial testing and have promise will receive a thorough field operational evaluation to verify the reliability and overall performance in real-life conditions.

The cost for testing and evaluation should be under $1,000,000, and FHWA has identified approximately $1,000,000 of IVHS (Intelligent Vehicle Highway System) funds which have been transferred to VPAS for the T&E effort. The FRA Office of Railroad Development (High Speed Rail Corridor Project) will have funds available in FY 1995 to help support the T&E effort.

5. ISTEA, Section 1077

Section 1077 required revision of the Manual on Uniform Traffic Control Devices (MUTCD) to grant states and local governments the discretionary authority to install STOP or YIELD signs at any highway-rail grade crossing without automatic traffic control devices with two or more trains operating across the highway-rail grade crossing per day. To implement Section 1077 the FHWA published on November 6, 1992 a Final Rule 92-11 in the Federal Register (57 FR 53029). This Final Rule incorporated standards into Section 8B-9 of the MUTCD.

The rule was effective upon issuance. In addition, on December 30, 1992, the FHWA issued an interpretation which defined "two or more trains a day" to mean: an average of two or more trains operating over the crossing each day for a period of one year prior to the installation of the STOP or YIELD control sign.

FRA and FHWA have developed a list of considerations to assist in the selection of crossings where it would be most appropriate to install such signs first. We have encouraged states, communities and railroads to develop a rational program for the installation of STOP or YIELD signs.

The following factors are suggested for consideration when reviewing a crossing for possible STOP or YIELD sign installation:

a. Will local law enforcement officials enforce the traffic control message?;

b. Volume, type and speed of highway traffic;

c. Frequency, type and speed of trains;

d. Number of tracks and the intersection angles;

e. Adequacy of stopping sight distances;

f. Need for more active control devices; and

g. Crossing accident history.

Crossings which should be considered first for STOP sign installations should be those where most of the following factors are met:

a. Local and/or state police and judicial officials will commit to a continuing program of enforcement.

b. The highway is secondary in character with low traffic counts. Recommended maximum of 400 Annual Average Daily Traffic (AADT) in rural areas, and 1,500 AADT in urban areas.

c. Highway traffic mix includes buses, hazardous materials carriers and/or large (trash or earth moving) equipment.

d. Train speeds exceed 30 mph and/or train movements are 10 or more per day, 5 or more days per week.

e. Rail line is used by passenger trains and/or a significant incidence of hazardous material lading.

f. Crossing is multiple track and/or approach is at a skewed (other than 90 degree) angle.

g. The line of sight from an approaching highway vehicle to an approaching train is restricted.

h. Installation of a STOP sign would not occasion a more dangerous situation than would exist with a YIELD sign.

STOP or YIELD signs shall not be used at crossings with active traffic control devices. STOP AHEAD or YIELD AHEAD Advance Warning Signs should also be installed. The placement of a STOP or YIELD Sign at a crossing shall conform to the requirements of MUTCD Section 2B-9 Location of STOP Sign and YIELD Sign.

The FRA has developed software and made available lists which group "passive" crossings, i.e., those without active warning devices, into categories based on information taken from the U.S. DOT/AAR (Department of Transportation / Association of American Railroads) National Highway-Rail Crossing Inventory and the objective criteria from the foregoing factors. The top categories include those crossings which should be reviewed and considered first for STOP signs (i.e., those most likely to realize a safety benefit). Several states and railroads have acquired these listings.

B. High Speed Rail

The FRA's Office of Safety has established guidelines for crossings on high speed rail corridors.

If rail speeds are to exceed 200 kph (125 mph), no at-grade (level) crossings, public or private, will be permitted across the rail right-of-way. All crossings in such high speed rail corridors must be closed or grade separated (a bridge built).

1. Public Crossings:

Where trains will be operating at speeds between 176 and 200 kph highway-rail crossings must be equipped with impenetrable barriers capable of precluding intrusion onto an operating track, i.e, stopping highway vehicles short of fouling the operating track(s). Such a barrier must be operated in conjunction with intrusion detection and train stop technology. This implies track circuits of sufficient length that logic circuitry can verify and communicate to the locomotive that: 1) the barriers are closed; and, 2) the crossing is clear of vehicles, while the train is still a sufficient distance from the crossing that a full service brake application (non emergency) would bring the train to a stop before reaching the crossing if either indicator was not favorable. (See requirement for "grade crossing **protection**" in the context of operating speeds above 110 mph (49 CFR 213.9(c)).)

In this context, the term "grade crossing **protection**" is separate and distinct from conventional "warning devices." Warning devices, which are defined by the Manual on Uniform Traffic Control Devices (MUTCD), are intended to warn motorists of the presence of a crossing and of impending rail activities for the purpose of highway traffic control at and over the crossing. Concerns for the safety of the motorist and the efficiency of highway traffic flow are the motivating factors, and the FHWA has taken the lead in establishing requisite standards. However, these concerns pale in comparison to concern for the safety of the rail operation (for passengers, crews and trains) where rail speeds exceed 176 kph. Conventional warning devices do not **protect** the integrity or safety of the rail movement at any speed, and this failure would be catastrophic at speeds above 176 kph. Thus, "protection" is defined to mean an effective barrier, i.e., one which precludes intrusion onto the rail right-of-way. The closest parallel to this situation currently addressed within the MUTCD is the reference to "resistance gates" for closing roads on approaches to movable bridges. See MUTCD Section 4E-13. The role of "highway traffic control" in such a setting is to alert the highway vehicle driver that an obstruction or barricade lies ahead, i.e., that the road is temporarily closed. The MUTCD currently defines the necessary elements for properly closing and/or barricading a road.

For new service on designated corridors at or above 128 kph (80 mph) to 176 kph, FRA's guidelines call for the conduct of a corridor analysis leading to elimination of not less than 25% (50% as the target) of crossings, with separation or active warning devices, to include gates, at the remainder. Constant warning time upgrades would be required, where not present. As warranted at selected crossings, encourage use of median barriers, special signing (e.g., active advance) and/or four quadrant gates.

If lightweight train sets are introduced, additional protection might be required for rail movements.

2. Private Crossings:

Should be individually analyzed, closed as warranted, and at a minimum subject to manual gates (normal position being closed and locked), and safety measures comparable to public crossings in the same corridor.

For train speeds from 176 to 200 kph, accidental intrusion on the rail right-of-way must be absolutely precluded. This means that private crossings must be equipped with locked gates linked to the train signal and control system, along with telephones and a fail safe vehicle (obstruction) detection at the crossing. Gates should be substantially constructed, i.e., able to absorb a moderate speed collision from vehicles likely to be using the crossings without fracturing. If the gate/barrier is opened (e.g., to accommodate an emergency) it can not be done until track clearance has been received from the railroad and trains in the territory have been advised.

Where passenger trains are scheduled to operate at speeds from 128 to 176 kph, private crossings should either be closed, grade separated, provided with a secured barrier, or equipped with automatic visual and audible traffic control devices which provide a minimum of 20 seconds warning of the impending presence of a train to users of the crossing. The traffic control device should include a full barrier gate system (covering all lanes, approach and exit) on each side of the rail right-of-way. The barrier (gate) will normally be closed (down) and will open on request (manually or automatically), if no train is approaching, for a period of time sufficient for the crossing user to negotiate the crossing.

Rail Speed KPH (MPH)	Public Crossings	Private Crossings
128 (80) to 176 (110)	Eliminate all redundant or unnecessary crossings. Install most sophisticated traffic control/warning devices compatible with the location, e.g., median barriers, special signing (possibly active advance warning), four-quadrant gates. Automated devices should be equipped with constant warning time equipment.	Closed, grade separated, provided with a secured barrier or equipped with automatic devices. Device or barrier should extend across the entire highway on both sides of the track, should normally be closed and opened on request, if no train is approaching, for a period of time sufficient to cross the track(s).
177 (111) to 200 (125)	Protect rail movement with full width barriers capable of absorbing impact of highway vehicle. Include a fail safe vehicle detection capability between barriers. Notify approaching trains of warning device or barrier failure or of an intruding vehicle in sufficient time for the train to stop short of the crossing without resorting to emergency brake application.	Protect rail movement with full width barrier or gate, normally closed and locked, capable of absorbing impact of a highway vehicle. Gate lock or control should be interlocked with train signal and control system and released by a railroad dispatcher. A fail safe vehicle detection or video system should monitor the area between the barriers. The crossing should be equipped with a direct link telephone to the railroad dispatcher.
Above 200 (125)	Close or grade separate all highway-rail crossings.	Close or grade separate all highway-rail crossings.

C. Light Rail

Many metropolitan areas are addressing transportation needs by establishing light rail transit systems or reestablishing street cars or trolleys. Light rail transit systems currently exist in eighteen cities in the United States and Canada. New operations often share existing streets with highway traffic. Sometimes they use medians or closely parallel existing streets; operate in exclusive rights-of-way; or share a right-of-way, and sometimes track, with conventional rail operations. In some instances, light rail transit systems may employ a combination of these scenarios.

Most systems have some grade crossings. Not surprisingly these corridors generate relatively large numbers of crossing and pedestrian incidents and casualties. New operations have quickly discovered that the most prevalent safety problem, and the one that draws the most public concern, is light rail versus motor vehicle collisions.

Some communities have operated light rail and commuter rail systems for many years, e.g., New Jersey Transit and San Francisco MUNI. Newer systems are experiencing grade crossing accidents and increasing public concern as a result of these incidents. Most of these accidents are not the result of unsafe operation of the rail vehicle, but rather a lack of education about the dangers of attempting to cross the tracks while a rail vehicle is approaching. The cultural diversity of the surrounding community, language barriers and the unfamiliarity with living in an environment with light rail vehicles at grade crossings also have an impact on the number of grade crossing accidents.

1. Metro Blue Line Grade Crossing Safety Program

In the three years since the opening of the Los Angeles Metro Blue Line (MBL), a 22 mile light rail system, there have been 182 train-vehicle and 24 train-pedestrian collisions resulting in 16 fatalities and numerous injuries (as reported through June 1993). There are 100 grade crossings on the MBL. Officials from the Los Angeles County Metropolitan Transportation Authority (MTA) are taking an aggressive and innovative approach to finding solutions.

The MBL Grade Crossing Safety Program was initiated in March 1993 to evaluate various means to discourage or prevent illegal movements being made by motor vehicles at grade crossings that are causing train-vehicle accidents. While the program is focused primarily on evaluating measures to decrease train-vehicle accidents, the safety program is also concerned with improvements that will reduce train-pedestrian accidents.

The MTA is seeking to apply innovative equipment and safety methods developed for street and highway traffic applications. These engineering improvements will address the unique characteristics of grade crossings and improve public safety. The program includes four elements:

Enforcement using sheriff's deputies and photo enforcement systems.

Engineering improvements including use of Intelligent Vehicle Highway Systems (IVHS) technology, warning devices, street and traffic signal improvements.

Legislation to establish higher fines and statewide rail safety educational programs.

Bilingual public information and safety education.

The photo enforcement program has been extremely successful in terms of reducing the numbers of motorists who are violating grade crossings. Over a four month period, a photo enforcement demonstration project resulted in an 84 percent reduction in the number of violations occurring at two targeted crossings.

Their efforts are worthy of emulation, as they have had success in reducing accidents.

The FTA, in collaboration with the FHWA and FRA, provided funding to the MTA to test and evaluate technologies that will support the enforcement of traffic laws and decrease the frequency of grade crossing violations and accidents.

2. Integration of Light Rail into City Streets

Through the Transit Cooperative Research Program (TCRP), the FTA funded a research project to improve the safety of light rail operations in shared rights-of-way and to provide guidelines that may be used in updating the Manual on Uniform Traffic Control Devices (MUTCD).

Korve Engineering, Inc. of Oakland, California is the recipient of a $250,000 TCRP contract to (1) identify problems and potential solutions, and (2) conduct in-depth behavioral analysis of the most significant issues that impact integration of light rail transit into city streets. The anticipated products from this project are (1) identification of methods now in use to mitigate hazards of light rail transit operations, (2) calculation of measures of effectiveness, (3) recommendations for additions to the MUTCD, (4) demonstration of at least one proposed technique to improve safety, and (5) recommendations for future research.

Using a hazard analysis approach, the project will identify the most effective control devices, public education techniques and enforcement techniques to improve safety for rail passengers, motorists and pedestrians. The project will identify the most promising techniques to address problems such as:

Lack of pedestrian awareness of approaching light rail vehicles.

Unsafe pedestrian activity in close proximity to tracks, stations and intersections.

Motor vehicles operating parallel to light rail tracks turning into the path of light rail vehicles.

Failure of motor vehicles to yield right-of-way to light rail vehicles at street crossings.

Motor vehicles obstructing tracks.

Motor vehicles driving around closed railroad gates.

Nonstandard crossing configurations (e.g., light rail vehicles that turn in intersections, skewed intersections).

Techniques to be analyzed will include passive and active signs; traffic signalization (including light rail indications); pavement marking, texturing and striping; geometric improvements; channelization; audible warning devices (bells, whistles, horns, etc.); intersection illumination; illumination and marking of light rail vehicles for better nighttime visibility; moveable traffic barriers; application of advanced technology; enforcement; and education.

An additional objective is to provide material for possible use in the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD addresses traffic control for highway-rail crossings, but light rail vehicles interact with motor vehicles and pedestrian traffic in more complex ways than do traditional railroads.

3. State Safety Oversight

Section 28 of the Federal Transit Act, as amended (FT Act) directs the FTA to issue a rule requiring states to oversee the safety of rail fixed guideway systems not regulated by the FRA. A Notice of Proposed Rule Making (NPRM) was published in the Federal Register on December 9, 1993. The NPRM proposes the FTA's State Safety Oversight Program, which should improve the safety of light rail fixed guideway systems.

Section 28 requires each state to designate a state oversight agency to be responsible for overseeing the rail fixed guideway system's safety practices. FTA may withhold Federal funds if a state fails to implement the oversight program.

More specifically, the statute describes the responsibilities of the state, the agency the state designates to provide oversight, and the type of activities the agency is expected to carry out. In most instances, this entity will be an agency of the state because most rail fixed guideway systems operate only in one state. Where a rail fixed guideway system operates in more than one state, however, the statute permits the affected states to designate any entity, other than the transit agency itself, to oversee that rail fixed guideway system.

D. Crossing Consolidation and Closure

A March 4, 1993 memorandum from FHWA's Associate Administrator for Safety and System Applications to the FHWA Regional Administrators provided direction: "When considering [highway-rail crossing] improvement options, the ultimate solution to train-vehicle collisions is to eliminate the crossing by constructing a grade separation or closing the crossing. ... In addition to considering the closure of unnecessary grade crossings, states and local communities should make every effort to minimize the number of new crossings." Implementation is left to the FHWA Region and Division offices working with FRA Region offices.

FRA has an ongoing project designed to encourage railroads and state transportation agencies to consolidate and close unnecessary crossings. Case studies of two dozen crossing consolidation and closure projects were prepared. The case studies highlight effective strategies that have been used to consolidate crossings, and the lessons that can be learned from unsuccessful closure projects. Case studies were selected to reflect the diversity of state law on the subject of crossing closure and the range of crossing consolidation experience on freight and commuter railroads in rural and urban areas.

In February 1993, Operation Lifesaver, Inc. (OLI) subscribed to the general notion of closing crossings for safety: "To enhance highway-rail grade crossing safety, Operation Lifesaver, Inc. endorses the concept of reducing the number of crossings through consolidation, elimination, grade separation and restricting the number of new crossings." Several state level OL programs are promoting crossing closure.

The Association of American Railroads (AAR) and the American Association of State Highway and Transportation Officials (AASHTO), working through the National Conference of State Rail Officials (NCSRO), have established an ad hoc committee to address the promotion of crossing closure programs. Both the FHWA and FRA are supporting this effort co-chaired by individuals from the Iowa Department of Transportation and the Union Pacific Railroad. The goal is to publish a report outlining the rationale for crossing closure, a compendium of state laws regarding crossing closures and openings, a series of "provisions" that might be incorporated in new state legislation to promote closures and limit openings (selection of provisions would depend on the structure of state government) and to provide some tools to promote progress (e.g., procedures, pamphlets, possibly a video). The committee is promoting a study by the National Cooperative Highway Research Program (NCHRP) to develop an analytical procedure for assessing a group of crossings (a corridor) and developing criteria for weighing the pros and cons of closing specific crossings within the group.

In August 1993, at the annual NCSRO meeting, the Safety Committee proposed a resolution which was positively received, to wit, that cash incentives to local governments for crossing closure should be permitted (at state discretion) from the Federally funded (Highway Trust Fund) crossing safety improvement program. Such a provision would have to be sanctioned by Congress. As proposed by NCSRO, the local jurisdiction receiving these funds would have complete latitude in their use. However, they could be used for some items or indirect costs which cannot be paid with Federal funds. Examples from FRA's case studies include landscaping and the extension of a water line to a new fire hydrant necessitated by the closure.

This resolution has been approved by both NCSRO and AASHTO state officers and was formally forwarded to the Department by AASHTO on May 12, 1994.

The FHWA will currently allow Federal funds to be used for purchasing a property "right" from a private entity for public purposes, but has not extended that allowance to a public entity.

Such a program will be needed, if not for all railroads' right-of-way, at least for high speed corridors.

Several railroads have established their own programs to promote crossing closure. Burlington Northern Railroad (BN), Conrail (CR), CSX Transportation (CSX), Norfolk Southern Corporation (NS) and Union Pacific Railroad (UP) are examples. They use different approaches, each with varying success, but learning as they go. For example, in Florida, CSX, "which represents 60 percent of the rail mileage in Florida, has agreed to be the applicant on crossing closures on their system, pay 100 per cent of the cost of closure and share the costs associated with roadway improvements required as a result of the crossing closure."[5] UP is working through their OL presenters and is willing to match the Nebraska cash incentive for local communities. (UP and BN have both agreed to match state incentive payments in Missouri as well, if the state approves a program.)

The legislatures of Kentucky, Missouri and Illinois have each recently enacted crossing closure initiatives. Missouri and Illinois have tasked rail offices in their respective states with studying the closure alternative. In the case of Missouri, the Missouri Division of Transportation has reported back and recommended a crossing closure plan describing both procedures and funding.[6] In Illinois, they are to publish specific criteria which will be considered when weighing the retention of an existing crossing or the opening of a new crossing. Authority to close crossings is (and was) vested in the Illinois Commerce Commission. In Kentucky, the Transportation Cabinet has been given the authority to close crossings used by less than 4,000 vehicles per day. The existence of this authority has led to many cooperative (between local communities, the Commonwealth and the railroads) ventures resulting in the closing of several crossings. The Cabinet has not yet had to exercise the "authority" in order to consummate a project. Florida DOT "discourages the opening of new public grade crossings." In fact, Florida's Secretary of Transportation has placed a moratorium on new at-grade crossings on Florida's Section 1010 corridor.[7]

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5 Report to the Governor and the 1994 Florida Legislature on the Safety and Security of Railroad-Highway Grade Crossings, January 21, 1994, page 12.

6 Executive Summary of the Missouri Grade Crossing Closure Study, Missouri Division of Transportation Staff, January, 1994.

7 Florida Report, page 11.

Currently, there are no Federal restrictions or standards on how many or what types of crossings should be consolidated within a given area. However, some jurisdictions have found the following criteria useful for selecting crossings for consolidation:

1. Consolidate crossings where there are more than four per mile in urban areas, and one per mile in rural areas and an alternate route is available;

2. Consolidate crossings which have fewer than 2,000 vehicles per day and more than two trains per day and an alternate route is available;

3. Eliminate crossings where the road crosses the tracks at a skewed angle or where the track is curved;

4. Link construction work with eliminations. This linkage will be especially important when upgrading rail corridors for high speed trains;

5. When improving one crossing (by grade-separation or installation of automated warning devices), consider eliminating adjacent crossings and rerouting traffic from these crossings to the improved crossing;

6. For every new crossing built, consolidate traffic from two or three other crossings; and

7. Eliminate complex crossings where it is difficult to provide adequate warning devices or which have severe operating problems (e.g., multiple tracks, extensive switching operations, long periods blocked, etc.).

Before consolidation, identify alternate routes for ambulances, fire, and other emergency vehicles. Past experience shows that even when communities support crossing consolidation, they may oppose proposed changes in traffic patterns. In these cases, "trade-offs," such as upgrading other crossings in the area of the targeted closure, have been successful.

When set against the backdrop of current high speed rail proposals, all this is particularly timely. Crossings are the major impediment to the realization of true wide spread high speed rail operations, both passenger and intermodal, in this country. The crossing problem must be solved, or we will not realize full potential. Consolidating crossings is the safest and only long term solution. The momentum which now exists must be nurtured.

E. Corridor Reviews

For the last 20 years, states have been able to identify and improve many hazardous highway-rail crossings, most often by installing train-activated warning devices with Federal-aid highway safety funds. Today, many of the most hazardous crossings have been improved. There is some concern, however, that too little attention has been paid to the less expensive safety improvements that are needed at a far greater number of crossings, including private crossings.

Under the current program, low-volume crossings are seldom reviewed by diagnostic teams and any work done at these crossings is usually limited to the installation of passive warning devices. Statistics show that more than half of the fatalities resulting from highway-rail crossing accidents occur at low-volume crossings where active warning devices may never be installed.

Actions have been taken over the years to encourage states to expand their programs to encompass significantly more crossings each year and emphasize low-cost improvements at crossings not often addressed by diagnostic teams. In a June 1983 memo, the FHWA's Office of Highway Safety urged its field offices to encourage states to consider a number of low-cost projects that had the potential to improve safety at crossings without active warning devices. Such projects included: (1) Vegetation clearing and other means of improving sight distance; (2) installing standard signs and pavement markings; (3) improving roadway approach grades and alignment; (4) improving crossing surfaces, and (5) closing unnecessary crossings.

It was pointed out that these low-cost improvements could frequently best be carried out if all the crossings along a railroad corridor or in a given area, such as an urban area or a highway district, were analyzed at the same time for possible improvement. This method of analyzing crossings is especially important in determining which crossings can be closed. The memo further pointed out that Federal-aid highway funds are eligible for making improvements in these corridors even if every crossing in the corridor does not appear on the state's high priority list of crossings.

In 1986, the FHWA published a report titled Demonstration Project No. 70, Railroad Crossing Corridor Improvements, which presented a model program combining the benefits of individual high-risk crossing programs with those of a corridor approach. The report also spelled out specific aspects of a corridor approach that should be emphasized to maximize a state's crossing safety effort.

In March 1993, FHWA's Associate Administrator for Safety and System Applications issued a memo reminding FHWA field offices that the ultimate solution to train-vehicle collisions is to eliminate crossings by constructing grade separations or closing the crossings. Again, these are the types of actions that can best be analyzed by looking at numerous adjacent crossings in a corridor or systems approach to crossing improvements.

F. Operation Lifesaver™ (OL) and OL, Inc. (OLI)

Operation Lifesaver™ is an active, continuing public education program designed to reduce the number of crashes, deaths and injuries at highway-rail intersections. It is sponsored cooperatively by Federal, state and local government agencies, highway safety organizations and the nation's railroads.

1. Education

Operation Lifesaver's success lies in educating people of all ages as to just how potentially hazardous grade crossings can be. Methods used to reach the public include civic presentations, early elementary and driver education curriculum activities, school bus driver programs, industrial safety, law enforcement programs and media coverage. Both OLI and FRA have produced Public Service Announcements (PSAs) for television and radio. Some state programs have also produced PSAs, including some in Spanish.

2. Enforcement

Nearly 50 percent of all highway-rail crossing accidents occur at crossings equipped with automated warning devices, indicating that some members of the public ignore the devices. This statistic underscores the need for increased enforcement.

The DOT does not enforce traffic laws at crossings, which is why the support of state, local, and railroad enforcement officers is so critical. The DOT and OLI work with state and local police, highway, and judicial authorities to promote broader enforcement programs and imposition of stiff fines for disregarding warning devices and STOP signs at highway-rail crossings. State and local law enforcement agencies are urged to "crack down" on motorists and pedestrians who disregard these laws and jeopardize their own as well as the lives of others. FRA/OLI are making available the Law Enforcement Television Network series, "On-Track," for training of police officers regarding enforcement of crossing safety laws. FRA, sometimes jointly with OLI, has displayed at national meetings of the International Association of Chiefs of Police, the National Fraternal Order of Police and the National Sheriffs' Association.

Vandalism of active warning devices at highway-rail crossings is also a problem which can be aided by police involvement. Approximately one in twenty warning device failures is reportedly attributable to vandalism, and vandalism is suspect in many more.

3. Engineering

The public is made aware of Federal, state and railroad programs that plan, install and maintain grade crossings. FRA/FHWA/OLI offer technical training to employees of railroads and state and local governments in crossing improvement and safety programs.

4. Funding

Operation Lifesaver, Inc. receives nearly 60 percent of its funding on a national level from FHWA ($300,000) and FRA ($100,000) grants. Private corporate sources providing funding include the Association of American Railroads (AAR), the National Railroad Passenger Corporation (Amtrak) and the Railway Progress Institute (RPI), with individuals providing small levels of support through individual and small corporate donations. As a 501(c)3 organization, OLI is federally tax-exempt, and all donations to it are tax-deductible, based on current IRS regulations for charitable deductions.

State and local programs are funded from myriad sources including state and corporate contributions. Some assistance, mostly non-financial, is provided by OLI. Many state programs are incorporated in a fashion similar to OLI.

5. Staffing

Located in Alexandria, Virginia, just outside of Washington, D.C., the National Support Center (NSC) serves first and foremost as a central coordinating point for all OL activities nationwide (national headquarters office). The headquarters employs three full-time staff members: Executive Director, Communications Director and Executive Assistant. The NSC functions on a full-time basis five days per week. OLI also employs a full-time individual designated as the National Field Coordinator (NFC), whose primary role is to offer direct technical assistance to the state OL programs. Working from a field office in Phoenix, Arizona, the NFC assists state programs, reorganizes dormant programs, helps maintain current programs and establishes new programs. The NFC provides the training necessary to have individuals certified as Operation Lifesaver Presenters.

There is an OL State Coordinator for each state (except Hawaii). This individual promotes and coordinates crossing safety and enforcement programs within the state, often orchestrating the efforts of speakers/presenters, displays at state and county fairs, special events, responding to and initiating media coverage, attending public hearings/meetings re crossing safety, developing and/or distributing promotional materials, etc.

G. Research

1. Locomotive Conspicuity

Many railroads have equipped locomotives with alerting lights (such as ditch lights, strobe lights, oscillating lights, low-level-additional-headlights, and flood lights) to make them more visible at night. In 1983, the FRA conducted a benefit-cost analysis of alerting lights and concluded that a Federal requirement that all railroads use such lights on every leading railroad car could not be justified. After comparing the safety records of railroads that equipped locomotives with alerting lights to those of railroads that did not equip their locomotives with such lights, the FRA found no evidence that alerting lights reduced highway-rail crossing accidents. The FRA determined, in light of this information and the maintenance and reliability problems found, that the costs of requiring alerting lights would far exceed the benefits. The 1983 report stated if the FRA issued such a regulation under these circumstances, railroads would be compelled to reallocate resources from programs already proven successful in reducing rates for crossing accidents to a less effective approach.

However, two years ago, in light of improved device reliability and in frustration with the continuing toll of crossing accidents, the FRA asked VNTSC to again research this option. In recent legislation, specifically the Amtrak Authorization and Development Act passed in 1992, the Congress directed the Secretary of Transportation to complete research by the end of 1993 and to issue final rules before July 1995 requiring "enhanced locomotive conspicuity measures." The legislation defines this as any "enhancement of day and night visibility of the front-end unit of a train, by means of lighting, reflective materials, or other perspective of drivers of motor vehicles at grade crossings."

2. Reflectorization of Rail Cars

In 1982, the FRA studied the safety potential of requiring some reflective patches on the sides of rail cars. Principally because of the rapid degradation of available materials at that time, the FRA concluded that such a requirement was not cost-effective.

However, in recognition of recent improvements in retro-reflective materials (more reflective ability and surface coatings that resist dirt accumulation and afford some ultra violet protection), the FRA is reconsidering this option.

Tests have been conducted at the Transportation Test Center in Pueblo, Colorado, to measure performance and to establish the optimal size and position of the materials on freight cars. Full scale testing (in revenue service), with the cooperation of three major railroads, is now underway in Alabama, Alaska, Georgia, Illinois, Indiana, Kentucky, Minnesota, Ohio, Tennessee, and Virginia. As part of the overall effort, accident experience and data will be reviewed. Human factors, specifically motor vehicle operator recognition, comprehension and response, will be assessed. Upon completion of these tests in FY 1994, the FRA will re-examine its policy on this matter.

3. Illumination

VNTSC is developing illumination standards for street lights at highway-rail crossings. The purpose of such lighting is two fold; to provide advance notice to the approaching motorist of the existence of a crossing, and to illuminate a train when one is in the crossing. FRA is sponsoring this effort. VNTSC will consider in its evaluation a cost comparison of solar-powered and commercially-powered illumination systems and applicability of standard highway illumination. A draft report and illumination guidelines have been circulated for peer review and is projected to be available to FRA by Summer 1994.

While illumination has failed to gain widespread recognition as a safety improvement option, it has several benefits. Illumination is a low-cost improvement, especially if commercial power is already available. In addition, placement, operation, and maintenance can be effected with only minimal railroad involvement. States may use Federal funding for such projects through ISTEA.

4. Train Horns

The FRA is working with the Association of American Railroads (AAR) to study the safety impact of whistle bans nationwide, to determine if nationwide Federal action is required.

Federal noise standards for railroads are established by the Environmental Protection Agency (EPA) and enforced by the FRA. However, because of their primary use as safety devices, locomotive horns and whistles are exempt from the EPA noise emission standards. The FRA is sponsoring research by the VNTSC to develop an optimal warning signal for locomotive whistles, which minimizes noise for communities while not compromising safety. VNTSC also is investigating potential alternative systems, such as audible warning devices installed directly at crossings. (A cooperative effort involving the State of Nebraska, the City of Gering, the Union Pacific Railroad and a private firm has produced some field testing of an Automated Horn System (AHS) mounted at the crossing. The Los Angeles County Transportation Commission is also considering a similar device offered by another firm.) Some Los Angeles County commuter trains have been equipped with an innovative train whistle device, somewhat toned down and mounted lower on the locomotive in order to minimize impacts on neighboring communities, but still meeting minimum FRA standards. (VNTSC and FRA are monitoring these efforts.) A final report with research project results is anticipated to be available in 1994.

5. Signing Innovation

The FHWA, the Ohio Department of Transportation (ODOT) and Texas A&M University (on behalf of the State of Texas) have been pursuing research regarding innovative signing for use at highway-rail crossings.

a. The FHWA has recently concluded an effort to contrast the recognition and interpretation of various proposed passive signing configurations. Signs considered included the Canadian and Buckeye Crossbucks as well as traditional and modified YIELD signs. A report of this study was published in December 1993.

b. ODOT has in progress a massive field experiment and comparison of a new crossbuck and YIELD sign configuration, called the Buckeye Crossbuck. Half of the crossings in Ohio which are not equipped with automated devices are now being equipped with the new sign, while the other half are being provided new, but conventional, crossbuck signs. Subsequent statistical assessments, two to five years after installation is complete, will provide conclusions regarding the efficacy of the proposed sign. Crash testing is also being planned, i.e., staged and monitored vehicle collisions with the new Buckeye Crossbuck.

c. The Texas Transportation Institute (TTI), part of Texas A&M University, has developed and has recently been experimenting with an innovative advanced warning sign for use at highway-rail crossings. Field and driver recognition and response experimentation has recently been completed. A report is being prepared.

6. Loss of Shunt:

The FRA is conducting a joint research project with the Association of American Railroads to study the reliability of train detection track circuits and to document potential or probable conditions contributing to "loss of shunt".

The safety and reliability of highway-rail crossing warning devices are a major concern of both the railroad industry and the FRA. The primary activation of a crossing warning device is through vehicle wheel sets which apply a shunt between the two rails along a designated section of track. This shunting action causes track circuit voltage to short-circuit and prevent electrical energy from reaching the control relays. This activates the relays which control the proper functioning of signals and highway-rail crossing gates and flashers.

It has been suggested that a loss of shunt may be occurring at certain locations, causing premature release of crossing warning systems. The inability to properly shunt the track circuit could be due to a number of individual parameters, or a combination of factors. Some suggested conditions leading to improper shunting include films or contamination at the wheel/rail interface; light axle loads; changes in the wheel/rail contact patch due to rail grinding practices or different wheel profiles; and truck hunting or irregular wheel rail surface. The exact combination of the above conditions that could lead to loss of shunt is not fully known, nor is it certain that these are the only items that adversely influence shunting.

This research program is intended to collect sufficient field data to document the occurrence of inadequate shunting and to document as fully as possible the conditions of both track and equipment that existed at the time the loss of shunt was experienced.

7. Photo-Enforcement:

FHWA, FTA and FRA are jointly funding an evaluation of a photo-enforcement demonstration being conducted by the Los Angeles County Transportation Commission. Early results at two crossings equipped with active photo-enforcement equipment indicate an 84 percent reduction in motorists driving around down gates. Crossing accidents along that portion of the light rail line where the devices have been installed are down 60 percent.

8. High Speed Rail Surveys

FRA has initiated investigation of hazard elimination alternatives at highway-rail crossings. FRA has also contracted for an investigation of current and new technologies for use at high speed rail crossings. Two contractors are involved:

Applied Systems Technologies, Inc. (ASTI) is investigating hazard elimination needs and options on the ISTEA Section 1010 corridors as well as the Northeast Corridor north end and the Empire Corridor. The research includes review of existing conditions on proposed high speed rail corridors and defines the problems with respect to the magnitude of the crossings affected, risk analysis of crossing warning devices proposed, overall view of current and innovative warning devices, prominent jurisdictional issues and any recommendations to resolve the identified problems. The contract was recently modified to identify and determine the degree to which liability issues may or have impeded progress in the crossing hazard elimination area.

Battelle Laboratories of Ohio is investigating the world-wide status of current and innovative technologies for use at high speed rail crossings. The research includes determining the feasibility and cost of each technology. Areas of concern include signal and train control, obstruction detection devices and active and passive warning devices. Another area of this research involves development of a methodology to assess alternative grade crossing technology for use on the proposed U.S. high speed rail grade crossings. Three testing options are included in this contract for either laboratory, computer modelling or field testing of the most promising technologies.

H. Truck and Bus Involved Accidents

A review of the data available on truck accidents at highway-rail crossings indicates a general decline in these accidents. In 1982 there were 555 truck-trailer and bus accidents representing less than eight percent of total highway-rail crossing accidents. These accidents resulted in 26 fatalities, four percent of total fatalities at public highway-rail crossings. In 1992, 385 truck-trailer and bus accidents occurred at public highway-rail crossings accounting for less than nine percent of the accidents at these crossings. Thirteen fatalities resulted, two percent of total crossing fatalities. These figures do not diminish the seriousness of these accidents. Truck collisions with trains often derail the trains and have catastrophic potential.

An unknown at this time is how many states consider driving around gates which are down, a serious driving offense, especially by a driver operating with a Commercial Driver's License.

I. Regulation

1. Inspection, Testing, Maintenance and Timely Response:

On January 20, 1994, FRA published a Notice of Proposed Rule Making (NPRM) (59 FR 3051) in which FRA proposed specific maintenance, inspection and testing requirements for active highway-rail crossing warning systems. FRA also proposed to require that railroads take specific and timely actions to protect the travelling public and railroad employees from the hazards posed by malfunctioning highway-rail crossing warning systems. This action was taken in response to a statutory requirement that FRA "issue rules, regulations, orders, and standards to insure the safe maintenance, inspection, and testing of signal systems and systems at railroad highway grade crossings." FRA also solicited comments on whether the parking of idle rail equipment or switching operations on track circuits which activate highway-rail crossing warning devices should be addressed, and how.

2. Locomotive Conspicuity

In October 1992, the Amtrak Authorization and Development Act was signed into law. This legislation required the Secretary to complete locomotive conspicuity research no later than December 31, 1993. It also provided that interim regulations be issued identifying ditch lights, crossing lights, strobe lights and oscillating lights as interim locomotive conspicuity measures, and authorizing and encouraging installation and use of such devices. Any locomotive equipped with such interim conspicuity devices on the date of issuance of final regulations will be considered in full compliance until four years after issuance of the final regulations.

As required by the statute, FRA issued, on February 3, 1993, interim standards regarding locomotive lighting to enhance conspicuity of trains. (58 FR 6899, to be codified at 49 C.F.R. 229.133) This interim rule identifies several auxiliary external lighting arrangements as acceptable interim locomotive conspicuity measures. This rule encourages the installation on locomotives of such lighting arrangements as are now widely used and available. This action is intended to increase the visibility of locomotives to motorists and thereby reduce the incidence of accidental collisions between motor vehicles and locomotives at highway-rail crossings. Lighting devices installed in conformance to acceptable current practice will not be immediately rendered obsolete when FRA issues final standards in this area.

A second interim rule was published May 13, 1994. This second interim regulation relaxes the dimensional standards for placement of the various auxiliary external lights on locomotives.

The statute also requires the FRA to initiate rule making for the final regulations no later than June 30, 1994. The final regulations are to be issued by June 30, 1995. Compliance is to be industry wide no later than December 31, 1997. This effort is on schedule.

3. Vegetation Clearance

Visibility up and down the track is critical for motorists approaching highway-rail crossings, especially at those crossings without automated warning devices. (Warning devices are often installed to compensate for sight obstructions, particularly for those which are seasonal and/or outside the control of railroad and highway authorities.) Maintaining clear sight distance on both highway and rail rights-of-way, i.e., clearing vegetation, is often a seasonal necessity. The FRA is considering the addition of a provision within revised track standards (currently being developed) requiring that the rail right-of-way on either side of highway-rail crossings be kept clear of vegetation.

4. Standing Trains, Locomotives or Cars:

Most railroads have operating rules which address the standing, spotting or parking of trains, locomotives and rail cars near public highway-rail crossings. These rules often stipulate that parked rail cars should be a minimum distance (e.g., 300 feet) from a highway crossing, and that if a train, locomotive or car is stopped where it may obscure the view of train movements on adjacent tracks, provision must be made to protect highway traffic. These rules also stipulate that equipment should not stand "longer than necessary," or switches be left open, where automatic warning devices will continue to operate because of such a presence.

In its recently issued grade crossing NPRM, FRA has requested public comment on the need to address situations where standing railroad equipment results in the continuous activation of warning devices.

5. Violation of Down Gates

The FHWA recently met with the American Association of Motor Vehicle Administrators (AAMVA) to discuss making grade crossing violations a serious traffic violation on a driver's Commercial Drivers License. A survey of state traffic laws will be conducted to document how states treat this offense now. A proposal to make grade crossing offenses a serious traffic violation will be addressed through the AAMVA committee structure. We expect a decision from the committee in August 1994.

J. Horns and Bans

Federal regulations currently require that each lead locomotive be equipped with an audible device that meets specific performance standards. However, Federal regulations neither prohibit nor mandate the sounding of train whistles. All the major railroads have an operating rule that requires their engineers to blow the horn at highway-rail grade crossings as a warning to drivers and pedestrians.

As documented by the FRA study entitled "Florida's Train Whistle Ban," train horns are an effective safety device. The study indicates that after Florida communities implemented nighttime whistle bans, accident rates nearly tripled at the impacted crossings. When state and local governments failed to repeal the bans, the FRA issued an emergency order requiring the use of train horns along the impacted rail corridor in Florida.

As a result of petitions received following our Emergency Order a series of remedial measures were defined with the involvement of state, Federal and city highway authorities. An amendment was issued in August 1993. Should these measures be implemented, the use of train horns may be suspended.

The measures include the "treatment" of all crossings in a "quiet zone" at least one-half mile in length with one of the following alternatives:

1. Permanently close the highway-rail crossing.

2. Close the crossing to highway and pedestrian traffic during ban (nighttime) hours.

3. Install sufficient gates at a crossing to fully block highway traffic from entering a crossing when the gates are lowered.

4. Install median barriers at a crossing which prevent highway traffic from driving around lowered gates.

5. Make adjacent street into one-way pairs and modify and/or relocate existing gates to completely block approaching lanes of traffic.

For safety reasons, the FRA will not endorse any proscription which encumbers the industry's practice of using train whistles or horns at highway-rail crossings unless remedial actions have been accomplished. The FRA is conducting a nationwide study, similar to the Florida Whistle Ban Study, to determine if Federal regulations addressing whistle bans should be initiated.

Accident figures recently compiled from data submitted by the Florida East Coast Railway (the railroad affected by Florida's whistle ban) for the 24 months before and after the FRA issued its emergency order indicates that night-time (10 p.m. to 6 a.m.) accidents at impacted crossings decreased 68.6 percent, from 51 to 16. By comparison, day time (16 hours) accidents at the same crossings (horns were never banned during the day) decreased in the same period by only 8.8 percent, from 34 to 31.

K. The Manual on Uniform Traffic Control Devices (MUTCD)

The MUTCD, published by the FHWA, "presents traffic control device standards for all streets and highways open to public travel...." Part VIII of the MUTCD addresses "Traffic Control Systems for Railroad -- Highway Grade Crossings."

A number of actions and developments have occurred or evolved over the last several years which are not addressed within the MUTCD. Among these are the advent of high speed rail and the overall resurgence of higher speed trains, passenger and intermodal freight, the reemergence of intra-city light rail operations and recognition of the specialized needs of traffic control in highway work zones which include a highway-rail crossing.

L. Training

1. National Highway Institute Program

In 1986, a Rail-Highway Grade Crossing Improvement Course was developed by the FHWA and made available through FHWA's National Highway Institute (NHI). It was designed to be introductory in nature. Between 1988 and 1991 more than 25 highway-rail courses were presented to approximately 1,000 employees of state agencies, railroad companies, local governments, Federal agencies and the railroad supply industry. Evaluations revealed that future training courses should be made available to short line and regional railroad operators.

The FRA and FHWA jointly sponsored the updating of the course to be more technical and include "good" and "bad" practices in the installation and maintenance of grade crossing warning systems; to address crossing design, warrants for warning system types, selection of crossing surfaces and geometric design and priority index calculations. NHI is offering the revised training course to interested parties.

2. LETN Series

FRA promotes training of police officers regarding enforcement of crossing safety laws and crossing accident investigations. By Fall 1994, FRA and Operation Lifesaver, Inc. will be making available a condensed version of the Law Enforcement Television Network (LETN) series, "On-Track," originally sponsored and aired by the FHWA, FTA and FRA in 1991 for training police officers. The new version will include four segments covering enforcement and accident investigation techniques, trespassing, vandalism and other railroad related crimes, safety and outreach programs, and issues concerning electric trains and mass transit.

3. Highway-Rail Grade Crossing Handbook

The Handbook, a joint effort of FHWA and FRA, is a general reference guide on highway-rail crossings, including characteristics of the crossing environment and users, and the physical and operational improvements for safe and efficient use by both highway and rail traffic. The second edition was published in 1986. Information on state programs in the Handbook was taken from a 1984 survey of states. Since the last edition was published, two major transportation bills have been enacted that impact the highway-rail crossing safety program. Also, there have been changes to the MUTCD, major research projects have been carried out relevant to highway-rail crossings, there has been a landmark decision by the Supreme Court that affects grade crossing responsibilities, and there have been a number of technological advances in traffic control devices and crossing surface products. Much of the information in the Handbook is in need of updating.

4. Compilation of State Laws and Regulations On Matters Affecting Highway-Rail Crossings

The current Compilation, a joint effort of FHWA and FRA, is a general reference guide and cross reference to state laws and regulations affecting highway-rail crossings. It was published in 1983 and is outdated.

M. Failure/Emergency Notification

In 1983, the Texas Legislature initiated (and pioneered) a statewide alert or early warning system designed to inform railroads of warning device/signal problems at crossings. Signs have been placed at each crossing equipped with an automated device instructing the reader:

TO REPORT MALFUNCTION OF
THIS RAILROAD SIGNAL
CALL TOLL FREE 1-800-772-7677
GIVE THIS LOCATION # _ _ _ _ _ _ _

The telephone is answered by the Texas Department of Public Safety (DPS) (state police). The crossing location number is the U.S. DOT/AAR National Highway-Rail Crossing Inventory number. The location number is then checked against a master list and the maintaining railroad is notified of the malfunction. In 1989, on average more than 14 calls per day were recorded by the DPS. Every motorist, law enforcement officer and highway maintenance worker is a potential participant.

The FRA has favorably evaluated this system and has recommended its adoption by other jurisdictions. Railroads operating in Texas have stated that at least half of the calls received from the DPS are for problems of which they (the railroads) were not already aware. Both Connecticut and Delaware have established variations. In Connecticut, signs instruct observers to call "911." In Delaware, only automated Conrail crossings (81 percent of Delaware's automated crossings are Conrail's.) are equipped with signs, and the telephone number is a Conrail 1-800 number. Several railroads have also adopted versions, some with and some without signs, some available to the public, some promoted only to state, county and city officials.

The basic element of any system to notify public and railroad officials of a potentially dangerous situation at a highway-rail crossings is the identity of the crossing itself. As part of the U.S. DOT/AAR National Highway-Rail Crossing Inventory program, most every crossing in the Nation was assigned a unique number. In most cases, these numbers were placed at the crossings; however, this was originally done in the mid-1970s. Many, but not all, states and railroads have retained this system and have kept the number posted at the crossing. Others have continued alternative, usually state, systems which predated the National Inventory. A few have allowed at least the on-site numbering to deteriorate. The result is that the Inventory numbering system is in jeopardy as a national system and resource.

See also Section Q.4 regarding malfunction reporting to FRA by railroads.

N. Private Crossings:

There are nearly 110,000 private highway-rail crossings on the U.S. rail system. Casualties and property losses resulting from accidents, and the ever present potential of a major railroad catastrophe, at these crossings is a continual concern. At present, responsibilities for private crossings are neither clearly understood nor consistently applied. This is an institutional problem which has impeded safety improvement programs at private crossings. Over the last decade, 1983 through 1992, accidents at private highway-rail crossings have vacillated between a high of 648 (in 1984) and a low of 445 (in 1992). Though the overall trend regarding accidents at private crossings has been favorable, it has not been as dramatic as improvements at public crossings. In most years, deaths at private crossings exceed the combined total of railroad related deaths from all causes except for trespassers and deaths at public highway-rail crossings.

The U.S. DOT/AAR National Highway-Rail Crossing Inventory recognizes four categories of private crossings, i.e., farm, industrial, recreational and residential. Nearly two-thirds of the 109,881 private crossings catalogued in the Inventory are in the first group, farm crossings. Nearly a quarter are industrial. Industrial crossings generate the most accidents with farm crossings a close second. But, on a per crossing basis, industrial crossings have the highest accident frequency, with recreational and residential crossings following a close second and third. Farm crossings are last by this measure.

1. Guidelines

Early in 1993, the FRA circulated a draft set of preliminary guidelines addressing the safety of private highway-rail crossings. This draft set forth definitions and general responsibilities. It suggested criteria for closure, basic signage and engineering, the use of train horns and treatments for private crossings in high speed rail corridors.

A public meeting was held in July, 1993, to discuss both the general issue of FRA involvement and the specifics raised by the guidelines. Participants differed regarding their views as to Federal involvement in this area. Some parties emphasized their view that if guidelines or rules are issued, rule making procedures should be followed.

FRA is currently reviewing the comments and materials received during and subsequent to this July meeting.

2. Snowmobile Crossings:

A recently enacted law of the Wisconsin legislature allows the creation of new crossings of railroad tracks for snowmobiles without the permission (or involvement) of the host railroad. Authority for issuing regulations pertaining to these crossings has been vested in the State's Department of Natural Resources (DNR). The law would allow "volunteers" to build and maintain snowmobile crossings.

The FRA is monitoring developments.

O. FRA's Regional Program Managers

FRA's regional and headquarter's efforts regarding highway-rail crossing (and trespasser) programs have been hampered by under-staffing. Prior to FY 1994, the headquarters division promoting crossing programs had a staff of five, all taken from related functions within the Office of Safety when the Division was created in 1991. Regional office efforts have fallen in the category of "additional duties."

The FY 1994 budget will augment this staffing by the addition of eight regional program managers, one for each region, and two additional personnel for the headquarters Division.

Once these individuals are on board, projected for August, they will provide program support, coordination and promotion to states, local governments and railroads with emphasis on:

Corridor Improvement Programs;
Operation Lifesaver;
Accident investigation; and
Trespass prevention.

FRA was also given authority to hire eight additional signal inspectors to help enforce the proposed inspection, testing and maintenance regulations as well as existing signal standards.

P. Integrated Intermodal Transportation Planning

ISTEA requires States and Metropolitan Planning Organizations (MPOs) to develop intermodal transportation plans, with new emphasis on considering freight and railroad issues. ISTEA further requires states to develop six management systems, including the highway Safety Management System (SMS), to facilitate more effective intermodal planning. The SMS, as defined in the implementing regulation, 23 CFR 500.103, is "a systematic process that has the goal of reducing the number and severity of traffic crashes by ensuring that all opportunities to improve highway safety are identified, considered, implemented as appropriate, and evaluated in all phases of highway planning, design, construction, maintenance and operation and by providing information for selecting and implementing effective highway safety strategies and projects." The regulation specifically addresses consideration of highway-rail crossings in the system, including developing data relating to highway-rail crossings, identifying hazardous highway-rail crossings and maintaining and upgrading safety hardware at highway-rail crossings.

The highway SMS, by fully considering all elements of highway safety, will provide a mechanism for evaluating the effectiveness of different safety strategies and guide the selection of safety measures. This provides an opportunity to consider highway-rail crossings in a broader context than crossing improvements alone. The cost and safety impact of consolidating grade crossings should now be considered in developing overall plans to improve highway safety.

Those implementing ISTEA in the State Departments of Transportation, MPOs and railroads, especially where planners are required to cross modal lines, are looking to the U.S. Department of Transportation for assistance and guidance.

Q. Data

1. Accident Reporting

Railroads are required (by the Federal Railroad Safety Act of 1970 and the Accident Reports Act) to report all accidents and incidents arising from the operation of a railroad that results in an impact occurring between on-track railroad equipment and an automobile, bus, truck, motorcycle, bicycle, farm vehicle, pedestrian or other highway user at a highway-rail crossing.

Railroads report this data monthly. Uses include safety and economic analyses to develop and target counter measures to include personnel resources, and regulatory and research initiatives. FRA compiles and issues an annual bulletin tabulating and summarizing accident reports.

2. The Inventory

In response to the Federal Railroad Safety Act of 1970, a joint government/industry effort to compile a national inventory of highway-rail crossings was initiated in 1972 and completed in 1976. The Inventory contains data regarding more than 70 physical and operational characteristics of all highway-rail crossings in the United States (more than 402,000 in 1976), including public and private, at-grade and grade separated, even pedestrian crossings. Each crossing was assigned a unique number which was displayed at the crossing. Although this was (and continues to be) a volunteer effort, every state, the District of Columbia and Puerto Rico participated, as did all railroads.

The FRA is custodian of this computer based file. In this role, the FRA processes changes and updates, more than 80,000 per year, which originate from railroads and states As a volunteer program, continuing participation by states and railroads has not been universal. There have been periods of high activity and periods of slack participation. Some railroads and some states participate more than others, and often, as management and priorities have changed, railroads and states have changed from non-participatory to active participant and vice-versa.

Railroads and states may obtain from the FRA a personal computer based software package known as the GX System which facilitates the update process and eliminates the bureaucratic exchange of paper. There is no cost to the railroad or state. The GX System is a self contained package allowing the user to retrieve records, update them, sort and print records and summary reports, and produce a magnetic disc with current update information for submittal to the National Inventory File. Each GX System request is answered with a custom database containing the requestor's crossings and necessary cross-reference and decode files. A second version of this package, now available, has the ability to accept and apply mass updates, e.g., train counts for all crossings on a given rail line.

The Inventory, as a national resource, is available to all, and the FRA actively promotes its continued application and maintenance. It is widely used by FRA and FHWA, Federal research programs, safety and economic analyses, program management and assessment, by states and railroads, by universities and consultants and by litigants. Though the lack of universal and consistent updating is a drawback, the Inventory remains a unique and useful resource.

3. Resource Allocation Procedure (RAP)

A software package has been developed and is available to railroads and states which combines accident histories (derived from accident reports) and Inventory data to make accident predictions. The predictions are then combined with cost and effectiveness information and available budget thresholds to develop warning device improvement programs which maximize the safety benefit realized per budget dollar expended. "Safety benefit" may be defined in terms of accident or fatality or casualty (fatality and injury) reduction.

This software was last revised in 1986-87. A User's Guide (Third Edition) was published in August 1987. Every second year, through a rather cumbersome process, constants within the accident prediction programs are adjusted to reflect accident experience of the most recent five years. Every three months new master files are created using current Inventory data. These files are used to respond to state and railroad requests for RAP data. Cost and effectiveness default constants have not been adjusted since the 1986-87 revision. (The defaults are only used if the requestor does not specify alternative values.)

This DOT program is not the only one available. Though widely used, many states and railroads have developed their own. Some use the DOT program as a "second opinion." Some have modified or adapted the DOT procedures for their own applications.

4. Malfunction Reporting

In 1992, the FRA initiated rules requiring railroads to report warning device malfunctions, both failures to activate (report within 15 days) and false activations (report in the month following occurrence), to the FRA. If an accident occurs coincident with a failure, a report must be submitted by telephone within 24 hours. The requirement to report false activations (but not failures to activate nor failures concurrent with an accident) will "sunset" in 1994.

Reporting has exceeded expectations, reaching nearly 4,000 per month. Though more than expected, this figure must be considered within the context of the nation's more than 60,000 crossings equipped with automated warning devices which activate well in excess of 650,000 times per day, more than 19 million times per month.

These reports have assisted the FRA in developing proposed inspection, testing, maintenance and timely response regulations.

5. SAMIS

The Federal Transit Administration (FTA) is a grant-making organization. From 1978 to 1989, safety statistics were collect from only 13 heavy rail transit agencies nationwide and only on a voluntary basis. The Safety Information Reporting and Analysis System (SIRAS) published these statistics annually. Mass transit safety statistics are collected through the authority of Section 15 of the Federal Transit Act, and in 1990, the first Safety Management Information Statistics (SAMIS) Annual Report was published.

SAMIS statistics are solicited from nearly 600 transit agencies. Safety information is collected on a wide variety of mass transit modes: automated guideway, commuter rail, demand responsive, light rail, motorbus, rapid rail and vanpool. For an incident to be reportable, it must involve a transit vehicle or occur on transit property, and result in death, injury or property damage in excess of $1,000. Section 15 reporting requirements do not currently distinguish among light rail, rapid rail or commuter rail accidents and do not identify location, e.g., at grade crossings.

Safety statistics are collected on Form 405 of the Section 15 reporting system, and the data is entered into the system for analysis and production of the SAMIS report. SAMIS statistics measure how many incidents, injuries and fatalities a transit agency experiences vis-a-vis collisions, derailments/left roadway, personal casualties and fires. These statistics are measured separately for every transit mode an agency operates.

Now that the FTA has collected three years of safety data, trend analysis will also be published in the next SAMIS Annual Report. Modifications to the Section 15 reporting requirements, e.g., security data, are being reviewed for inclusion in the Section 15 report.

6. The Railroad Network GIS

The FRA has developed a Geographic Information System (GIS) that replicates the United States Railroad, Highway and Waterway Networks on a personal computer. It will be used to analyze railroad issues as they relate to the entire transportation system, such as the traffic flow simulation of different commodities and intermodal movements. The highway and waterway networks were provided by FHWA and the U.S. Coast Guard respectively.

The Railroad Network, created by FRA, represents all routes in the United States (160,000 miles) owned by over 500 railroads. It includes line specific information such as ownership, trackage rights, traffic volume and passenger service. It is maintained by FRA and is available to the public (except proprietary information). Among FRA's applications for this network is the flowing of hazardous material shipments and the subsequent study of the routes currently being used.

All highway-rail crossings in the U.S. DOT/AAR National Highway-Rail Crossing Inventory System are not yet located in the GIS. However, that effort is currently in progress. Its completion will allow a broad systems approach to future national grade crossing analysis.

R. Trespass Prevention

The trespass problem has grown worse in recent years. Trespasser fatalities have exceeded 500 deaths per year each year since 1990. The Department of Transportation and the industry have recognize the need for a focused effort.

1. The Workshop

In March 1992 the FRA hosted the first Workshop on Trespasser Prevention, a one day meeting in Washington, D.C. The meeting was well attended. Fifteen railroads, three Federal agencies and two associations met. Topics addressed included definitions and available data, the homeless as trespassers, illegal immigrants as trespassers, hobos as trespassers and the potential of involving Operation Lifesaver, Inc. (OLI). Other presentations dealt with measures which have worked in reducing trespassing (e.g., involving the local community), and those which have not (e.g., signs along the right-of-way).

The Workshop concluded with a consensus that: 1) better data is needed; 2) because of the diversity of regional trespass problems, programs should be developed on a regional basis; 3) programs should promote community involvement, targeted media campaigns, legislation authorizing enforcement and civil fines, and peer counseling (re the psychological handling of traumatic events) for those who must deal with trespass casualties; and, 4) OLI should receive guidance on how best to utilize their resources.

Minutes of the Workshop are available.

2. Data

From monthly Injury and Illness Summary Reports currently submitted by railroads, the FRA is able to cull the following data regarding trespasser casualties:

Month of Occurrence (based on month for which report is submitted);
Railroad reporting;
Age of casualty; and,
State in which casualty occurred.

Noticeably absent is information related to the setting in which the casualty occurred, the date, day and time of occurrence and the person involved and their activities at the time of the incident.

FRA has begun to segregate, tabulate, analyze and publish the available data. FRA covered 1991 calendar year statistics in the first annual Trespasser Bulletin.

The 1992 Bulletin indicates that, over a ten year period, based on fatalities per 100 right-of-way miles, fifteen states and the District of Columbia have above average rates. Seven of these and the District of Columbia exceed the average by a factor of at least two. The seven include California, Connecticut, Florida, Maryland, Massachusetts, New Jersey (highest) and New York. This same bulletin also indicated that for the last ten years, more deaths occurred to individuals aged 21 to 25 than in any other 5-year age group.

The National Center for Health Statistics (NCHS) in Atlanta, Georgia collects data from Death Certificates. Attempts have been made by the U.S. Centers for Disease Control to reconcile the FRA and NCHS data bases, but these were hampered by definitions, e.g., what is "railroad related," which varied and by resource limitations of both agencies.

3. OLI Grant

In FY 93, OLI accepted a $50,000 grant from the FRA to develop and target a campaign to discourage trespassers and vandalism on railroad property. A campaign plan has been developed which will target the sixteen states with the highest incidence of trespasser and vandalism problems. This campaign will include radio public service announcements, brochures and palm cards, posters and letters to selected organizations. Activity should initiate in June 1994.

OLI currently limits their trespass oriented activities to the fulfillment of this grant obligation.

4. Related FRA Activities

FRA has prepared and continues to distribute a pamphlet targeting law enforcement officials, titled, "The Safety Enforcement Initiative." The pamphlet stresses that "FRA is working to improve crossing safety and prevent trespassing." It goes on to develop the point that the "FRA does not have jurisdiction over traffic and 'no trespassing' laws. That's why we need the support of state, local, and railroad enforcement officers." It then addresses the question of "What can you do to prevent trespassing?" This pamphlet has been well received and widely distributed.

FRA has become a regular displayer at national police meetings, specifically the International Association of Chiefs of Police (IACP), the National Sheriffs' Association (NSA) and the National Fraternal Order of Police (NFOP). In this way we are reaching state and city police chiefs (IACP), county sheriffs (NSA) and the officer on the street (NFOP). The first two of these are annual meetings. The NFOP meets every two years. OLI often participates with FRA, sharing space and jointly manning our displays.

FRA has requested $82,000 for FY95 with which to conduct a study of the demographics of trespasser fatalities and potential counter measures. This research will start with a survey and determination of the types of individuals and activities which are involved or result in trespasser casualties.

5. Vandalism

Railroads are reporting nearly 200 incidents per month of vandalism to automated warning devices at highway-rail crossings. This figure does not include vandalism caused damage to other railroad facilities, equipment and lading. Various provisions of Federal law address crimes directed at railroad equipment, passengers and employees. See 18 U.S.C. 1991 (entering a train to commit a crime), 18 U.S.C. 1992 (wrecking trains), and 15 U.S.C. 1281 (destruction of property moving in interstate commerce). While in many instances, vandalism to warning devices at highway-rail crossings may be considered to be within the scope of one of the above statutes, there is no Federal statute dealing directly with vandalism of these devices. Many states have similar statutes.

6. Railroads and others

Several railroads have initiated, or are in the process of establishing, activities of their own. In 1992, the Long Island Railroad successfully involved communities in an aggressive campaign to reach potential trespassers and law enforcement officials with effective warning messages. In 1991, twelve railroads in the U.S. southwest teamed together with the U.S. Immigration and Naturalization Service, the Drug Enforcement Agency, the U.S. Border Patrol, the U.S. Customs, and the U.S. Army in a successful interdiction effort, apprehending over 12,000 illegal immigrants and seizing 1,200 pounds of marijuana and cocaine. Norfolk-Southern Corporation is currently preparing a video on trespassers and vandalism which will be compatible with the planned OLI campaign.

A 1990 Florida statute limits liability of railroads and landowners concerning trespasser deaths and injuries. The statute grants immunity in those situations where the trespasser was impaired by alcohol (.10 bac or higher) or illegal chemical substances at the time of the accident.

Appendix D

Driver (public) Education Papers

Research on Driver Education Regarding Highway-Rail Crossings: An Overview

By: John Killpack
Global Exchange

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Research on Driver Education Regarding Highway-Rail Crossings: An Overview

As research has been conducted to determine methods of reducing the incidence of highway-rail grade crossing crashes, a common result, whether the study addressed enforcement, human factors or crossing improvements, has been a further demonstration of the need for effective driver education. But actual research on the most effective means of educating drivers on their responsibilities in avoiding crashes at crossings has been limited.

Various studies have demonstrated that:

- Many drivers do not correctly understand the stopping distance required by trains;
- Many are not confident regarding the correct behavior for drivers at crossings;
- Many do not consistently understand the train operator's limitations in avoiding a crash;
- Many do not understand the most effective means of detecting the potential approach of a train at a crossing;
- Many are overconfident in their ability to correctly judge distances, and closing rates of approaching trains;
- Many do not understand the hazards associated with multiple track crossings;
- Many underestimate the potential risks associated with ignoring both active and passive warning devices;
- Many believe that crossings without active warning devices are no longer in use;
- Many are overconfident in their familiarity with crossings they negotiate regularly;
- Many overestimate the delays that result from waiting for a train to pass through a crossing; and,
- Many fall prey to peer pressure to take what they believe to be well-calculated risks in ignoring traffic control devices

While there is little debate regarding the need for more comprehensive driver education on highway-rail grade crossing safety, the few studies that have evaluated the effects of driver education programs have failed to demonstrate any positive correlation between safe driver behavior at crossings and the driver's understanding of the crossing environment, the properties of approaching trains and driver responsibility.

Many of the driver lapses outlined above are not unique to highway-rail grade crossings. Red light runners and speeders have the same impatience with traffic control devices and regulations; drivers who fail to wear their seat belts or who drink and drive underestimate the risks associated with their behaviors; and, drivers who run red lights believe that they have a special understanding of the patterns of the lights they pass through regularly. Some of these behaviors, such as seat belt use and drinking and driving have been successfully influenced through a combination of consistent education and enforcement; and, efforts continue to address red light running and speeding, with some demonstrated success.

The U.S. Department of Transportation in partnership with Operation Lifesaver has recently launched a comprehensive new campaign to educate drivers on highway-rail grade crossing safety. As part of the campaign's development, a limited focus group study was conducted to better understand driver perceptions, beliefs and attitudes regarding their responsibility at crossings, and their understanding of the highway-rail crossing environment. The study was also designed to test potential campaign messages and creative executions.

Groups of young adults aged 17 to 20 and adults aged 30 to 50 were held in Baltimore, Maryland and Austin, Texas. Markets and specific study sites were selected based on their proximity to areas with a relatively high concentration of railroad crossings, and to provide some geographic diversity in the study. While the incidence of train-motor vehicle crashes and related deaths in the Baltimore area is fairly typical of the nation taken as whole, Texas and the Austin area have an above average incidence of crashes and related fatalities.

Among the characteristics used to screen drivers for participation in the groups were: frequency of passing through highway-rail crossings (at least three times a week as a part of their regular travels); a mix of drivers based on regular crossing at active and passive sites; and, approximately 50 percent of group members had been cited for a moving traffic violation within the past three years. Groups were nearly equally divided based on sex.

Topics Discussed in the Focus Groups

Each of the focus group sessions consisted of three parts:

> A preliminary discussion of perceptions, attitudes and experiences regarding highway-rail grade crossings and crossing warning devices;

A review of five potential public information and education campaign message statements; and

A review of three television public service announcements in story board form.

Perceptions, Attitudes and Experiences Regarding Highway-Rail Grade Crossings
To gain a better understanding of the group members' awareness of, attitudes toward and experiences with highway-rail grade crossings (or 'railroad crossings' as they were described for ease of discussion) each group started with a preliminary discussion that focused on: group members' descriptions of different kinds of crossings and the attributes that make them different; aided and unaided discussion of the different types of warning devices used at crossings; the incidence with which typical drivers are confronted with a train at a crossing; perceptions of how long it takes for a train to go through a crossing; how fast trains are typically going when they pass through crossings; what the proper action for the motorist is at active and passive crossings when trains are and are not present; perceptions regarding general motorist compliance with crossing warning devices; and discussion of any instances when it is acceptable to ignore warning devices at a railroad crossing.

Following the introductory discussion, the moderator told the group that hundreds of people are killed each year in train-motor vehicle crashes and asked then asked: what can be done to make crossings safer; who's responsibility it is to yield at a crossing (the motorist or the train operator); if it is possible for the motorist to tell how fast a train is moving; and how long it takes the typical train to stop.

Review of Campaign Messages After the general preliminary discussion, group members were asked to evaluate five potential campaign messages for clarity, believability and whether they could potentially influence driver behavior at highway-rail grade crossings. In each instance, the message was shown and read by the moderator and group members were asked to provide their reactions to each on a scoring sheet provided prior to general discussion. The order in which the messages were presented was varied from group to group in an attempt to avoid any biases based on order of presentation. Following the presentation and discussion of the prepared messages, the group was asked for any ideas for messages that they believed could be more effective than those presented.

The messages presented were designed to deal with five broad issues:

That trains are unable to stop quickly;

That trains are often moving faster than they appear to be;

That trains take up to a mile and a half to stop on average;

That a car will always lose in a car-train collision; and

And that warning signs can save lives.

In general the respondents had a difficult time understanding the concept of a campaign message and reacted to the statements presented as if they were advertising headlines.

<u>Review of Public Service Announcement Concepts</u> Following the discussion of the potential message statements, group members were asked to review preliminary concepts for three different television public service announcements in storyboard form. To help the groups better understand how a storyboard relates to a finished television spot, a storyboard and the corresponding finished commercial for a spot unrelated to the current study were shown.

Group members were then asked to evaluate three storyboards for clarity, believability and whether they believed that they could potentially influence driver behavior at highway-rail grade crossings. In each instance, the storyboard was shown and read by the moderator with an explanation of the action, sound effects and production techniques, and group members were asked to provide their reactions to each on a scoring sheet provided prior to general discussion. The order in which the storyboards were presented was varied from group to group in an attempt to avoid any biases based on order of exposure. Following the presentation and discussion of the prepared concepts, the group was asked for any ideas for spots that they believed could be more effective than those shown.

The public service announcement concepts presented dealt with three separate issues: the force of trains and the implications for car-train crashes; the inability of drivers to correctly judge distances and closing rates of trains approaching crossings; and, the third-party (train operator) emotional devastation that can result from a car-train crash.

Although reactions varied significantly from group to group, clear trends emerged over the four groups.

Findings
The study findings confirm many of the behaviors and perceptions documented in earlier, quantitative work. The results of the focus groups indicate that motorists are confident in their knowledge of train behavior and their ability to safely navigate highway-rail grade crossings. For the most part they are unaware of the frequency of the car-train crashes that occur at crossings.

A significant portion of the respondents are not confident in the accuracy of crossing warning devices, and prefer to rely instead on their experience and their senses for cues on when it is safe to cross the tracks. Based on the group discussions, it is not unusual for motorists in all demographic groups to drive around activated crossing gates.

Communication message statements and public service announcement concepts presented to the groups met with mixed reactions. Overall the group members favor an emotional communication approach that focuses on the broad consequences of unsafe behavior at crossings (although ignoring warning signals is clearly not considered to be unsafe by a significant portion of the respondents). Some group members, particularly younger drivers are not confident in their understanding of the proper approach to crossings, and will benefit from further education.

Conclusions and Recommendations

Conclusions

Respondents for the most part have a good working familiarity with trains, highway-rail grade crossings, and the warning devices used to mark crossings, and are confident in their ability to cross railroad tracks safely.

A subgroup of young drivers, which appears to be subject to peer pressure, is unsure of the proper behavior at crossings, and is looking for clear direction on the "right thing to do."

Potential change motivators tested in the groups: the potentially misjudged speed of trains; the stopping distance required by trains; and the severity of the consequences of a car-train crash for the occupants of the car, are well known and as a result are not likely to cause significant change among drivers at railroad crossings.

The frequency of car-train crashes (every 90 minutes) does appear to be new information for many drivers and may be effective in influencing behavior.

A significant portion of the respondents believe that railroad crossing warning devices are set incorrectly (trigger too far in advance of a train passing through the crossing and remain active too long past the crossing event) and malfunction frequently. As a result, although the devices can be seen as a cue for cautious behavior, the respondents for the most part do not rely on them in making decisions regarding crossing the tracks.

Based on the groups conducted, driving around activated crossing gates appears to be a common occurrence without regard to age, sex or socio-economic status.

Although there is some dissension, for the most part drivers recognize that crossing safely at a highway-rail grade crossing is the responsibility of the motorist, not the train operator. (Respondents do believe that there are physical changes that could be made to make highway-rail grade crossings safer.)

Respondents believe that communication focusing on pain and suffering caused to friends, relatives and others (both those killed and injured and those left behind) will be more effective in influencing behavior than those focusing on the consequences for the driver.

Emotional communications, as characterized by one of the public service announcements presented in the groups, appear to have the greatest potential for influencing driver behavior at crossings. Some of the strength of the emotional concept appears to be derived from its implication of harm to others resulting from careless driver behavior.

<u>Recommendations</u>
Use emotional executions to dramatize the consequences of inappropriate driver behaviors at crossings.

Avoid executions that convey the message that drivers should "obey railroad crossing warning signals," which will not be effective at this time.

Develop new public service announcement executions that recognize peer pressure and exploit "obligation to friends" concern to reach young drivers. Provide this group with explicit instructions on how to react at a crossing.

Highlight the frequency of car-train crashes (every 90 minutes) in communications.

Develop long term strategies to create objective mechanisms to certify accuracy of warning devices, and based on that certification, develop communications to build motorist awareness of signal accuracy.

Develop updated educational materials aimed at young drivers to clarify the proper response at highway-rail grade crossings.

The campaign created based on this qualitative study is currently in distribution. While use of, and driver exposure to, the campaign is being measured, no follow-up study has been planned to date to measure any correlation between exposure to the messages and actual driver behavior.

Driver Education Curriculum on Highway-Rail Crossings

By: Barbara Brody

Although there has been some research on the effectiveness of Driver Education, there is no research on the correlation between a driver's understanding of the crossing grades, crossing environment and responsibility and driver education. There has never been any research done on what effective railroad crossing message or material works for the novice driver.

Over the last 10 years Driver Education has gone from a school based course to private schools which in turn has changed from being part of the educational system to a business. The amount of time spend on subjects like railroad crossing grades is usually at the discretion of the instructor. Most private schools and public schools do not budget money on spending for railroad crossing material. Over the last 10 years most money has gone for programming in the area of occupant restraint and alcohol and drug impaired driving.

Our biggest resource both from an informational and material standpoint is Operation Lifesaver. By far the states that have an active state organization have an active educational component. Operation Lifesaver provides material for the primary student, middle grade student and high school student. Materials available for schools are such things as pins, hats, coloring books, and educational videos. Most high schools use the video "Why Wait" as part of their high school curriculum. Unfortunately the materials from Operation Lifesaver is not free and if you come from a state that does not have either an active organization or the state organization does not have funds then the schools have to pay for the materials. If railroad crossing grades are not a high priority in your district than chances are you do not spend money on material. I urge us to find ways to fund railroad grade crossing material to every school that has a traffic safety component.

When we teach the novice driver we need to teach as though the student will be involved in a railroad crossing grade sometime during their driving career. We must teach anytime is train time, always expect a train. We also must utilize Operation Lifesaver's speakers bureau. This is a free service and I feel very worthwhile. I would urge Operation Lifesaver not only to train speakers to speak in front of high school students but to also be able to speak in front of primary students as well. Speaking to first and second graders takes a special talent and special training.

Through student surveys we know that seeing something hands-on has the most lasting educational effect on students. Therefore having a mock train crash is the most effective educational tool we can offer our students. Unfortunately this is not easy to do. Bringing students to a railroad crossing grade and watching the impact a train has when it hits a car, seeing their friends badly injured or dead, and seeing the rescue squads working to save their friends may not be very feasible in most places. But a well worth project if it can be arrange.

Why are teenagers involved in train collisions? There are many reasons for this. Teens like to take risks. Beating the train is a high risk dare. We know that teens take more risks when they are with other teens than when they are driving by themselves or with adults. We know teens take more risks when they are under the influence of alcohol and other drugs. We know that judgement and loss of inhibitions occur after only one or two drinks. We know that teens tend to drive faster when under the influence of alcohol. We also know that most of the time teens drive over railroad crossings without ever seeing a train and when they do not expect one a train appears. They have been driving through the train intersection so many times when no train has appeared that they unconsciously drive through the crossing. Then on a given day they enter the intersection when a train appears and they do not have the concept to remember that by the time the conductor sees you entering the tracks he cannot stop.

I have taught over 1000 students to drive yet even though we have two crossings near by I have never had the hands on opportunity to have one of my students actually enter the railroad crossing and experience the red lights going and the gates down.

What can be done to help educate the novice driver? Obviously putting railroad crossing grade education material in every driver education course is a start. We know that our youths have interacted with the rail crossing far early than their driving age. Many youths have walked on the rails or drove their bikes, snowmobiles, or ATV's during their primary years. Having railroad grade crossing education in the primary grades is very important. One of the reasons seatbelt usage has increased over the last five years is because the primary age group has been educated to buckle-up and in turn they remind their parents to do the same. The seatbelt message has used a comprehensive approach. You see it, hear it, and use it every time you are in a car. A more comprehensive approach should be used concerning railroad crossing grades. More PSA's should be on TV and the radio. More posters should be available to put up in schools, community centers, and on billboards in areas that have many train crossings. We must have law enforcement give tickets to individuals early. If they are breaking the law on their bikes or as pedestrians they need not a warning but a consequence. Studies have shown that if young people get caught and have consequences given to them early, they are less likely to break the same law. However, studies have shown most teens believe they will never get caught and if they get caught the consequences are so light they do not feel it is a deterrent for them.

We also must have better role models for our youths. If young people see their parents illegally crossing railroad grades that leaves a lasting impression that totally negates any thing they learned in school. As adolescents the message is simple. You can cross illegally and not get caught or hurt. The railroad crossing lights and gates are only a warning and not a regulatory message as they should be.

We know that most train collisions involving teens happens with more than two teens in a vehicle. We should be supportive of the gradual licensing system that is being studied throughout the country, New Zealand and the province of Ontario. The gradual licensing system supports such things as night curfews, limited numbers of teens in a car, parent involvement and training.

In closing we cannot expect Driver Education to teach about railroad crossing grades alone. It must be part of an educational comprehensive approach that starts early on in school, enforced by good parent role modeling, constant reminders through PSA's and other visual means, as well as law enforcement taking an active preventive approach. This combination has worked well with bringing the seatbelt usage way up and reducing drinking and driving fatalities. We must look at the potential of a gradual licensing system and phase in some of its components early on.

Appendix E

Enforcement Papers

Highway-Railroad
Grade Crossing Research Needs Workshop

ENFORCEMENT
HISTORICAL PERSPECTIVE

By: Yvonne M. Shull
National Highway Traffic Safety Administration

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THE ROLE OF LAW ENFORCEMENT

IN

HIGHWAY-RAILROAD GRADE CROSSING

In 1994, over 6,000 people were hit by trains. Some were in their cars or trucks. Others were on foot. Almost every one had ignored warning signs or signals, or trespassed on railroad property. Over 3,500 of these people were killed or maimed for life. The tragic waste of life continues even as you read this; almost every 90 minutes in America, a driver who fails to yield at a highway-rail crossing is hit by a train. Law enforcement agencies must play a significant role in the enforcement of these violations to reduce the number of Americans killed or injured at highway-railroad grade crossings.

Historical Perspective

Railroad transportation in the United States had its beginning during the 1830's and became a major factor in accelerating the great westward expansion of this country. The railroad provided a reliable, economical and rapid method of transportation. Initially, safety at railroad grade crossings was not considered a problem. Trains were few and slow, as were highway travelers who were usually on foot, horseback, horse-drawn vehicles, or cycles. In the early 1900's with the invention of the automobile, railroad-highway grade crossing safety became more of a concern. The number of grade crossings grew with the growth in highway miles to support the mobility of the automobile. In most cities and towns, the grid method of laying out streets was used, particularly in the Midwest and the west. This provided for a railroad-highway grade crossing for every street in that grid that intersected with the railroad.

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A majority of the railroad-highway grade crossings are along rural and local roadways. In these areas, the Office of the Sheriff generally has the primary responsibility for traffic enforcement. Historically, it has been considered unpopular for an elected official such as the Sheriff to strictly enforce traffic violations. So, in many areas the right of way violations at railroad-highway grade crossings have been overlooked. Enforcement action was only taken on flagrant violations committed in the presence of an officer.

In order to reduce the number of right of way violations, injuries, and deaths along railroad-highway crossings. An aggressive, systematic traffic safety program must be designed and implemented across the country. Law enforcement agencies are an essential element in this program, and must play a major role in the safety effort.

Elements of a Traffic Safety Program

For many years, the National Highway Traffic Safety Administration has been developing and implementing successful traffic safety programs. These programs were used to combat the problems of drinking and driving and other unsafe driving behavior, and to increase the usage of occupant protection systems. The programs are based on the principles of education, enforcement, and engineering, or the three E's. Any comprehensive traffic safety program including railroad-highway grade crossing can be based upon these principles. Law enforcement can play an important role in each of the three E's.

Education

The education aspect of law enforcements role in highway railroad grade crossings can be broken into two sections. The first is the education of the officers. Every officer must be educated about the railroad and its unique environment. By educating the officers, they will then understand the danger of railroad highway grade crossing, and be more aware of the violations when they occur. An additional benefit of educating the officers, is they are generally the first line of education and defense for the public. Many times, law enforcement officers are present when the violation occurs or the first to contact a violator that has been reported. These officers cannot only take appropriate enforcement action for the violation, but they can also educate the violator during this initial contact.

The second role law enforcement agencies have in the education aspect of traffic safety is to be a partner with all other safety advocates. Agencies should support public information and education programs. Strong public information and education programs in the area of seat belt use and drinking and driving have proven to be very effective.

Enforcement

Law enforcement agencies will be the key component in all enforcement activities. Therefore, they should be included in all planning and implementation stages of a highway-railroad crossing safety program. To encourage consistent enforcement of crossing violations, a model policy and procedure for highway railroad grade crossing enforcement are helpful. The model policy and procedure allow law enforcement leaders to easily incorporate this program into their routine enforcement strategies. The combination of officer training and model enforcement policies and procedures should increase the officer's awareness to the problem. They will also provide strategies to effectively combat the problem and guidance for the appropriate enforcement action.

Engineering

Law enforcement will play a very limited role in the engineering aspect of highway-railroad grade crossing safety. Although limited, their role is extremely important. The officers on routine patrol are generally the first to receive the call of problems at a crossing. They must be trained to recognize malfunctioning signal equipment and the proper notification procedure to assure the timely repair of the signaling devices. Most officers patrol the same area each day. It is important they realize their duty to be wary of any changing conditions at the crossings in their area. Items such as overgrown brush or trees, advertisement signs, or any other condition may block the drivers vision or reduce the sight distance. These conditions must be reported and repaired to insure the original design of the crossing remain the same.

Summary

Historically, law enforcement agencies have done little or no enforcement of highway railroad grade crossing violations. With the increasing number of light rail systems in congested urban areas the issue of safety at highway-railroad crossings must be addressed. All law enforcement leaders need to assure that highway-railroad crossings are part of the routine traffic enforcement of their agency.

Captain Les Reel
Ohio State Highway Patrol

Appointed May 11, 1973

Assignments:

Trooper, Wilmington
1973-1981

Sergeant/Assistant Post Commander, Chillicothe
1981-1985

Lieutenant/Post Commander, Hamilton/Cincinnati
1985-1987

Staff Lieutenant/Assistant District Commander, Central Ohio
1987-1990

Staff Lieutenant/Assistant District Commander, Southwest Ohio
1990-1993

Captain/Executive Officer of Statewide Operations
1993 to present

Southern Police Institute - Graduated 1989

Captain Reel has worked with Operation Lifesaver since 1985. He can be contacted at the Ohio State Highway Patrol Operations section at (614) 466-2300 or by mail at 660 East Main Street, Columbus, Ohio 43205.

Ohio's Operation Lifesaver Program

Successful? Effective?

You be the judge.

	1990	1991	1992	1993	1994
Crashes	311	311	263	254	214
Deaths	60	55	45	42	37
Injuries	139	121	84	89	76

Change from 1993 to 1994

Crashes	-16%
Deaths	-12%
Injuries	-15%

Change from 1990 to 1994

Crashes	-31%
Deaths	-39%
Injuries	-45%

Ohio has experienced a consistent decrease in railway associated incidents even though rail traffic has increased, the number of licensed drivers has increased, and the number of vehicle miles driven has increased.

Note: These statistics reflect train/vehicle and train/pedestrian crashes at public grade crossings only. Incidents related to trespassers, private crossings, or suicides are not included.

Ohio's Operation Lifesaver Program
Keys to Success

1. An Effective State Coordinator

2. Multi-Agency, Multi-County, Multi-Rail Enforcement Efforts

   <u>Media</u>, <u>Media</u>, <u>Media</u>

3. Trespass Issues

4. Legislation - "Wallet Syndrome"

5. Crossbuck Upgrading

6. Crash Statistics - Target Appropriate Violators

Ohio's Operation Lifesaver Program
Keys to Success

1. An Effective State Coordinator

The coordinator must be energetic, enthusiastic, and believe in the program.

A traffic law enforcement background opens the door to getting many police agencies involved. A civilian might encounter resistance.

Knowledge and empathy of problems encountered by police agencies participating in special enforcement efforts has enhanced the program.

The coordinator recognizes the importance of the "3 Es," but emphasizes enforcement as the catalyst of the three. Often the most effective way to gain compliance is through the wallet.

Believes strongly in use of media before and after an enforcement event. Public awareness is paramount.

2. Cooperative Multi-Agency, Multi-County, Multi-Rail Enforcement Efforts

Sharing of personnel and equipment by law enforcement and rail systems is vital in the prevailing cutback economy.

Media participation is the key to educating the public about the dangers of rail crossing accidents. Remember, the size of the effort often dictates the amount of media coverage received.

An example of an "officer on a train" event that originated in the Hamilton County area involved the following agencies:

Law Enforcement

Ohio State Highway Patrol (lead agency). Provided aircraft for surveillance and enforcement for all agencies.

Hamilton County Sheriff's Department
Butler County Sheriff's Department
Preble County Sheriff's Department
Sharonville Police Department
Union Township Police Department
Hamilton City Police Department
Middletown City Police Department
Eaton City Police Department
CSX Police Department (simultaneously utilized trains
Norfolk Southern Police Department from both rail systems)

Media
Cincinnati Enquirer
Hamilton Journal
Middletown Gazette
Dayton Daily News
Channel 5 (Cincinnati)
Channel 9 (Cincinnati)
Channel 12 (Cincinnati)
Channel 2 (Dayton)
Channel 7 (Dayton)
several radio stations

Courts
Some judges and prosecutors were invited to observe the enforcement effort to give them a first hand look at the problems.

Note: 402 funds were obtained to assist with Operation Lifesaver program in 1993. In fiscal 1995, 402 funds will be used to develop a roll call training video for law enforcement officers. This tape will emphasize rail crossing enforcement techniques.

The following two pages include a basic Operations Plan and an Activity Recap sheet to be completed by each participating law enforcement agency and faxed to a central location for tabulation. After tabulation, this information is released to the media along with any special interest stories.

Officer on a Train Event Operations Plan

Date of event:

Railroads involved:

Program coordinator (police):

Program coordinator (railroad):

Starting locations and times:

Terminating locations and times:

Train routing and timetable (refer to track charts):

Police departments involved:

	Agency Name	Contact	Telephone
1			
2			
3			
4			
5			
6			

Assignment of grade crossing coverage by police department:

Officer to ride locomotive:

Officer observer in aircraft:

Radio communication channel:

Enforcement activity recap coordinator (refer to recap forms):

Names and locations of media involved:

Other discussion items:

Officer on a Train Event
Activity Recap

Date of event: ____________________

Police agency reporting: ______________________________________

________ Total officers participating (enforcement only)

________ Total highway/rail grade crossings monitored

________ Total grade crossing violations observed

________ Total grade crossing violators apprehended

________ Total grade crossing violation citations issued

________ Total grade crossing violation warnings issued

________ Total other type citations issued

Remarks: ____

____

____

____

Please telephone or fax this recap to <u>(name of activity recap coordinator)</u> at <u>(telephone and fax numbers)</u> no later than <u>(time and date activity recap is due)</u>.

Officer on a Train Event

Meet with "operational" personnel from all participating agencies, including rail officials, to schedule and plan event.

Without trains, the event won't happen.

Select a lead agency where a "command post" for the detail will be established.

Assign an "operational officer" from the lead agency and each rail system involved to remain at the command post during the event. It is the responsibility of these individuals to assure that enforcement officers are kept appraised of train locations. (Multiple trains from different rail systems may be used. Officers travel from one track to another as needed.)

While not necessary, aircraft is a tremendous advantage to officers on the ground.

Designate a press information officer to act as liaison with local media. All media releases for the group should go through this press information officer.

Railroad officials should commit special trains for the detail in addition to normal train traffic. Scheduling trains is vital to having enforcement officers in position. Interceptors must be kept advised of times of arrival.

Room should be reserved on one of the trains for public officials, members of the media, and members of special interest groups. Cameras are routinely used on the engine to transmit a picture of crossing violators back to the passenger cars. The media often use this tape on local news broadcast to emphasize the problem.

Approximately three days prior to the event, provide crash statistics and other pertinent information to the media as a "teaser."

On the day of the event, invite the media to a combined briefing and news release.

It is important to cover as many crossings as possible with "interceptor" units.

Officers assigned to rail crossings should not consider this a "covert" detail, however, should position their patrol cars at a distance from the crossing to allow motorists to react as though no officers were present.

Motorists who violate the crossing laws are to be stopped and either warned or cited. Enforcement action should be taken on any other violations when appropriate, such as no operators license, DUI, no seat belt, and major vehicle defects.

At the completion of the enforcement effort, all participating agencies will tabulate total arrest figures to the "lead agency command post." The information will be immediately provided to all available media.

This follow-up media effort is critical to voluntary compliance and the reduction of crossing crashes. Motorists will be more aware of the inherent dangers of crossing infractions and next time a train approaches they will ask themselves, "Is there an officer on that engine?"

While this type of enforcement seems primitive to some, combined with education and engineering, is extremely effective.

3. Trespass Issues

Another area of major concern is the trespass violation. Trespass violations account for nearly as many deaths as crossing violations. In Ohio, rail systems began compiling information on these infractions and have challenged one another to curb them through enforcement. The networking of such information will be useful to police officers and rail systems.

4. Legislation

As previously stated, compliance with traffic laws is often directly related to the costs associated with a citation. Legislation is about to be introduced to increase the penalty for crossing violations. The penalty should fit the violation.

Certainly, a train derailment could result in extensive property damage and multiple deaths. A train transporting even one car load of hazardous material may cause massive evacuations of residents and businesses.

Committees are working on legislation to increase rail trespass penalties as well.

Other states are encouraged to seek similar legislation.

5. Buckeye Crossbuck Upgrading

The crossbuck upgrading project has been in motion since 1992. Conrail has replaced all of the crossbucks at their crossings and other systems should complete replacements in 1995. Research will be conducted (tentatively in 1996) to measure the effectiveness of the larger, reflective style signs once all of the 3,750 crossings in Ohio have been upgraded.

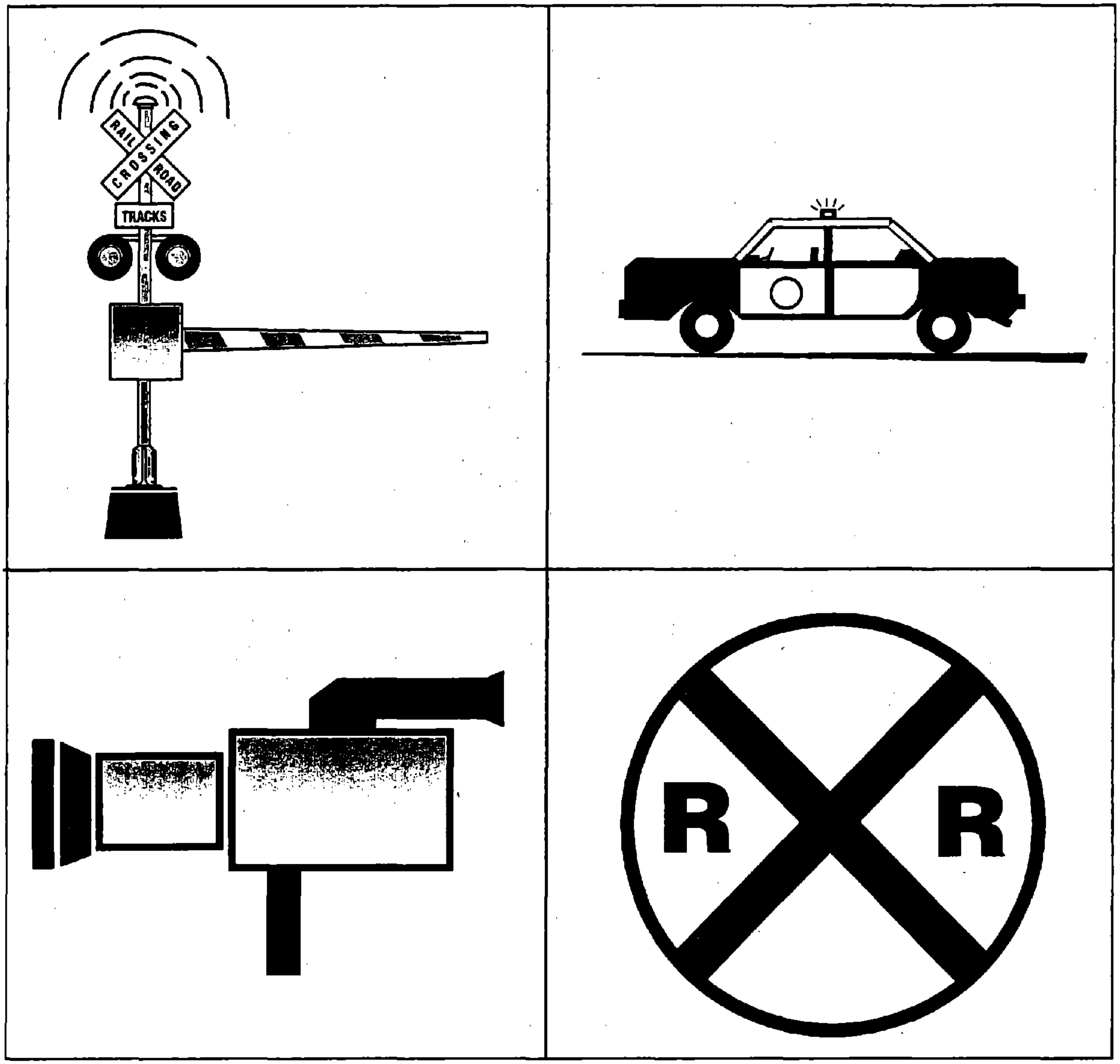
The highly visible warning devices may also encourage law officers to more strictly enforce crossing violations.

6. Crash Statistics and Research

All states are encouraged to compile crash statistics and determine who is injured and killed at crossings. Statistics should be used to effectively direct education efforts.

Rail crossing injuries and deaths are the most preventable of all traffic injuries and deaths. Do not underestimate the importance of your efforts or the impact you make. Persistence, zest, enthusiasm, and aggressive media efforts make a difference.

LOS ANGELES
METRO BLUE LINE ENFORCEMENT PROGRAM



By:

Lou Hubaud, Director of Safety Management
Metropolitan Transportation Authority
Los Angeles, CA
(213) 244-6468

and

Linda Meadow, Systems Safety Manager
Metropolitan Transportation Authority
Los Angeles, CA
244-6419

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LOS ANGELES METRO BLUE LINE ENFORCEMENT PROGRAM

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LIST OF FIGURES

1.0 INTRODUCTION

Operation of Light Rail Transit (LRT) in urban shared right-of-way attracts ridership, and is a lower cost solution to transit. However it introduces the potential for collisions to occur between motorists, pedestrians or bicyclists and the train. The Institute of Transportation Engineers (ITE) conducted a survey of 17 LRT properties concerning light rail safety concerns and problem areas. The most critical areas of concern identified by the survey respondents included:

- Motorists disobedience of traffic laws, specifically motorists running around closed crossing gates or making illegal turns in front of the train at intersections;
- Motorists confusion over traffic signals, light rail signals and signage at intersections;
- Pedestrian inattention or confusion at grade crossings and station areas.

Each of these problems has been experienced by the Los Angeles County Metropolitan Transportation Authority (MTA) at crossings on the 22-mile Metro Blue Line (MBL), as shown in Figure 1. This light rail line runs in downtown city streets and adjacent to Southern Pacific freight lines for 12 miles. The MBL has experienced over 250 train/vehicle and train/pedestrian collisions in over four years of MBL revenue operations (July 1990 - January 1995). The collisions have resulted in 27 fatalities and numerous injuries.

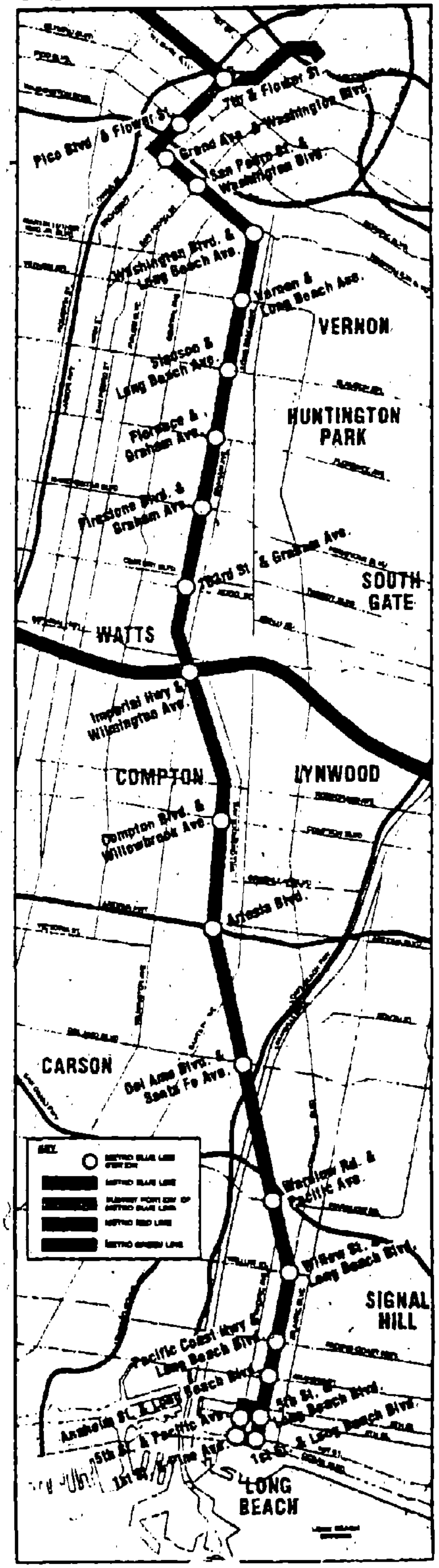
Public Perception of Grade Crossing Problem Areas

A key component to the design of any safety improvement program is to assess the attitude of the communities along the right of way towards the rail line. The MTA performed a bilingual (English and Spanish) survey or persons who live along the MBL and who use MBL grade crossings at least one time per week. Residents were asked to identify problem areas that affect safety at grade crossings.

- Drivers and pedestrians don't understand that Blue Line trains get to the intersection within 20 seconds after lights start flashing (80%)
- .Drivers trying to "beat the train" by driving around lowered crossing gates (76%)
- Southern Pacific's freight trains are long and slow (70%)
- Drivers and pedestrians don't understand that two, sometimes three, trains can go through an intersection at the same time (70%)
- Not enough barriers to keep pedestrians and children off the tracks (68%).

Metro Blue Line
Transit Stations

Figure 1



Los Angeles Metro Blue Line Grade Crossing Safety Program

To respond to these problems the Board of Directors of the MTA initiated the Metro Blue Line Grade Crossing Safety Program in March 1993. This program was designed to evaluate various means to discourage or prevent illegal movements being made by vehicles at grade crossings which are causing train/auto accidents. While the program is focused primarily on evaluating measures to decrease train/auto accidents, the safety program is also concerned with improvements that will reduce train/pedestrian accidents. The MTA is seeking to apply innovative equipment and methods developed for street and highway traffic applications. These engineering improvements will address the unique characteristics of MBL grade crossings and improve public safety.

The safety program includes four elements:

- *Enforcement* - using sheriff's deputies and photo enforcement systems.
- *Engineering*- including use of Intelligent Transportation Systems (ITS) technologies, warning devices, street and traffic signal improvements.
- *Legislation* - establish higher fines, return of fine revenues to transit authorities and statewide rail safety educational programs.
- *Education* - bilingual public information and safety education.

2.0 SHERIFF'S DEPUTIES ENFORCEMENT PROGRAM

From startup in July 1990 through June 1994, the MTA contracted with the Los Angeles County Sheriff's Department to provide police services for the MBL. Sheriff's deputies were highly visible on station platforms and riding trains. This high level of security served to discourage criminal activity on the trains and at the station areas and parking lots.

Starting in June 1992, for a 90 day demonstration period, the Sheriff's Transit Services Bureau established a traffic detail to provide for increased enforcement of traffic violations at selected grade crossings. Ten traffic detail deputies were deployed two shifts per day, seven days per week, for nearly 13 weeks. The traffic deputies wrote 7,760 citations in 90 days. Due to the success of the program, continuing funding for six deputies was authorized. These deputies issued over 14,000 citations under this effort.

Deputies obtained information from violators on a short survey questionnaire for a total of 1,500 violators. The responses, shown below, indicated that many of the violators were frequent users of the grade crossing.

Trip Purpose

40 percent - work/school
37 percent - leisure

Trip Frequency

63 percent - frequent users of mid-corridor crossings
45 percent - frequent users of street running locations

Reason for Violation

40 percent - "thought it was safe"
25 percent - "in a hurry"
28 percent - "didn't see signal"

3.0 PHOTO ENFORCEMENT DEMONSTRATION PROGRAM

To address the problem of motorists' disobedience of traffic laws (specifically going around grade crossing gates), the MTA conducted five demonstration projects involving the installation of photo enforcement systems at four grade crossings along the MBL.

Photo enforcement technologies have been used worldwide including the United States, Europe and Canada to capture speed and red light running violations. Photo radar techniques are commonly used for speed violations. The use of photo enforcement for speed and red light running violations has significantly reduced accident rates wherever it has been used.

Photo enforcement systems involve the use of high-resolution cameras to photograph violators and provide one or more photographs of the vehicle, its license plate, and the driver's face as the basis for issuing a citation. Superimposed onto each photograph is the date, time and location of the violation, as well as the speed of the violating vehicle and number of seconds of elapsed time since the red flashing lights were activated. At crossings with traffic signals, the number of seconds of amber and red signal time are shown.

The U.S. Department of Transportation funded an evaluation of the effectiveness of photo enforcement at MBL grade crossings. Funding participants include the Federal Railroad Administration, the Federal Highway Administration and the Federal Transit Administration.

Photo Enforcement Installation at Gated Crossings

The photo enforcement cameras are mounted in a bullet proof box on top of an 12 foot pole. A bilingual (English and Spanish) sign tells motorists that photo citations are issued to violators (see Figure 2). The camera, located on the southeast corner of the intersection, views the eastbound traffic lanes, monitoring through traffic and left turns from the parallel roadway. Inductive loop detectors buried in a shallow cutout in the road are used to detect the presence of a vehicle when the gate arms begin their descent. The typical configuration of photo enforcement equipment at a grade crossing is shown in Figure 3. When the violator's

Figure 2

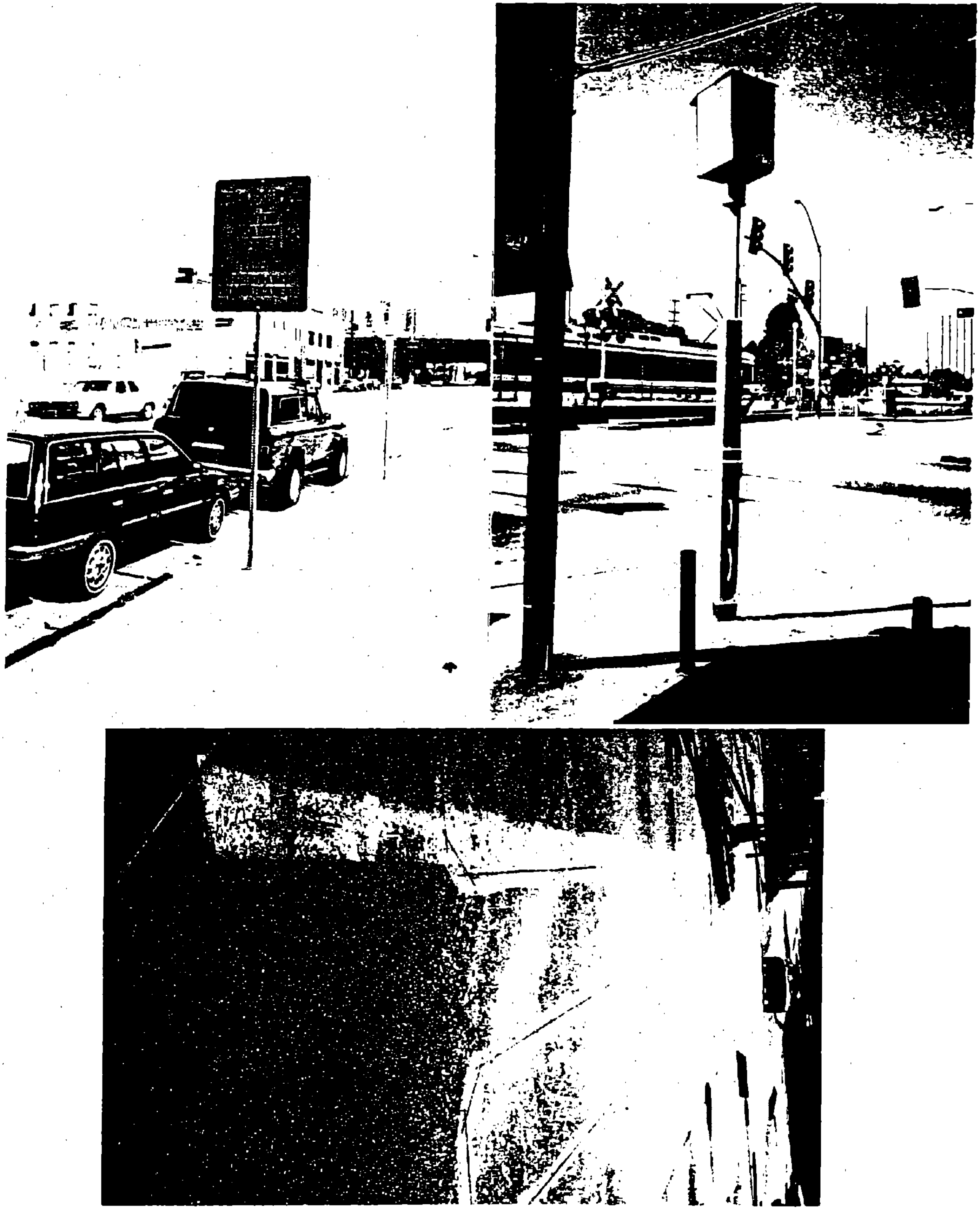


PHOTO ENFORCEMENT LOCATION

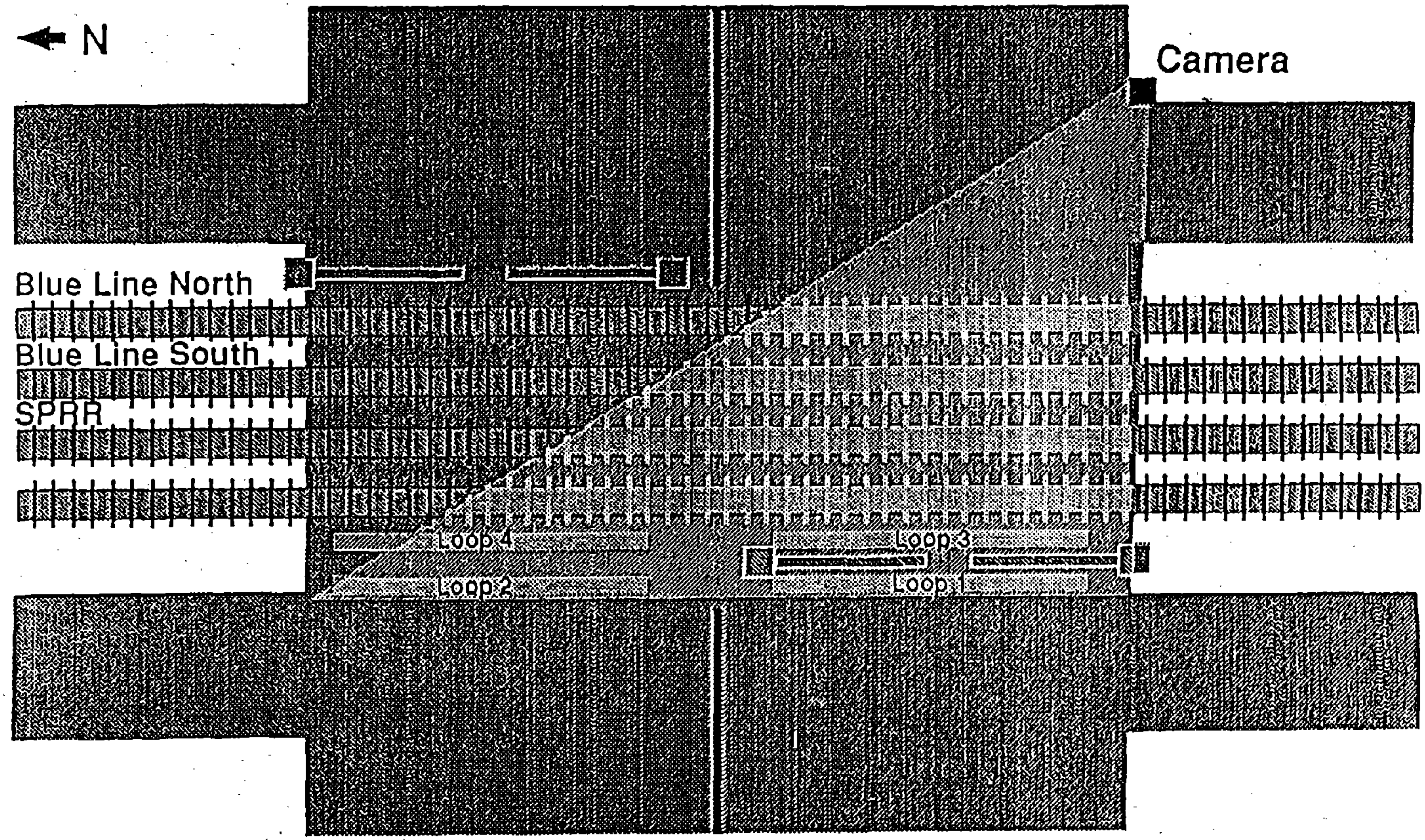


Figure 3

crosses the detection loops while the grade crossing signals (gate arms) are in operation, a photograph is taken with data superimposed. Then, approximately 1.2 seconds later, another photo is taken which shows the vehicle traversing the intersection (see Figure 4).

Film is sent to the vendor for processing as shown in Figure 5. The vendor develops the film, views each photo to see the license plate and image of the driver, and then runs a Department of Motor Vehicles check to determine the registered owner of the vehicle. A citation is printed in both English and Spanish and is sent to the registered owner. Citations are issued within 72 hours of the violation.

Photo Enforcement at Non-gated Crossings

At non-gated crossings, in street running segments, the camera photographs violators making left turns against a red light (red left turn arrow). Street running territory has traffic signals and light rail signals, but no rail crossing gates or other warning equipment.

At the intersection of Los Angeles Street and Washington Boulevard in the City of Los Angeles, inductive loop detectors have been cut into the street to detect automobiles making left turns against a red left arrow indication.

Results

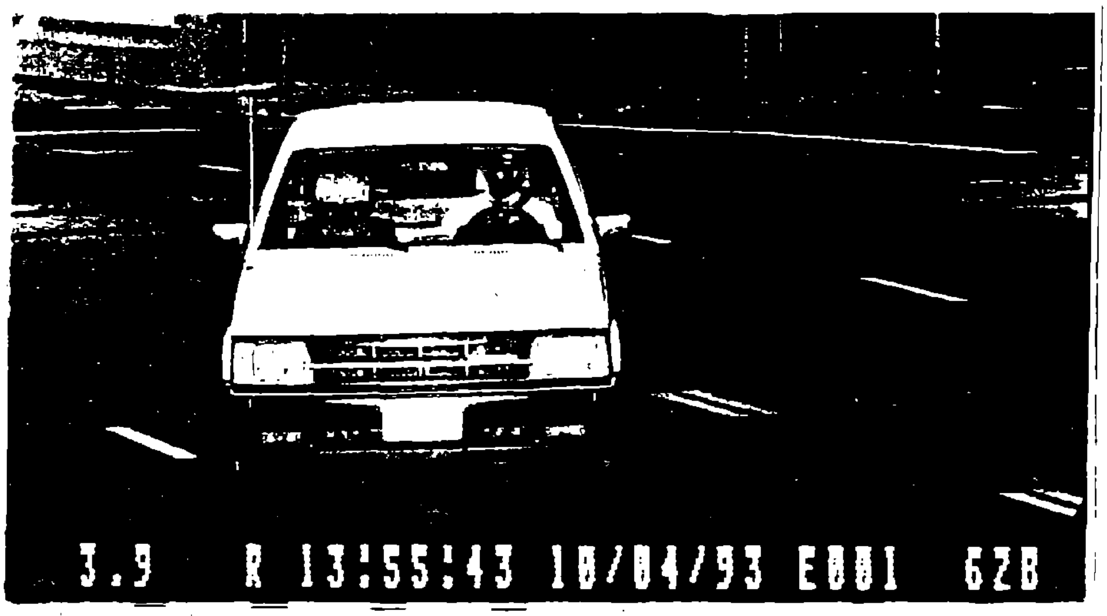
The photo enforcement program has been extremely successful in terms of reducing numbers of motorists who are violating grade crossings. Four photo enforcement demonstration projects were conducted. Two projects were located at gated crossings and two at non-gated crossings.

Gated Crossings

Compton Boulevard. This demonstration program was started on November 19, 1992. For the first two months, the camera equipment was operated at the two crossings in the City of Compton (Alondra Boulevard and Compton Boulevard, approximately 0.5 miles apart) where poles were installed without any press coverage, public announcements, or signs. During this period, counts were made of the number of violations to serve as a baseline for evaluating the effectiveness of the equipment.

On January 19, 1993, a press conference was held to announce the use of the equipment at the two crossings. Warnings were sent to motorists violating the crossing signals and gate arms when trains were approaching. Signs were installed at the crossing on February 11, 1993. On March 19, 1993 violators were issued citations. The four-month photo enforcement demonstration project at Compton Boulevard was completed July 19, 1993.

The demonstration project resulted in a 92% reduction in the number of violations occurring at the crossing, ending up at 0.15 violations per hour for the last two months of the project (see Figure 6). Citations were processed by the Compton Municipal Court. Over the four months


3.9 R 13:55:43 10/04/93 E001 628

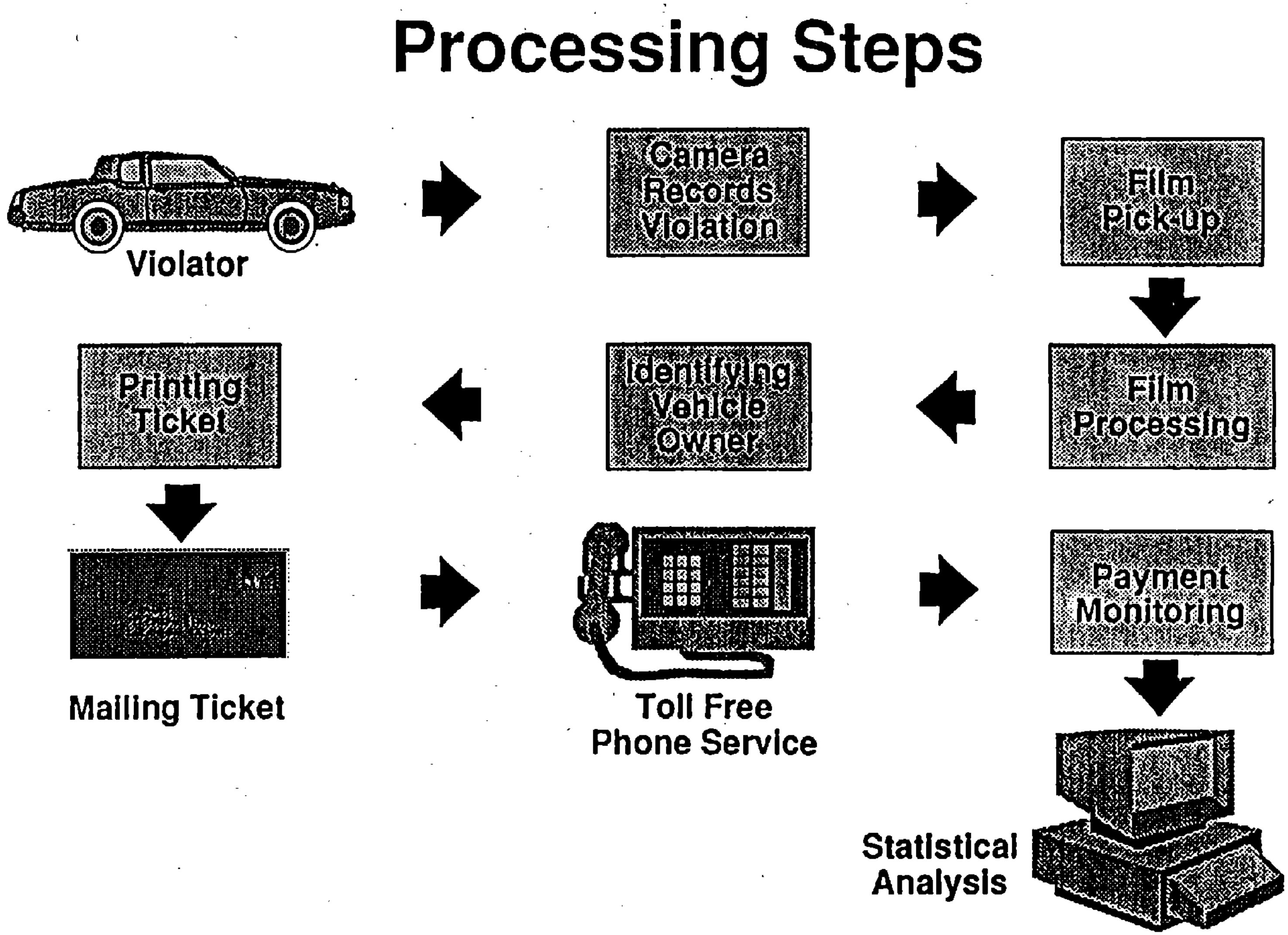
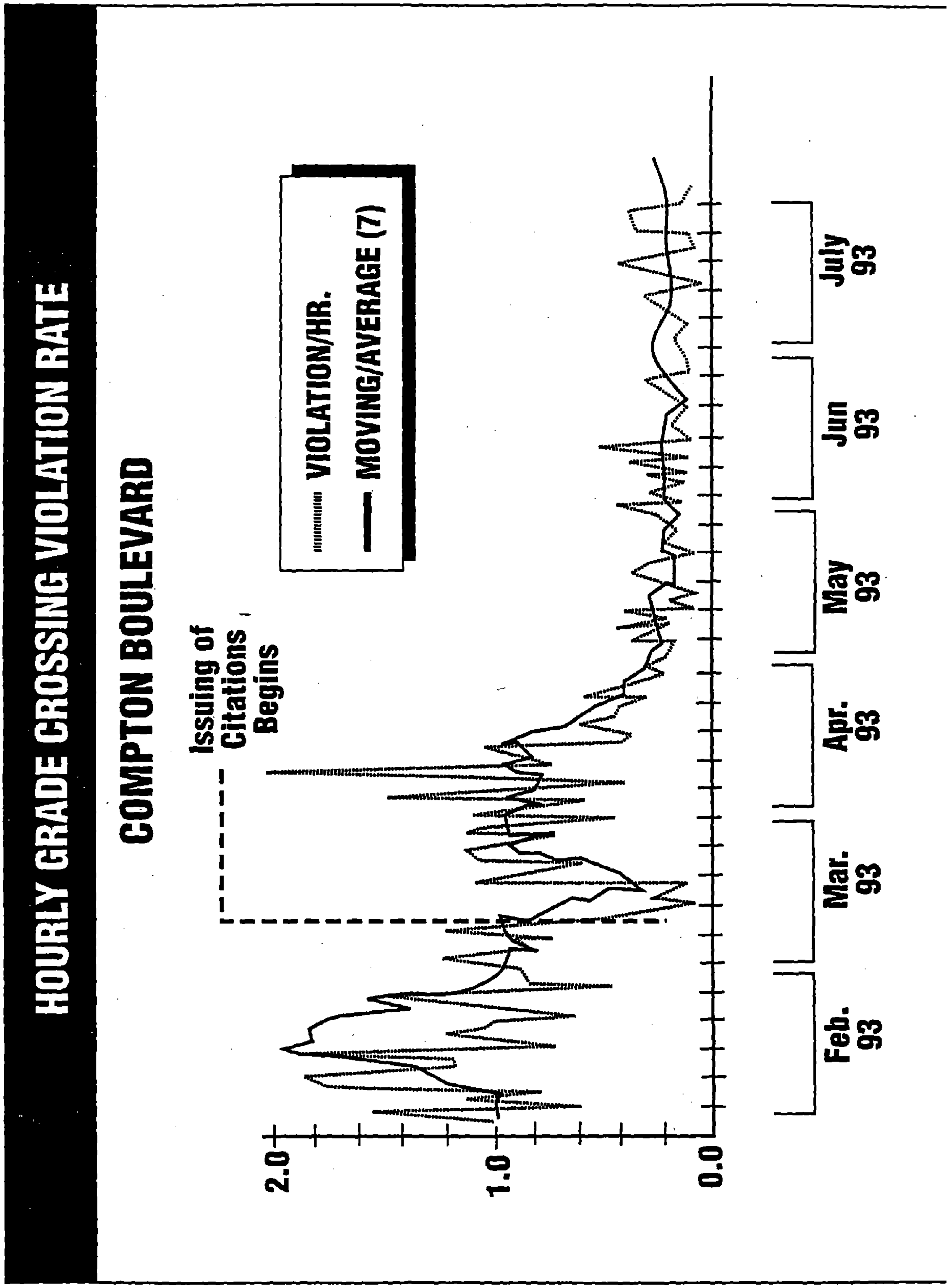

Processing Steps
Violator
Camera Records Violation
Film Pick-up
Film Processing
Identifying Vehicle Owner
Printing Ticket
Mailing Ticket
Toll Free Phone Service
Payment Monitoring
Statistical Analysis

Figure 5

Figure 6


HOURLY GRADE CROSSING VIOLATION RATE
COMPTON BOULEVARD
Issuing of Citations Begins
VIOLATION/HR.
MOVING/AVERAGE (7)
2.0
1.0
0.0
Feb. 93
Mar. 93
Apr. 93
May 93
Jun 93
July 93

of the demonstration project, 548 violations were recorded by the camera equipment at the crossing; 232 citations were issued to violators.

The camera equipment was reinstalled at Compton Boulevard on September 9 and left there through the end of September 1993 to determine if the violation rate had declined further. With a visible sign and camera box, but no citations issued, the violation rate declined to one violation every 12 hours (or .07 violations per hour).

Alondra Boulevard. A three-month demonstration project was completed at Alondra Boulevard on September 9, 1993. Signs, a camera pole and cabinet were installed for about six months at this location prior to citations being issued. Grade crossing violations dropped from 0.5 violations per hour in December 1992 to 0.16 violations per hour in September 1993 when the demonstration project was completed. The rate of violations had declined to approximately 0.28 violations per hour when citations were first issued in June 1993, indicating that a portion of the reduction in grade crossing violations could be attributed to the signs, installation of the pole and cabinet, and enforcement efforts at Compton Boulevard. Over the three months of the demonstration project, 254 violations were recorded by the camera equipment at the crossing with 142 citations were issued to violators.

Twenty percent of the citations issued (79) resulted in calls to the vendor to view the photo. Out of these calls, 26% of the motorists who called to make an appointment did not appear. Initial figures on the rate of payment of citations show the payment rate to be approximately the same as for citations issued by the Los Angeles Sheriff's Department Traffic Detail.

Non-Gated Crossings

Los Angeles Street and Washington Boulevard. This intersection has a very high number of left turn violations. At this intersection, the camera equipment has been installed to capture left turns made against a red left turn arrow from eastbound Washington Boulevard to northbound Los Angeles Street (towards downtown Los Angeles). The camera has a 150 mm lens which provides photographs showing a closer view of the driver's face and vehicle license plate. Issuance of warning notices began on October 27, 1993.

Photo enforcement equipment was operational at the intersection of Washington Boulevard and Los Angeles Street for about seven months from September 1993 through the middle of April 1994. The equipment was installed to record left turns made across the MBL tracks against a red turn left arrow (towards downtown Los Angeles). For about six weeks from February 15 through March 31, a total of 510 citations were issued to violators recorded at the intersection.

The rate of left turn violations on weekdays declined approximately 34% over the duration of the demonstration project, dropping from 2.02 per hour on the average during September and October to approximately 1.34 per hour for the month of March. This is a much lower percentage reduction than experienced for crossing violations at Compton Boulevard and Alondra Boulevard.

Other Demonstration Projects

The other two demonstration projects have involved testing alternative camera system and vehicle detection technologies. The first project, completed in April 1994, used low resolution digital camera system to record left turn violations. Images of the recorded violations were stored and transmitted by a cellular telephone link at night, eliminating the need to change and develop film. The second project underway in the City of Long Beach involves the use of "video loops" implemented using the AUTOSCOPE system to detect motorists making illegal left turns across the MBL tracks.

Systemwide Installation

The enhanced enforcement efforts on the Metro Blue Line have heightened public awareness of rail grade crossing safety. Additionally, these efforts have resulted in a 72% reduction in the number of train vs. vehicle collisions at intersections with gated crossings (see Figure 7). Because of the success of the photo enforcement demonstration projects, on February 22, 1995, the MTA Board of Directors authorized the award of a contract to U.S. Public Technologies (USPT) for the installation and operation of photo enforcement equipment at 17 grade crossings on the Metro Blue Line. It is expected that the equipment will be in place and operational at 10 crossings by the end of 1995. Equipment will be installed and operational at the remaining seven crossings during 1996.

USPT will install two poles and cabinets for the camera equipment at each of the 17 crossings. Detector loops will be installed at each crossing to trigger the camera system when a motorist enters the crossing after the railroad gates have started down or are already in their lowered position. Only ten camera systems will be provided by USPT. The cameras will be rotated from one crossing to another so that each crossing is monitored for a week's time every three weeks on the average. USPT will also be providing citation processing services for two years.

4.0 LEGISLATION

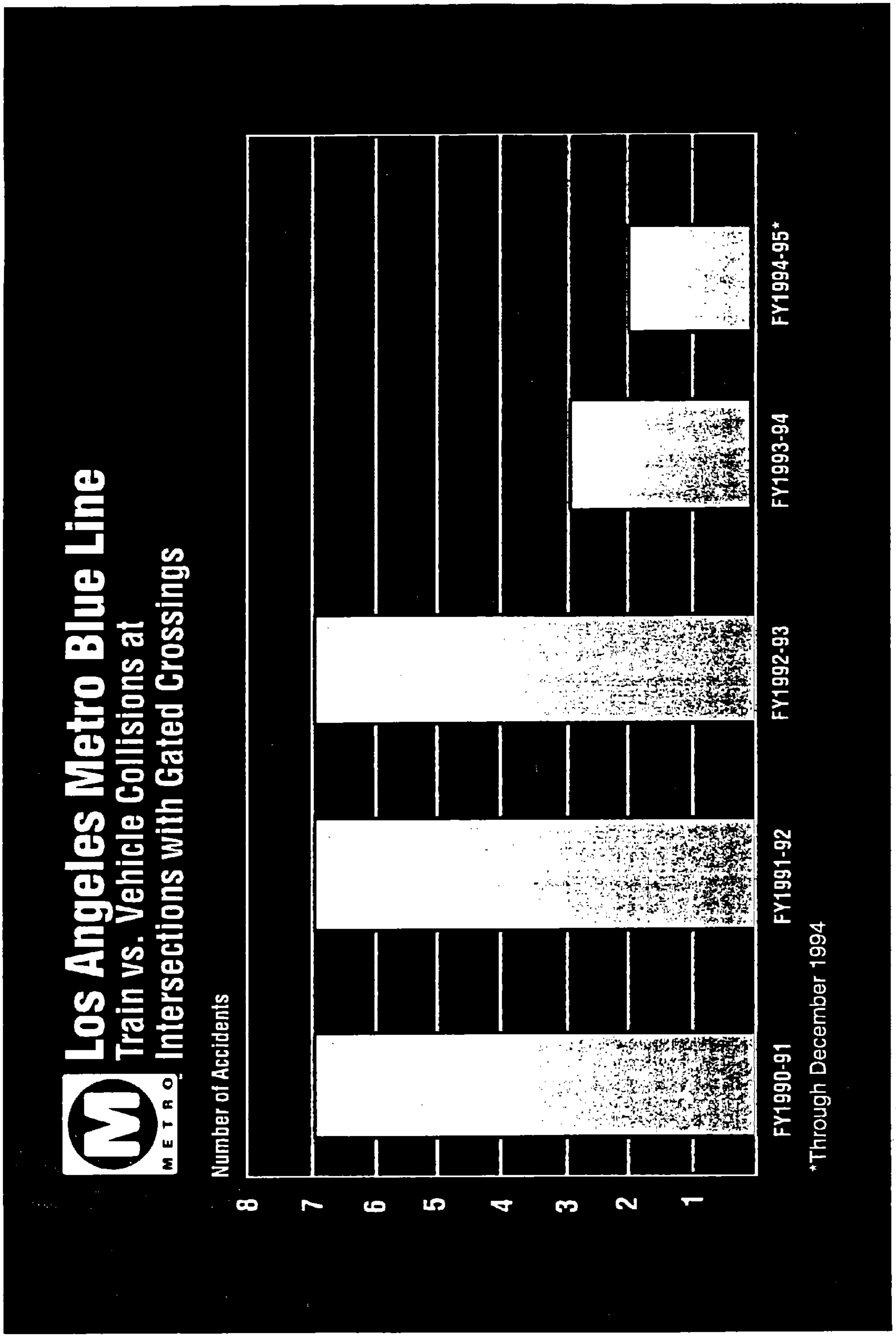
The MTA successfully sponsored the Rail Transit Safety Act which seeks to decrease the number of rail-related accidents by imposing additional fines and points upon persons who violate rail grade crossing safety laws (see Figure 8). The Act provides county transportation authorities, local governments, and law enforcement agencies with the tools needed to implement expanded enforcement and public education efforts targeted at rail grade crossing safety.

Specifically, the Rail Transit Safety Act provides for the following:

1. An additional fine for grade crossing violations.

Currently, depending upon the jurisdiction, the fine for not stopping at a grade crossing when the warning signals are flashing or for driving around a closed gate is $104, whereas the fine for a High Occupancy Vehicle (HOV) lane violation, where the violation does not threaten the

Figure 7



METRO
Los Angeles Metro Blue Line
Train vs. Vehicle Collisions at
Intersections with Gated Crossings
Number of Accidents
8
7
6
5
4
3
2
1
FY1990-91
FY1991-92
FY1992-93
FY1993-94
FY1994-95*
*Through December 1994

Figure 8

LEGI-TECH BILL TEXT REPORT 10/18/93

AB 1035 PAGE 1

722 An act to amend Sections 369g and 369i of, and to add Sections 369a and 369b to, the Penal Code, and to add Section 1656.3 to the Vehicle Code, relating to rail transit traffic safety.
Approved by Governor October 2, 1993
Filed with

LEGISLATIVE COUNSEL'S DIGEST

AB 1035, Archie-Hudson. Rail transit traffic safety.

Existing law authorizes the establishment of transportation commissions and transportation authorities, as specified, to deal with local transportation and improvement needs.

This bill would contain legislative findings and declarations regarding the necessity for rail transit safety programs and would authorize in each county with a population greater than 500,000 in which a transportation commission or authority has been established and it owns or operates rail transit facilities, the commission or authority to provide and disseminate appropriate educational materials, as specified, to traffic schools to aid in reducing the number of rail-related traffic accidents.

Existing law prohibits specified activities with regard to trespassing on railroad property and railroad crossings.

This bill would authorize the court to order any person convicted of specified rail transit related traffic offenses to attend a traffic school which offers, as a part of its curriculum, a film developed or caused to be developed by a transportation commission or authority on rail transit safety. This bill would also authorize the court to order a person cited for these specified violations to pay additional fines, as specified, to be allocated as specified. This bill would limit application of this provision to counties with a population greater than 500,000.

Existing law makes it a misdemeanor for a person to ride, drive, or propel any vehicle upon and along the track of any railroad through or over its private right-of-way, without the authorization of its superintendent or other officer in charge.

This bill would make it a misdemeanor for a person to ride, drive, or propel any vehicle upon and along the track of any railline owned or operated by a county transportation commission or transportation authority without the authorization of the commission or authority. Because this bill would create a new crime, it would impose a state-mandated local program.

Existing law makes a person who enters or remains upon the property of any railroad without the permission of the owner of the land, the owner's agent, or the person in lawful possession and whose entry or presence or conduct upon the property interferes with, interrupts, or hinders, or which, if allowed to continue, would interfere with, interrupt, or hinder the safe and efficient operation of any locomotive, railway car, or train, guilty of a misdemeanor.

This bill would specify a similar prohibition with regard to any rail

DELETED MATERIAL IS IN BRACKETS []. ADDED MATERIAL IS CAPITALIZED.

transit related property owned or operated by a county transportation commission or transportation authority. Because this bill would create a new crime, it would impose a state-mandated local program.

Existing law requires the Department of Motor Vehicles to publish a synopsis or summary of the laws regulating the operation of vehicles and the use of the highways.

This bill would require the California Driver's Handbook published by the department in compliance with the above requirement to include language regarding rail transit safety.

The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for a specified reason.

The people of the State of California do enact as follows:

SECTION 1. This act shall be known and may be cited as the ''Rail Traffic Safety Act.''

SEC. 2. Section 369a is added to the Penal Code, to read:

369a. (a) The Legislature hereby finds and declares the following:

(1) Rail transit traffic safety programs are necessary to educate the public about the potential for harm and injury arising from an individual's disregard for, and violation of, rail-related traffic safety laws, and to increase the consequences for those persons violating rail-related traffic safety laws.

(2) Currently, there does not exist a unified statewide system to deal with the ever increasing problem of rail-related traffic safety violators, and to provide a method of educating the public.

(b) In each county with a population greater than 500,000 in which a transportation commission or authority has been established and it owns or operates rail transit facilities, the commission or authority may provide and disseminate appropriate educational materials to traffic schools to aid in reducing the number of rail-related traffic accidents, including, but not limited to, a film developed or caused to be developed by the transportation commission or authority on rail transit safety.

SEC. 3. Section 369b is added to the Penal Code, to read:

369b. (a) This section shall only apply to counties with a population greater than 500,000.

(b) The court may order any person convicted of a rail transit related traffic violation, as listed in subdivision (c), to attend a traffic school which offers, as a part of its curriculum, a film developed or caused to be developed by a transportation commission or authority on rail transit safety.

(c) For a first offense, a court may, at its discretion, order any person cited for any of the following violations to attend a traffic school offering a rail transit safety film prepared by a county transportation commission or authority, pay an additional fine of up to one hundred dollars ($100), or both:

(1) Section 369g.

(2) Section 369i.
(3) Subdivision (c) of Section 21752 or Section 22451 of the Vehicle Code.

(d) For a second or subsequent violation as provided in subdivision (c), a court shall order a person to pay an additional fine of up to two hundred dollars ($200) and to attend a traffic school offering a rail safety film prepared by a county transportation commission or authority.

(e) All fines collected according to this section shall be distributed pursuant to Section 1463 of the Penal Code.

SEC. 4. Section 369g of the Penal Code is amended to read:

369g. (a) Any person who rides, drives, or propels any vehicle upon and along the track of any railroad through or over its private right-of-way, without the authorization of its superintendent or other officer in charge thereof, is guilty of a misdemeanor.

(b) Any person who rides, drives, or propels any vehicle upon and along the track of any railline owned or operated by a county transportation commission or transportation authority without the authorization of the commission or authority is guilty of a misdemeanor.

SEC. 5. Section 369i of the Penal Code is amended to read:

369i. (a) Any person who enters or remains upon the property of any railroad without the permission of the owner of the land, the owner's agent, or the person in lawful possession and whose entry, presence, or conduct upon the property interferes with, interrupts, or hinders, or which, if allowed to continue, would interfere with, interrupt, or hinder the safe and efficient operation of any locomotive, railway car, or train is guilty of a misdemeanor.

As used in this subdivision, ''property of any railroad'' means any land owned, leased, or possessed by a railroad upon which is placed a railroad track and the land immediately adjacent thereto, to the distance of 20 feet on either side of the track, which is owned, leased, or possessed by a railroad.

(b) Any person who enters or remains upon any rail transit related property owned or operated by a county transportation commission or transportation authority without permission or whose entry, presence, or conduct upon the property interferes with, interrupts, or hinders the safe and efficient operation of the railline or rail-related facility is guilty of a misdemeanor.

As used in this subdivision, ''rail transit related property'' means any land or facilities owned, leased, or possessed by a county transportation commission or transportation authority.

(c) This section does not prohibit picketing in the immediately adjacent area of the property of any railroad or rail transit related property or any lawful activity by which the public is informed of the existence of an alleged labor dispute.

SEC. 6. Section 1656.3 is added to the Vehicle Code, to read:

1656.3. The department shall include within the California Driver's Handbook, as specified in subdivision (b) of Section 1656, language regarding rail transit safety.

SEC. 7. No reimbursement is required by this act pursuant to Section 6 of Article XIIIB of the California Constitution because the only costs which may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, changes the definition of a crime or infraction, changes the penalty for a crime or infraction, or eliminates a crime or infraction. Notwithstanding Section 17580 of the Government Code, unless otherwise specified in this act, the provisions of this act shall become operative on the same date that the act takes effect pursuant to the California Constitution.

life of the driver or of others, is $271. The Rail Transit Safety Act authorizes the court to levy an additional $100 fine for a first violation of a rail grade crossing safety law. If a person is convicted of a second or subsequent offense, the court may order an additional fine of $200.

2. Traffic School for Grade Crossing Violations

A person convicted of a grade crossing violation may be ordered to attend traffic school and view a film on rail transit safety.

3. Requires Department of Motor Vehicles (DMV) Driver Handbooks to include a section on rail transit grade crossing safety.

Rail transit safety at grade crossings is not emphasized in DMV Driver Handbooks. The Act requires DMV to include language regarding rail transit safety.

The MTA has also supported the Rail Transit Enforcement Act which clarifies the use of high resolution photo equipment to identify violators of rail grade crossing safety laws and issue citations without a law enforcement officer present (see Figure 9). This legislation is significant in that it removes the institutional barriers to photo enforcement.

A key factor to make photo enforcement a technology of choice to enhance grade crossing safety is the ability to have a portion of the fine revenues returned to the transit agency or transportation authority. In this manner, the fine revenues will pay for the continued operation of the photo enforcement system. The MTA is sponsoring amendments to existing grade crossing legislation to return portions of fine revenues to transportation agencies.

At the U.S. Rail Summit held at the Department of Transportation on September 30, 1994 Secretary Pena fully endorsed the use of photo enforcement to reduce grade crossing accidents. He encouraged the development of legislation that returns portions of fine revenues to transportation agencies.

Citations will be issued in accordance with the provisions of the recently-enacted Rail Transit Safety Enforcement Act. The Act established the procedures to be used for issuing citations for grade crossing violations using photo enforcement equipment in the State of California. It is also provides authority for placing holds on license and vehicle registration renewals for violators not responding to citations. Other states such as Texas are in the process of developing legislation to support photo enforcement equipment that will issue citations to motorists who violate grade crossing laws.

CONCLUSION

Photo enforcement is an effective tool to combat the ever rising levels of grade crossing accidents. Experience on the Metro Blue Line in Los Angeles has shown dramatic reductions in grade crossing violations and corresponding reductions in train/automobile accidents. This technology can be used on existing rail lines or can be inserted into the design of future rail lines.

violation of Section 22451, or, with respect to a rail crossing, of Section 21453 or 22101 based on an alleged violation recorded by an automated rail crossing enforcement system, and delivered by mail within 30 days of the alleged violation to the current address of the registered owner of the vehicle on file with the department, with a certificate of mailing obtained as evidence of service, an exact and legible duplicate copy of the notice when filed with the magistrate shall constitute a complaint to which the defendant may enter a plea. Preparation and delivery of a notice to appear pursuant to this section is not an arrest.

(b) A notice to appear shall contain the name and address of the person, the license plate number of the person's vehicle, the offense charged, and the time and place when, and where, the person may appear in court or before a person authorized to receive a deposit of bail. The time specified shall be at least 10 days after the notice to appear is delivered.

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Figure 9

Senate Bill No. 1802

CHAPTER 1216

An act to amend Sections 22451 and 40509 of, and to add Sections 210, 21362.5, and 40518 to, the Vehicle Code, relating to vehicles.

[Approved by Governor September 30, 1994. Filed with Secretary of State September 30, 1994.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1802, Rosenthal. Automated rail crossing enforcement system.

Existing law requires the driver of any vehicle approaching a railroad grade crossing to stop not less than 15 feet from the nearest rail and not to proceed until he or she can do so safely, as specified.

This bill would specify that the above restriction applies to rail transit grades, authorize the equipping, by governmental agencies, in cooperation with law enforcement agencies, of automated rail crossing enforcement systems, as defined, provide a special written, mailed notice to appear procedure in connection with alleged certain violations recorded by an automated rail crossing enforcement system, and limit the availability of photographic records to the purposes of the bill.

The people of the State of California do enact as follows:

SECTION 1. This act shall be known and may be cited as the "Rail Traffic Safety Enforcement Act."

SEC. 2. The Legislature hereby finds and declares the following:

(a) The expansion of rail transit systems in California increases the need for rail transit traffic safety programs.

(b) Most rail-related traffic accidents are caused by motorists ignoring crossing gates and other warning signals and driving into the path of oncoming trains. An analysis of accidents related to the metropolitan blue line in Los Angeles found that 79 percent of those accidents were caused by motorists driving around closed crossing gates or making illegal turns against warning lights in front of oncoming trains.

(c) Automated rail crossing enforcement systems that photographically record violations occurring at rail crossing signals and rail crossing gates are a significant deterrent to these violations where motorists are aware of the presence of the automated systems. Grade crossing violations were reduced 65 percent in a demonstration project in Los Angeles using these systems. Similar results have been seen in Europe and other parts of the United States.

SEC. 3. Section 210 is added to the Vehicle Code, to read:

210. An "automated rail crossing enforcement system" is any

system operated by a governmental agency, in cooperation with a law enforcement agency, that photographically records a driver's responses to a rail or rail transit signal or crossing gate, or both, and is designed to obtain a clear photograph of a vehicle's license plate and the driver of the vehicle.

SEC. 4. Section 21362.5 is added to the Vehicle Code, to read:

21362.5. (a) Railroad and rail transit grade crossings may be equipped with an automated rail crossing enforcement system if the system is identified by signs clearly indicating the system's presence and visible to traffic approaching from each direction.

Only a governmental agency, in cooperation with a law enforcement agency, may operate an automated rail crossing enforcement system.

(b) Notwithstanding Section 6253 of the Government Code, or any other provision of law, photographic records made by an automated rail crossing enforcement system shall be confidential, and shall be made available only to governmental agencies and law enforcement agencies for the purposes of this section.

SEC. 5. Section 22451 of the Vehicle Code is amended to read:

22451. (a) The driver of any vehicle approaching a railroad or rail transit grade crossing shall stop not less than 15 feet from the nearest rail and shall not proceed until he or she can do so safely, whenever the following conditions exist:

(1) A clearly visible electric or mechanical signal device or a flagman gives warning of the approach or passage of a train or car.

(2) An approaching train or car is plainly visible or is emitting an audible signal and, by reason of its speed or nearness, is an immediate hazard.

(b) No driver shall proceed through, around, or under any railroad or rail transit crossing gate while the gate is closed.

(c) Whenever a railroad or rail transit crossing is equipped with an automated rail crossing enforcement system, a notice of a violation of this section is subject to the procedures provided in Section 40518.

SEC. 6. Section 40509 of the Vehicle Code is amended to read:

40509. (a) If any person has for a period of 15 or more days violated a written promise to appear or a lawfully granted continuance of his or her promise to appear in court or before the person authorized to receive a deposit of bail, or violated an order to appear in court, including, but not limited to, a written notice to appear issued in accordance with Section 40518, the magistrate or clerk of the court may give notice of the failure to appear to the department for any violation of this code, or any violation that can be heard by a juvenile traffic hearing referee pursuant to Section 256 of the Welfare and Institutions Code, or any violation of any other statute relating to the safe operation of a vehicle, except violations not required to be reported pursuant to paragraphs (1), (2), (3), (6), (7), and (8) of subdivision (b) of Section 1803. The notice shall be given within 60 days of the failure to appear. If thereafter the case in which the promise was given is adjudicated or the person who has violated the court order appears in court or otherwise satisfies the order of the court, the magistrate or clerk of the court hearing the case shall sign and file with the department a certificate to that effect.

(b) If any person has, for a period of 15 or more days, willfully failed to pay a lawfully imposed fine within the time authorized by the court or to pay a fine pursuant to subdivision (a) of Section 42003, the magistrate or clerk of the court may give notice of the fact to the department for any violation, except violations not required to be reported pursuant to paragraphs (1), (2), (3), (6), (7), and (8) of subdivision (b) of Section 1803. If thereafter the fine is fully paid, the magistrate or clerk of the court shall issue and file with the department a certificate showing that the fine has been paid.

(c) (1) Notwithstanding subdivisions (a) and (b), the court may notify the department of the total amount of bail, fines, assessments, and fees authorized or required by this code, including Section 40508.5, which are unpaid by any person.

(2) Once a court has established the amount of a fine and any assessments, and notified the department, the court shall not further enhance or modify that amount.

(3) This subdivision applies only to violations of this code that do not require a mandatory court appearance, are not contested by the defendant, and do not require proof of correction certified by the court.

(d) Whenever any person has for a period of 15 or more days willfully failed to obey any court order concerning a violation of this code other than failure to appear or pay a fine, the department shall suspend the person's privilege to operate a motor vehicle until compliance with the court order is shown. The magistrate or clerk of the court may give notice of any noncompliance of a court order to the department. The suspension shall not become effective until 45 days after the giving of written notice by the department to the person or until the end of any stay of suspension. However, this subdivision does not apply to court orders concerning violations enumerated in paragraphs (1), (2), (3), (6), and (7) of subdivision (b) of Section 1803.

(e) With respect to a violation of this code, this section is applicable to any court which has not elected to be subject to the notice requirements of subdivision (b) of Section 40509.5.

(f) Any violation subject to Section 40001, which is the responsibility of the owner of the vehicle, shall not be reported under this section.

SEC. 7. Section 40518 is added to the Vehicle Code, to read:

40518. (a) Whenever a written notice to appear has been issued by a peace officer or by a qualified employee of a law enforcement agency on a form approved by the Judicial Council for an alleged

E-44

EFFECTIVE USE OF TRAFFIC CONTROL DEVICES AT HIGHWAY-RAILROAD GRADE CROSSINGS

Highway-Railroad Grade Crossing Safety Research Needs Workshop
April 1995

Hans W. Korve
President
Korve Engineering, Inc.
155 Grand Avenue, Suite 400
Oakland, CA 94612
(510) 763-2929

Hal Wanaselja
Rail Group Manager
Korve Engineering, Inc.
155 Grand Avenue, Suite 400
Oakland, CA 94612
(510) 763-2929

José I. Farran
Senior Transportation Engineer
Korve Engineering, Inc.
155 Grand Avenue, Suite 400
Oakland, CA 94612
(510) 763-2929

Douglas M. Mansel
Transportation Engineer
Korve Engineering, Inc.
155 Grand Avenue, Suite 400
Oakland, CA 94612
(510) 763-2929

EFFECTIVE USE OF TRAFFIC CONTROL DEVICES AT HIGHWAY-RAILROAD GRADE CROSSINGS

Hans W. Korve[1]
Hal Wanaselja[2]
José I. Farran[3]
Douglas M. Mansel[4]

INTRODUCTION

As early as 1877, the United States Supreme Court addressed at-grade crossing safety in the case of *Continental Improvement Company v. Stead*, 95 U.S. 161(1877). The Court discussed the duties, rights, and obligations of railroad companies vis á vis the highway user that crosses the railroad companies' tracks. These duties, rights, and obligations were found to be "mutual and reciprocal." Further, the Court said that a train has preference and the right-of-way at crossings because of its "character," "momentum," and "the requirements of public travel by means thereof," but the railroad, in turn, is bound to give due, reasonable, and timely warning of the train's approach. Today, with the re-emergence of passenger rail travel in the form of commuter and light rail transit (LRT) systems, as well as high speed rail systems, at-grade crossing safety is an important issue because of accidents at highway-railroad crossings.

[1]President, Korve Engineering, Inc., 155 Grand Avenue, Suite 400, Oakland, CA 94612
[2]Rail Group Manager, Korve Engineering, Inc., Oakland, CA
[3]Senior Transportation Engineer, Korve Engineering, Inc., Oakland, CA
[4]Transportation Engineer, Korve Engineering, Inc., Oakland, CA

In March 1994, the Transportation Research Board, Transit Cooperative Research Program (TCRP) retained a team lead by Korve Engineering, Inc. to conduct research with the overall objective of improving the safety of at-grade LRT crossings. An additional objective of this research project, entitled "Integration of Light Rail Transit into City Streets," was to develop material for inclusion into a new light rail-highway grade crossings Part of the *Manual of Uniform Traffic Control Devices* (MUTCD). A significant portion of this research conducted for TCRP and the research conclusions apply to general highway-railroad at-grade crossing safety. An important product of this project was the identification of key areas that need further research, especially for at-grade crossings in urban areas.

RESEARCH ISSUES

Highway-railroad grade crossing traffic control devices design, installation, and use have, for all practical purposes, remained unchanged since the turn of the century. At-grade crossing control devices, which have been used virtually unchanged for years, include the regulatory railroad crossing (crossbuck) sign (R15-1), the flashing light signal, and the crossing gate (which was initially manually controlled).

Generally, the historic design and uniform use of highway-railroad traffic control devices, is considered to be good and sound traffic engineering practice. As specified in the MUTCD introductory Part I, Section A-2, "Requirements of Traffic Control Devices":

> "Uniformity of traffic control devices simplifies the task of the road user because it aids in recognition and understanding. It aids road users, police officers, and traffic courts by giving everyone the same interpretation. It aids public highway and traffic officials through economy in manufacture, installation, maintenance, and administration. Simply stated, uniformity means treating similar situations in the same way."

The key concept of the MUTCD uniformity principle is "treating similar situations in the same way" by using the same traffic control devices. When highway-railroad traffic control device standards were initially adopted (e.g., flashing light signal, crossbuck, etc.), motor vehicle traffic volumes were very low and other traffic controls devices governing motor vehicles were virtually non-existent.

However, motor vehicle traffic volumes are now large, especially in urbanized areas, and traffic controls devices have become highly sophisticated. Further, with the re-emergence of urban passenger rail service, high speed trains, and light rail transit, at-grade crossings cannot be considered a "similar situation" to the typical highway-railroad at-grade crossing of the past. In general, in urbanized areas motorists and pedestrians interact with commuter rail trains and light rail trains more frequently at grade crossings because of the very nature of the type of rail services now being offered (e.g., shorter train headways and train consists with higher operating speeds).

In addition to the different nature of at-grade crossing operations of today's commuter, high speed, and LRT systems, more specific issues of inconsistency and inadequacy of crossing control devices were found:

Inconsistent Meaning of Traffic Control Devices at or near Grade Crossings

Generally at highway-railroad grade crossings, there is an inconsistent use of color codes and traffic control device meanings from a traffic engineering perspective. For example, the flashing red lights of the typical railroad flashing light signal assembly, is generally considered to be a warning device to indicate when a train is approaching. This is specified in the Uniform Vehicle Code Section 11-701, "Obedience to Signals Indicating Approach of Train":

> "Whenever any person driving a vehicle approaches a railroad grade crossing . . . the driver of such vehicle shall stop within 50 feet [15.2 meters] but not less than 15 feet [4.6 meters] from the nearest rail of such railroad, and shall not proceed until safe to do so when . . . a clearly visible electric or mechanical signal device gives WARNING of the immediate approach of a railroad train. . . ."

However, flashing red lights, according to the MUTCD and Uniform Vehicle Code, are regulatory (not warning) in nature and generally mean stop and proceed when safe. At grade crossings motorists should be regulated more formally to stop until the train has safely cleared the crossing. According to the MUTCD and Uniform Vehicle Code, this type of signal indication should be provided by means of a solid red, circular indication, similar to a standard traffic signal. If, indeed, a device is employed at a grade crossing to give warning of the immediate approach of a train (prior to the solid red indication just described), it should display the traditional yellow caution signal to indicate to the motorist that the "proceed" or "go" phase for the highway is about to be terminated. For example, in Germany a two-head traffic signal which is normally dark is used in conjunction with gates. As a train approaches, a solid yellow is shown for a warning time and turns to solid red when the gates start to descend. The use of standard traffic lights in conjunction with gates is an area requiring further research.

The standard crossbuck sign (R15-1) is considered to be a regulatory sign for motorists; however, neither the MUTCD nor the Uniform Vehicle Code regulates any specific action on the part of the motorist or pedestrian when a crossbuck sign is encountered. The sign contains substantial verbiage, and because of its size and color scheme (black on white), it may be difficult to recognize from afar. Alternative designs for the crossbuck that are currently being used in Canada and Europe command more attention of motorists and/or pedestrians, and also provide better visibility for the crossing, especially at night. The signs are shaped as a white crossbuck, without words, and with a reflective red outline. Future research is recommended to test motorist and pedestrian reaction to such a sign. Further research may look into the application of this type of signs to indicate a different type of at-grade crossing environment, such as a high speed rail or LRT, which represent a distinct level of risk.

Poor Coordination between Railroad and Traffic Engineering Efforts

At many at-grade crossings, there are often separate design and installation of traffic control devices by the traffic engineer, and railroad crossing devices by the railroad engineer. The end result is crossings that are cluttered with traffic control devices and railroad signal assembly hardware. This is especially true at urban locations where space is often tight and traffic signals are frequently needed adjacent to an at-grade crossing. As the MUTCD, Section 2A-6 (Excessive Use of Signs) alludes, traffic control devices, if used in excess, "tend to lose their effectiveness." Drivers can become confused or simply ignore the signs and/or signals altogether.

In our research of various LRT systems, we have observed poor integration of highway traffic control devices with railroad signal warning devices. At some crossings, a motorist approaching on a perpendicular street may see over a dozen flashing red light signal indications, most of them cantilever supported, to indicate that a train is approaching. Furthermore, standard traffic signals are sometimes mounted on a mast arm near the cantilever that supports the flashing light signals.

Motorists approaching these crossings see a large amount of signal hardware and general signal clutter, which makes motorist's decision making difficult.

In general, the TCRP Project A-5 research recommends that cantilever supported flashing light signals should not be used when traffic signals are mounted on a mast arm at or near an at-grade crossing. They should only be used at mid-block at-grade crossings. However, future research is required to determine exactly when a crossing is considered to be "mid-block."

Another example of the poor coordination between traffic engineering and railroad engineering professionals occurs in the way track is constructed through an at-grade crossing. Often, contrasting pavement or a special crossing material, which extends several inches beyond the outside edge of the rails and has a different texture and color than the adjacent asphalt or portland cement concrete roadway surface, is placed along the trackbed through the crossing. Motorists and especially pedestrians often wait just outside the edge of the contrasting paved area for a train to pass. However, the edge of the trackbed and the roadway, which is interpreted by motorists and pedestrians as a safety line, remains well within the dynamic envelope of the train, especially at turns, and therefore conveys the wrong message to the road user. The lack of coordination between the trackbed designer and the roadway designer often leads to this situation where the contrasting paved area does not extend far enough to encompass the full dynamic envelope of the train, thus creating a potentially dangerous crossing environment for pedestrians and motorists alike. Design criteria and plan review procedures need to be developed for grade crossings to assure that the dynamic envelope of the rail vehicles is clearly delimited at the crossings.

Lack of Standard Warrants for Traffic Control Devices at or near Rail Grade Crossings

In general, there are no warrants regarding the level of protection required for at-grade crossings as a function of motor vehicle traffic volumes and/or train service frequency. (However, the Institute of Transportation Engineers, Technical Committee 6A-42 has developed grade separation recommendations for LRT systems.) Possible crossing treatments providing various levels of protection, from the lowest to the highest, include the following:

- No crossing control device except for a Railroad Crossing (Crossbuck) sign (R15-1)
- Stop sign (R1-1) controlled at-grade crossing
- Flashing light signal assemblies
- Standard traffic signals
- Two-quadrant automatic crossing gates
- Two-quadrant automatic crossing gates with enforcement measures or a raised roadway median island
- Full barrier or four-quadrant automatic gates
- Crossing closure or grade separation

The Federal Railroad Administration (FRA) provides some general guidelines requiring certain levels of protection based on train speed through an at-grade crossing as follows:

- Where trains operate below 175 km/h (110 mph), the crossing shall be equipped with an "existing" at-grade crossing protection system (i.e., two-quadrant crossing gates, traffic signals, flashing light signal assemblies, stop signs, etc.).
- Where trains operate between 175 km/h (110 mph) and 200 km/h (125 mph), the crossing shall be equipped with a full barrier or four-quadrant crossing gate system.
- Where trains operate above 200 km/h (125 mph), the crossing shall be closed or grade separated.

In addition to these FRA guidelines, which are based only on train speed through a crossing, other documents such as the *Railroad-Highway Grade Crossing Handbook* (published by the Federal Highway Administration) provide guidance in assessing crossing safety and operations based on accident history, traffic volumes, and train service characteristics. However, these documents only provide a formula-based methodology to rank grade crossings based upon their relative safety/danger and predictable collision rates, given *a priori* the level of protection at each crossing.

The California Public Utilities Commission (CPUC) has a similar formula-based methodology to determine whether crossings are eligible for grade separation. The following is an example of such a calculation:

$$P=\frac{V(T+0.1LRT)}{CF}(AH+BD)+VS+RS+CG+AR+PT+OF$$

This formula yields the priority index number (P) for the grade crossing. One could then compare this P with other values of P obtained from different grade crossings to determine the priority for which crossings should be grade separated. The necessary input data are: the average 24-hour vehicular traffic volume (V), the average 24-hour train volume (T), the average 24-hour light rail vehicle traffic (LRT), the total cost of the grade separation project (C), the cost inflation factor (F), the accident history at the crossing (AH), and the average time that the roadway is "blocked" due to train passage (BD). Further, other special factors could add to the priority index and thus increase the probability that the crossing will be eligible for grade separation funding. These factors include the vehicle speed limit on approach to the crossing (VS), the prevailing speed of the trains (RS), complex crossing geometries (CG would be higher for more complex crossing situations), the availability of alternate routes around the crossing in question (AR), the type of train traffic (PT would be higher if most of the trains using the crossing where passenger trains), and other factors (OF) which include emergency vehicle usage frequency, school bus usage frequency, community impact, etc.

Thus, aside from the FRA standards, which are specific only when trains operate above 175 km/h (110 mph), these methodologies, while useful for ranking at-grade crossing safety for possible funding for level of protection upgrades, are virtually useless in determining the level of protection and traffic control devices needed at grade crossings. Future research is needed to establish warrants for each of these devices, as well as the parameters that should be included to calculate them. These warrants should be based on train speeds, train frequencies, crossing configuration, stopping sight distances, adjacent land uses, traffic volumes, and other factors affecting risk at the grade crossing, similar to traffic signal warrants and design standards used in highway engineering practice.

In addition, further research is needed to determine the appropriateness of four-quadrant gates. With the re-emergence of passenger rail service in the United States, including commuter trains and LRVs, four-quadrant crossing gates should be considered for installation at crossings where vehicles are likely to violate or "drive around" two-quadrant crossing gates.

Given the relative high cost of grade separating a crossing and given that it is not always feasible to close a crossing, other, more advanced crossing protection systems should also be researched. In Illinois, for example, vehicle-arresting barriers are being tested at three locations along the Southern Pacific right-of-way between Joliet and Granite City. These types of systems have been used in highway construction zones and are similar to the arresting nets installed on aircraft carriers. The barriers have energy absorbing devices on either side of an arresting net that can stop a motor vehicle without injury to occupants. These crossing devices are a step beyond regulatory and warning devices; they actually protect the occupants in the intruding vehicle. A different approach is being used in Sweden, where four quadrant gates are equipped with vehicle occupancy detection and gate malfunction detection devices. These gates are being tested in the U.S. in Connecticut. In case of an incident, they transmit that information to the approaching train, which then stops automatically. The area of advanced crossing protection systems requires further research.

Lack of Pedestrian Crossing Considerations and Pedestrian Crossing Treatment Warrants

To date, there are no guidelines or warrants for the design and installation of at-grade pedestrian crossing control devices. Interactions between pedestrians and trains are substantially different from those between motorists and trains. In general, motorists tend to be more acutely aware of their dynamic environment. Pedestrians, on the other hand, operate largely in the relatively safe venue of the protected sidewalk area, and do not routinely share the same continuous, attentive edge. When crossing the travel path of motor vehicles or trains, pedestrians should then shift to a similar state of awareness as that exhibited by motorists. However, this is not always the case. Also, unlike motor vehicles, trains cannot swerve or stop quickly enough to compensate for the pedestrians who ignore pedestrian signals or cross tracks at random.

The TCRP Project A-5 examined general guidelines based on level of risk of a collision with a train for several pedestrian crossing control devices: active pedestrian warning signs, the flashing light signal assembly, pedestrian automatic gates, swing gates, and crossing channelization ("Z"-type or bedstead barrier type crossing configurations).

Warrants for Pedestrian Crossing Control Systems

Although the TCRP Project A-5 work has attempted to suggest applications for certain types of pedestrian crossing control devices, future research should be conducted to develop specific warrants for these devices based on pedestrian volumes, train speeds, crossing configuration, stopping sight distance, adjacent land use, existence of passenger transfers at nearby stations, and other factors that may impact pedestrian safety near the railroad tracks.

Table 1 "Recommended Applications for Pedestrian Crossing Controls", on the next page, which was developed for the TCRP Project A-5 to serve as a guide for placement of pedestrian crossing control devices, is the first step in developing some type pedestrian warrants. This table was adapted from a similar one that was prepared by the California Traffic Control Devices Committee, Light Rail Safety Subcommittee for inclusion in the California *Traffic Manual,* which is similar to the MUTCD for California applications.

TABLE 1
RECOMMENDED APPLICATIONS FOR PEDESTRIAN CROSSING CONTROLS

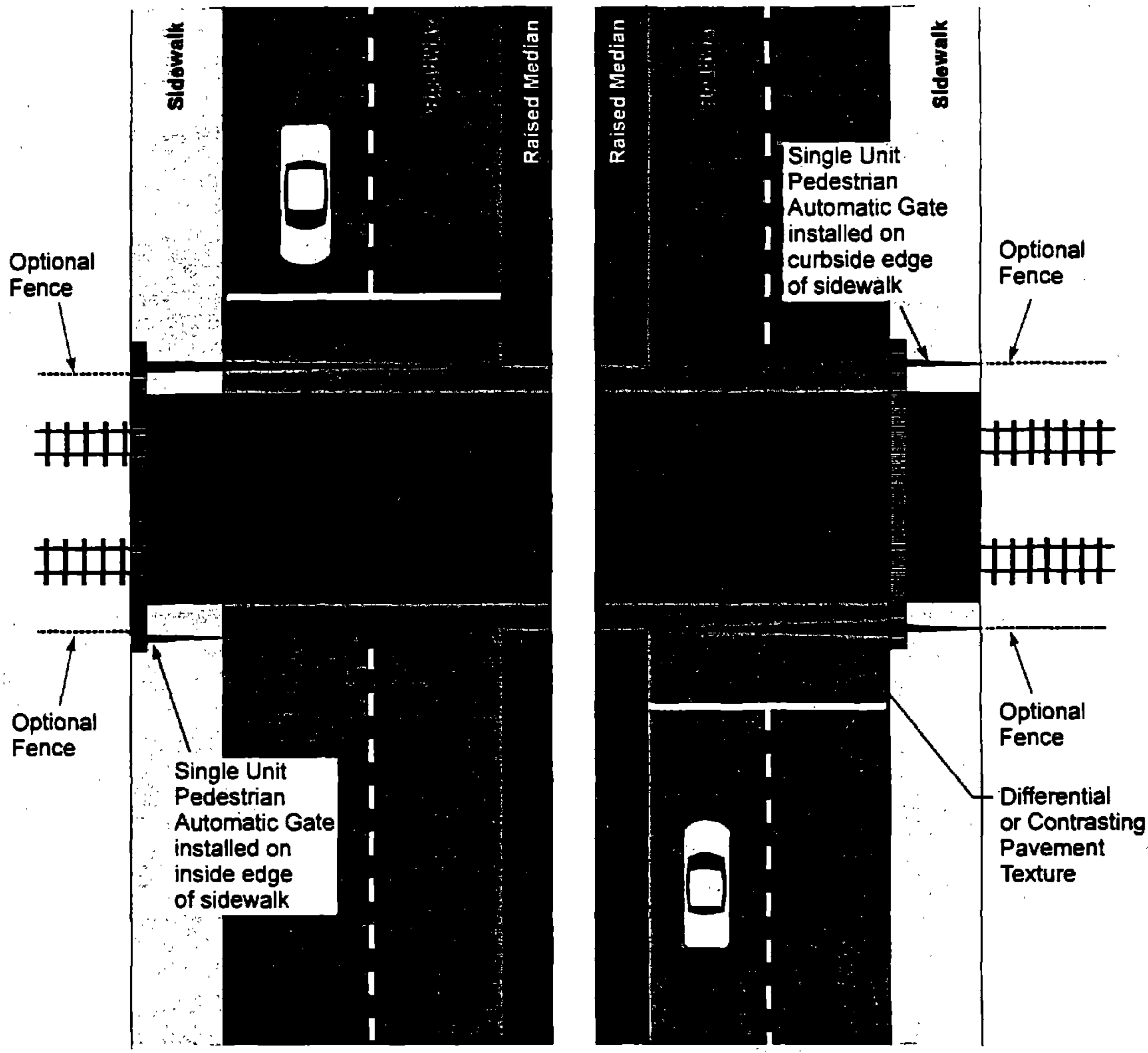
PEDESTRIAN RISK LEVEL[1]	CROSS STREET IS CONTROLLED BY STOP-SIGNS			CROSS STREET IS SIGNALIZED[2]			CROSS STREET HAS AUTOMATIC GATES		
	Ped. Warning Sign	Flashing Signal Assembly	Ped. Automatic Gate[3], Swing Gate, or Channelization	Pedestrian Signal[4]	Swing Gate or Channelization	Ped. Automatic Gate[3]	Flashing Signal Assembly or Ped. Signal[4]	Swing Gate or Channelization	Ped. Automatic Gate[3]
LOW	Should	May	May	Should	May	May	Should	May	May
MEDIUM	Not applicable	Should	May	Should	Should	May	Should	Should	May
HIGH	Not applicable	Should	May	Should	Should	Should	Should	Should	Should

1 *Pedestrian Risk Level* is a function of pedestrian volumes, train speed, crossing configuration, stopping sight distance, adjacent land use, existence of transfers, and other factors that may impact pedestrian safety.
2 A crossing controlled by standard traffic signals.
3 When stopping distance is inadequate pedestrian automatic gates shall be used.
4 A "pedestrian signal" displays the symbolic "WALK/DON'T WALK" or legend equivalent

Further research is needed to relate warrants to the pedestrian risk level. Generally, higher pedestrian volumes, shorter stopping sight distances, and complex crossing geometries imply an increased potential for a collision between train and pedestrian, and thus a higher risk level should be assigned. However, high, medium, and low potential risk levels should be defined quantitatively (i.e., warrants) based on the above considerations.

Table 1 prescribes different pedestrian control devices based on potential level of risk to the pedestrian and the type of traffic control device on the cross street. As described previously, several of these pedestrian control devices have been researched as part of TCRP Project A-5. Some of these devices, although requiring further research to determine exact usage guidelines and warrants, appear to have great potential for reducing collision between trains and pedestrians. These devices include:

Pedestrian Automatic Gates Pedestrian automatic gates are the same as motor vehicle automatic gates except that the gate arm is shorter. They physically close the pedestrian path to prevent pedestrians from crossing the tracks when the gates are activated by an approaching train. These gates are especially effective when motor vehicle automatic gates are placed on the inside edge (behind) the sidewalk and standalone pedestrian automatic gates are installed in the off-quadrant, also on the inside edge (behind) the sidewalk (Figure 1, Option A). An alternate gate placement on the outside edge of the sidewalk is shown in Figure 1, Option B.



OPTION A
Where motor vehicle automatic gates are installed on the inside of the sidewalk extending across the sidewalk and roadway

OPTION B
Where motor vehicle automatic gates are installed on the curbside of the sidewalk with a separate pedestrian gate arm

FIGURE 1
PLACEMENT OF PEDESTRIAN AUTOMATIC GATES

Swing Gates Swing gates require pedestrians to pull a 1-meter (42 inches) or shorter gate in order to enter the crossing, and to push a gate in order to exit the track crossing area. The gates are designed to return to the closed position after passage of a pedestrian. In order to avoid the risk of trapping a pedestrian on the track area, these gates have not normally been locked closed when a train is approaching. These gates are designed to return to the closed position after the passage of a pedestrian. However, research is required to determine the desirability of automatically locking the gate as a train approaches, with a push bar on the track side so it can be opened if a pedestrian is trapped. Operators have opposed this approach due to perceived liability issues, but such a device would provide greater protection for pedestrians than unlocked gates.

Crossing Channelization Crossing channelization controls the direction in which pedestrians move as they approach a crossing. On a double track system, these designs turn pedestrians in a maze- like, Z-shape fashion before they cross the tracks, forcing them to look in the direction of oncoming trains. These types of channelization should not be used when trains operate on a single track with two-way operations since, in some instances, pedestrians may be forced to look the wrong way, as a train approaches.

Pedestrian Warning Signs A new sign that should prove effective in reducing collisions between train and pedestrians was developed as part of the TCRP project. This internally illuminated sign is activated when a train approaches the crossing. It displays the message SECOND TRAIN - LOOK

LEFT/RIGHT and alerts pedestrians that a second (third, fourth, etc.) train is approaching the crossing, shortly following another train, from a direction that might not be expected. Further research is needed to determine the appropriate and more effective symbols to be used on the sign as a substitute for the words.

CONCLUSIONS

A summary of potential research areas for improving the use of traffic control devices at highway-railroad grade crossings that would greatly benefit the public and the transportation/railroad community include the following:

- Study the effectiveness of standard traffic signals (or perhaps, high intensity traffic signals) in conjunction with automatic gates at grade crossings to increase motorist compliance.

- Study the effectiveness of alternative, more visible, crossbuck signs and to define what actions motorists should take at such crossings.

- Determine the most effective type of intersection traffic control devices to be used at "mid-block" railroad at-grade crossings.

- Establish institutional arrangements to forge and provide better coordination between the traffic/transportation and railroad engineering community.

- Develop criteria for the effective definition of the rail vehicle's dynamic envelope (contrasting pavement, pavement markings, delineation, etc.).

- Develop warrants for at-grade crossing traffic control devices considering all of the factors involved in grade crossing protection.

- Develop warrants for at-grade pedestrian crossing control devices, and establish what devices are most appropriate for each type of situation, including swing gates that lock automatically.

- Determine the best type and display for pedestrian warning signs in multi-track railroad alignments.

- Determine when to use four-quadrant gates and/or other sophisticated protection devices to achieve a more positive vehicle control.

- Study the legal liability issues related to the rail operator and the road entity to define responsibilities for the installation and maintenance of grade crossing protection devices.

However, this research should not be conducted for the sake of further research. Once preliminary research has been conducted in each of these areas, an implementation program should be in place between the research agency (e.g., the Transportation Research Board), the Federal Highway Administration, the Federal Railroad Administration, the Federal Transit Administration, and the National Highway Traffic Safety Administration to implement the recommendations and determine how full-scale demonstration projects should be funded once preliminary research results indicate that certain traffic control devices could provide increased safety at highway-railroad grade crossings. Further, an action plan should be prepared by these Administrations to implement at-grade crossings improvements as a result of successful demonstration projects by way of new regulations, additions to the MUTCD, establishment of guidelines and other means as appropriate.

As it can be seen, at-grade crossing traffic control devices and the level of safety each one provides is an area that is extremely fertile for further research. With warrants for the proper installation and consistent application of various traffic control devices at or near grade crossings, the public as well as the traffic and railroad communities stand to benefit from increased safety at crossings.

Appendix F

Human Factors Papers

DRIVERS AS DECISION MAKERS AT RAIL-HIGHWAY GRADE CROSSINGS

Neil D. Lerner and Donna J. Ratte'
COMSIS Corporation, Silver Spring, Maryland

A recent review of driver behavior at rail-highway crossings (Lerner, Ratte', and Walker, 1989) revealed a number of decision making problems faced by motorists as they negotiate the area of an at-grade crossing. It was also noted that many in the safety community hold an unsympathetic and counterproductive "blame the victim" attitude and an apparent double standard in interpreting driver actions. Without denying the responsibility of the driver in vehicle-train collisions, this paper argues that there are important human factors issues that contribute to driver error in decision making. Fourteen such factors are identified and discussed and implications for rail-highway safety are considered.

INTRODUCTION

The reduction of fatalities at rail-highway grade crossings during the past 25 years represents a major success story in highway safety. In the mid-1960's, the U.S. experienced about 1,500 fatalities a year resulting from motor vehicle collisions with trains at crossings (with a peak of 1,657 in 1966). Through two decades the number of deaths has dropped to the point where by the mid-1980's the U.S. experienced only 500-600 such fatalities per year. This is in spite of the fact that the "exposure index" (based on the product of train operations and highway travel) has gone up by about 40% during this period. Much of this gain can be attributed to the upgrading of the level of protection provided at many crossings. The level of protection afforded can range from only passive devices (e.g., crossbucks), to train-actuated signals, to automatic gates, to actual grade separation of the highway and the tracks.

Despite this dramatic reduction in deaths, the safety problem should not be seen as solved. Although over the last few years the number of railroad crossing accidents and the number of related injuries have remained at an approximately stable level, there has been a noticeable increase in the number of fatalities (from 556 in 1987 to 628 in 1988 to a preliminary estimate of 716 in 1989). Furthermore, even at the reduced levels, 600 annual deaths and over 2000 annual injuries still constitute a serious public safety concern.

In order to further reduce the remaining number of accidents, it may be beneficial to better understand and appreciate the problems of driver perception and behavior involved in the negotiation of a rail-highway grade crossing. COMSIS Corporation recently provided an extensive review of the literature on this issue. In this paper, we will give a brief overview of the literature review, and then focus on one aspect of special interest. That aspect is the decision making problems faced by the driver as he approaches and negotiates a rail-highway crossing.

REVIEW OF DRIVER BEHAVIOR UNDER THE 1987 "SURFACE TRANSPORTATION ACT"

In the Surface Transportation and Uniform Relocation Assistance Act of 1987, Congress required the Federal Highway Administration to study the safety, cost, and operational concerns of rail-highway crossings. One portion of this effort was an extensive literature review and analysis of all aspects of driver behavior at rail-highway crossings (Lerner, Ratte', and Walker, 1989). "Driver behavior" was broadly defined to include not only overt actions, but also perception, decision processes, knowledge, and attitudes, and so forth. This review included the following areas:

Comprehension: of traffic control devices, of responsibilities, of accident factors
Detection/Recognition: of the crossing, advance signs, signals, trains
Perception: dynamic factors in perceptual judgment (train speed, own speed, distance)
Decision Making: at all points, including approach, go/no go decision, etc.
Compliance: with traffic control devices and grade crossing regulations
Impairment: by alcohol, drugs, fatigue
Driver Characteristics: age, sex, risk taking, familiarity with site

Driver behavior problems, issues, and potential countermeasures were found at all of these levels, and the discussion cannot be summarized in the limited space here. The interested reader is referred to Lerner et al. (1989). In addition to the many specific findings, there emerged the need to consider driver behavior at rail-highway crossings within a broader driving context. A particular crossing site, and its associated traffic control devices, must be viewed as part of a rail-highway system. Further, the driver brings to the situation his own history and perceptions, including in most cases substantial familiarity with the particular crossing. Finally, the maneuver of approaching and negotiating a crossing should be viewed from the driver's perspective, where it is but one aspect of the more general driving task.

With this broader context in which to view driver actions, a greater appreciation was achieved for the difficulties facing the driver, as a continuous decision maker, as he approaches and negotiates a grade crossing. This view of the driver appears to be different from a prevalent attitude among the rail crossing safety community, which often has a denouncing, blame-the-victim feeling. A new appreciation may help foster more effective attitudes and strategies among the highway safety community. The remainder of this paper considers the performance of the driver at a crossing as a decision maker, and the nature of the complications he may face.

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HOW BAD ARE THESE DRIVERS?

Why do drivers continue to have collisions with trains? Often what is written or said by the highway and railway safety communities suggests that the driving public in general, and the accident-involved drivers in particular, are simply bad drivers: careless, reckless, or uninformed. Without denying the responsibility of the driver, however, there also seems to be a double standard here with respect to other kinds of highway accidents. For some reason, there appears to be more of a "blame the victim" philosophy and a different set of criteria for judging a driver's actions.

Because trains are very limited in the avoidance actions they can take, responsibility for accident avoidance rests almost entirely with vehicle operators. Thus, the very fact of a vehicle-train collision implies some failure on the part of the driver. Descriptions in the literature frequently describe drivers as "reckless" or "impatient," "disregarding" signals, driving at "inappropriate" speeds, and otherwise being irresponsible. Field studies at rail highway crossings similarly often describe the driving public as reckless in these settings.

In considering this harsh stereotype of the driver at a rail-highway crossing, we could not help but have the feeling of a double standard with respect to other highway situations where the problems of the driver are viewed more sympathetically. Several observations are relevant to this:

(1) Crossing the tracks "in front of a train" is held to be a careless act, and studies have categorized as extremely risky those maneuvers which provide "only" ten seconds of clearance between the vehicle leaving the crossing and the arrival of the train (some studies even evaluate twenty seconds of clearance as indicating a risky or aggressive maneuver). In other traffic situations, however, a ten second margin would be considered as quite long. For example, the <u>mean</u> gap in traffic accepted by crossing or turning vehicles is well under ten seconds (e.g., 7 seconds, OECD, 1974), with many drivers accepting only a few seconds. Likewise, highway design standards (e.g., intersection sight distance) presume the safety of much smaller clearance times. Furthermore, intentional crossing in front of a train usually involves initial slowing or stopping, scanning, and accurate perception of available time (Meeker and Barr, in press).

(2) Profiles of drivers involved in vehicle-train collisions do not suggest that these victims are unusually poor drivers. Alcohol and speed appear to be less frequently involved than for other types of accidents, and the age and sex of victims suggest that if there are any meaningful differences from highway accidents in general, it is that groups known to be greater risk-takers (young drivers, males) are underrepresented. From his study of fatal crossing accidents in Australia, Wigglesworth (1979) found that typically drivers were reported as driving "steadily" or "slowly," and that "the overall impression .... was that in most cases, the accident occurred to a law-abiding citizen, going about his or her daily work...unrelated to breach of any regulation."

(3) The number of incidents, and particularly injury-causing accidents, is not particularly large. About 5,800 vehicle-train accidents occur each year on public roads, with a majority these involving no injury. These accidents include all types of vehicles, roadway conditions, environments (rain, snow, darkness), crossing types, and accident causes. With over 180,000 at-grade public crossings (FRA, 1989), we estimate (using 1988 data) that there is only about one injury-producing accident per every 90 crossings and (assuming about two trains per crossing per day) per about 65,000 train crossings. These numbers would not appear to suggest an exceptionally careless driving public.

(4) For other traffic situations, traffic engineers and other safety professionals are willing to <u>presume</u> that the majority of drivers are prudent. For example in setting speed limits, the behavior of the traffic stream (e.g., 85th percentile driver) is often taken as a guide. Yet at rail crossings where the norm is inconsistent with the desired behavior (e.g., an urban site where a dozen vehicles may routinely cross in front of a train after the onset of the signal), the typical driver is viewed as a careless scofflaw.

Why this apparent double standard exists in viewing the driver is not clear, but it may be counter-productive for safety. The facts do not seem to warrant the view that the at-risk driver negotiating a rail-highway crossing is a typically poor or reckless motorist. While one cannot deny that crossing safety <u>is</u> the driver's responsibility, and drivers do make misjudgments and poor decisions, the appropriate position of the human factors practitioner is to ask how the motorist's decision task can be improved, rather than simply blame him, after the fact, for his failure. Presuming that the driver is irrational, or just needs to be "educated," diverts attention from the root causes of driving problems.

THE DRIVER AS A DECISION MAKER AT RAIL-HIGHWAY CROSSINGS

In analyzing the literature, we found the most useful view of the driver, consistent with other human factors literature, to be that of a person who is continuously making decisions, based on all of the information available to him. To understand his actions, we must be sensitive to the information he does (and does not) have available, the behavioral options that exist, the costs and benefits of alternatives (from the driver's perspective), and the biases and attitudes he brings to the situation. Based on the analysis of the literature, our view is that the typical driver at a rail-highway crossing is a reasonably rational, if imperfect, decision maker who is trying to optimize his situation based on his knowledge and the facts at hand. He relies not only on formal information from the traffic engineer (e.g., signs, markings, signals), but also his own experience and the actions of others. The typical accident victim is usually quite familiar with the locale, and even the specific crossing, and has definite expectancies about the site's geometric, operational, and hazard characteristics.

Accepting this view of the driver as a decision maker, we can ask about the many factors that can influence decision making at a site. The Lerner et al. (1989) report described a number of these factors at length and discussed their implications. To take one illustrative example, consider the problem of conflicting safety concerns. At unprotected crossings, an after-the-fact analysis may often suggest that the driver did not slow down sufficiently so that he had adequate sight distance along the track and adequate decision time to reach an appropriate judgment. Safety literature, such as that put forth by "Operation Lifesaver," warns drivers to slow down and be defensive on the approach to a crossing, and even proffers the "stop, look, and listen" message (even though stopping is not mandatory for typical vehicles). However, the driver is not soley considering the risk of a possible train (which objectively may have a very low likelihood), but also the risks of collisions with other traffic, particularly vehicles behind him. Comprehensive data on vehicle-vehicle collisions near rail-highway crossings are not available, but certainly the majority of crashes in the vicinity of a crossing do not involve a train (Mortimer, 1988). Speed variability becomes greater near a crossing, and vehicle headways become short when some vehicles slow down. Drivers of vehicles (e.g., buses, certain trucks) which have special requirements to stop at unprotected crossings show serious concern about rear-end collisions and in fact often disregard the stopping requirement (Lerner et al., 1989). Bowman and McCarthy (1985) quote a trucking industry representative: "from the motor carrier's point of view, the grade crossing problem is greater in terms of vehicle-to-vehicle collisions than from train-vehicle collisions... The trucking industry believes that each time a stop can be eliminated, an accident producing situation can also be eliminated." At many crossings, then, a driver may suffer a conflict between slowing sufficiently to have ample warning of a train, versus risking collision from following traffic. Whether the driver's decision is cast as correct or incorrect, there is certainly a decision problem which can be overlooked in describing a vehicle-train collision as due to a careless driver not slowing sufficiently.

The Lerner et al. (1989) report identified fourteen significant factors potentially contributing to decision making errors at rail-highway crossings, which are briefly described below.

Information Limitations and Ambiguity

The information presented to the driver may be both limited and ambiguous. Some examples of limited information include: distinction of active vs. passive crossings in advance signing; train direction, speed, distance; location of the hazard zone. An example of an ambiguous situation is a driver approaching a crossing and being aware that he does not see any flashing lights; does this mean that it is a passive crossing, an active crossing with no train approaching, an active crossing with the flashing lights not yet in view, or an active crossing with a signal that is not working properly?

Information Credibility

Warnings lose their effectiveness if they are not credible, and this is a concern for grade crossing traffic control devices. Credibility can be weakened by such circumstances as inappropriately long warning times, false signals, signing retained at abandoned crossings, or even the low-train volume crossing where a driver repeatedly encounters (passive) warnings with no subsequent trains.

Expectancies Regarding Trains

Drivers have general expectancies about train traffic, and may have specific expectancies about the particular crossing being encountered; accident studies have found a large number of victims to be locally familiar. Relevant types of expectancies include the likelihood of a train, train schedules, train speed, and the length of delays if a train is encountered.

Expectancies Regarding Crossings

Drivers also have expectancies about the crossing site itself. For example, many motorists believe that all, or nearly all, crossings are protected by active devices. Expectancies may also be induced by the nature of the roadway; for example, if there is a high-quality road with good sight distance, the driver may not expect sight distance problems along the track.

"Costs" of Compliance

Viewed as a choice situation, any driving decision may have both "costs" and "benefits." The costs of compliance with grade crossing warnings include delay and annoyance. Research suggests that many drivers have exaggerated estimates of the length of a typical delay.

Temporal Constraints

Processing information, making a decision, and executing that decision takes time. The duration of that process can be long relative to the temporal constraints imposed at many crossing sites, due to factors such as limited sight distance, vehicle speeds, train speeds, and the complexity of decisions.

Competing Inputs

Drivers are always forced to share attention across a variety of driving subtasks; consideration of the likelihood of a train, or its closing rate, is never the driver's sole concern. Sometimes other inputs, such as potential conflicts with other traffic, or road geometry, may be especially commanding. Negotiating the tracks themselves, particularly if bumpy, can command motorist attention away other crossing-related decision making.

Decision Making as a Disruptive Activity

The very act of having to make a decision can be disruptive. Increased "mental workload" and switching of attention can impair complex task performance. Furthermore, mental activity can affect overt behavior in a manner that is not appreciated by the driver; for example, a driver may slow down while making a decision, but not take his slowing into account in that decision.

Recognition of Capabilities and Biases

In making decisions about the safety of various actions (e.g., gap acceptance), the motorist must recognize his own abilities and limitations. Various "illusions" peculiar to the perception of trains can bias judgments of speed and distance in ways in which the driver is unaware. Also, his experience about the accuracy of such judgments will be based primarily on feedback from vehicle traffic situations, inflating his estimate of accuracy.

Conflicting Messages

Rail-highway crossing signs and signals are only part of the total message, formal and informal, that the motorist receives. The very appearance of the roadway, as well as the actions of traffic, may carry the implicit message "keep moving."

Other Safety Concerns

A driver's actions may be influenced by concerns with other safety considerations, such as maintaining headway or path tracking. This factor was illustrated earlier in the discussion of vehicle-vehicle collisions.

Effort

Safety behaviors are sensitive to the degree of effort involved, even when that effort would appear to be trivial relative to the consequences of a collision. One example is at oblique rail-highway crossings, where the driver must turn considerably to look up the track in one direction. Given the visibility problems at oblique crossings, one might expect drivers to exhibit more looking behavior at such sites, but the opposite appears to be true.

Social Influences

Driving is an activity that does not take place in a social vacuum, and can be influenced by social factors. For example, drivers generally make more cautious decisions when there are passengers in the car, except when a male driver is accompanied by a male passenger, in which case decisions may be more risky. Driver decisions can also be influenced by other motorists in various ways (social pressure, social facilitation, local norms).

Emotional Reactions

A driver's decisions at grade crossings can be influenced by his emotional state. For example, frustrations of driving in traffic can lead to impatience and aggressive driving.

In noting these decision-making factors, none of this is intended to understate the range of other types of problems that impact grade crossing safety: inadequate understanding, visibility, difficult perceptual judgments, attitudes toward law and toward safety, alcohol or drug impairment, and so forth. But the emphasis on viewing the driver as a rational person who is not making the kind of decisions we want puts the problem in a helpful context. We can then attempt to understand and address the kinds of factors that influence these decisions.

IMPLICATIONS

The view of the driver offered here suggests that while better education of the driving public regarding rail-highway safety may be beneficial, and may improve driver safety attitudes, it may nonetheless be of limited effectiveness because the greater part of the problem is in the difficulty faced by the driver as a decision maker. Rather, this view emphasizes countermeasure approaches directed at: making the information credible and usable; making the proper behavior clear and well defined; removing conflicts; making other options less desirable; influencing behavior early in the decision chain; and considering driver information in a system context. Some of these objectives are accomplished through raising the level of crossing protection using standard procedures, e.g., upgrading a passive crossing to one protected by train-activated flashing signals, or further upgrading to a gate. However, these can be costly and so cannot be seen as appropriate at all crossings. Lerner et al. (1989) further discuss some alternatives, but the challenge remains to develop more effective, cost-efficient treatments that meet the real problems of drivers. Acknowledging that there are such problems, and defining them, are steps that may have been overlooked too often by a willingness to label the driver as simply careless or reckless.

ACKNOWLEDGMENTS

The literature review upon which this article is based was funded by the Federal Highway Administration (Contract DTFH61-88-Z-00145). However the contents of this article reflect the views of the authors, who are responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the Department of Transportation.

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DRIVER BEHAVIOR AT

RAIL-HIGHWAY GRADE CROSSINGS:

A SIGNAL DETECTION THEORY ANALYSIS

Thomas G. Raslear, Ph.D.

Office of Research and Development

Federal Railroad Administration

INTRODUCTION

Signal Detection Theory (SDT) is often used in studies of sensory psychology and perception to describe laboratory experiments in which subjects are asked to detect small changes in very well-controlled, precisely defined stimuli such as the intensity of a monochromatic light or the frequency of a pure tone. Consequently, it may seem odd that such a theory can be of any practical use in describing the situation that occurs when the driver of an automobile approaches a grade crossing and must decide whether it is safe to drive across the railroad track(s). Locomotives and trains are not well-controlled and precisely defined stimuli like those used in the sensory laboratory. By comparison with the stimulus changes used in the laboratory, a locomotive surely represents an enormous potential change in the sensory environment of the automobile driver. Why then is this theory applicable to the driver at the grade crossing? The answer to this question lies in an examination of the types of accidents that occur at grade crossings which suggest that motorists have difficulty with the tasks of detecting trains and related decision-making at grade crossings. For instance, motorists regularly drive into the side of passing trains at grade crossings and drive directly in front of approaching trains at close range. These accidents suggest that an examination of the grade crossing from the perspective of SDT and human information processing may provide a useful model for analysis, research, and the development of new strategies for grade crossing accident prevention.

The plan of this analysis is as follows. In Section I, the basic model of SDT is described with reference to a driver approaching a grade crossing with a train also approaching. The driver's task is to decide if he can cross the tracks safely or if he must stop. The treatment employs some mathematics, which can be omitted without losing the sense of the model. In describing the basic model, it becomes apparent that accident rates for different types of grade crossings are predicted by the SDT model to vary with train frequency. Section II examines accident rates at grade crossings and develops a Poisson process model of accident probability with reference to the frequency of trains and cars at grade crossings. The Poisson model predicts maximal accident rates and is useful for evaluating the effectiveness of different grade crossing devices in preventing accidents. The maximal accident rate concept is also used in Section III in applying SDT to a quantitative analysis of grade crossing devices. Section IV examines the implications of the SDT analysis for various schemes to improve grade crossing safety, contrasts the SDT model with existing models of accident prediction, and suggests areas of research which can be implemented to achieve Goal # 2 of the RDV Action Plan for Grade Crossings:

> Improve our understanding and knowledge of motorist behavior at grade crossings in causing collisions between trains and motor vehicles - including: 1) detection, recognition, perception and comprehension of warning devices and trains; and 2) decision making, perception of collision risk, and motivation involved in circumvention of active warning devices - in order to improve upon design, deployment and operation of grade crossing protection devices.

Section V models the performance of an ideal motorist who uses information concerning the distances

I. SIGNAL DETECTION THEORY

Detection of a Signal in a Background of Noise

The point of view to be developed here is that a motorist at a grade crossing with an approaching train is in an analogous situation to an observer attempting to detect a signal in a background of noise (for a more detailed description of SDT than is provided in this section consult Green and Swets, 1974 and Egan, 1975). In both instances, it is often difficult to distinguish signal from noise, and a decision is made which is not solely dependent upon the sensory information alone. From this point of view, the locomotive is a multi-sensory signal, and the same is true of the background noise. The train or locomotive has auditory, visual, tactile (vibration), and olfactory components which contribute to its "signalness". The background noise also consists of a variety of auditory, visual, tactile and olfactory components. In the SDT model both the signal and the noise are represented as a single perceptual continuum which varies in magnitude. Signals, such as the locomotive, are capable of producing perceptual magnitudes which vary between encounters, even when all of the sensory components are identical. Consequently, there is a probability distribution of perceptual magnitudes which are associated with a particular locomotive configuration (e.g., size, loudness, color, brightness, etc.). This distribution of perceptual magnitudes has a mean and variance which can be used to specify the perceptual magnitude of the locomotive as a signal. Similarly, the background noise also has a distribution of perceptual magnitudes which can also be specified by a mean and a variance. For the sake of simplicity it is often assumed that the distribution of perceptual magnitudes for noise and signal are gaussian or normal. Additionally, the basic SDT model assumes that the variances of signal and noise distributions are equal. Neither assumption is critical to the theory.

Figure 1 is a typical representation of noise and signal-plus-noise distributions in SDT. It should immediately be noted that the distributions overlap. The chief difference, from this point of view, between a signal and noise is that, on the average, signals have a larger mean percept magnitude than noises. The perceiver (the motorist in our case) can only distinguish between a signal and noise on the basis of the magnitude of the perceptual event. Given a perceptual event, the perceiver must decide if the event represents a signal or noise. The perceiver does this by adopting a criterion. In Fig. 1, a criterion line has been drawn to illustrate. If a perceptual event has a magnitude which falls to the right of the criterion, the perceiver decides that the event is a signal. If the event has a magnitude which falls to the left of the criterion, the perceiver decides that the event is not a signal. Hence, we have the following four-fold table, Table 1.[1] There are two response categories: "Yes, Stop (the train is too close)." and "No, Don't stop (the train is not too close).", and there are two possible events: a train is close to the crossing and a train is not too close to the crossing (or not present).

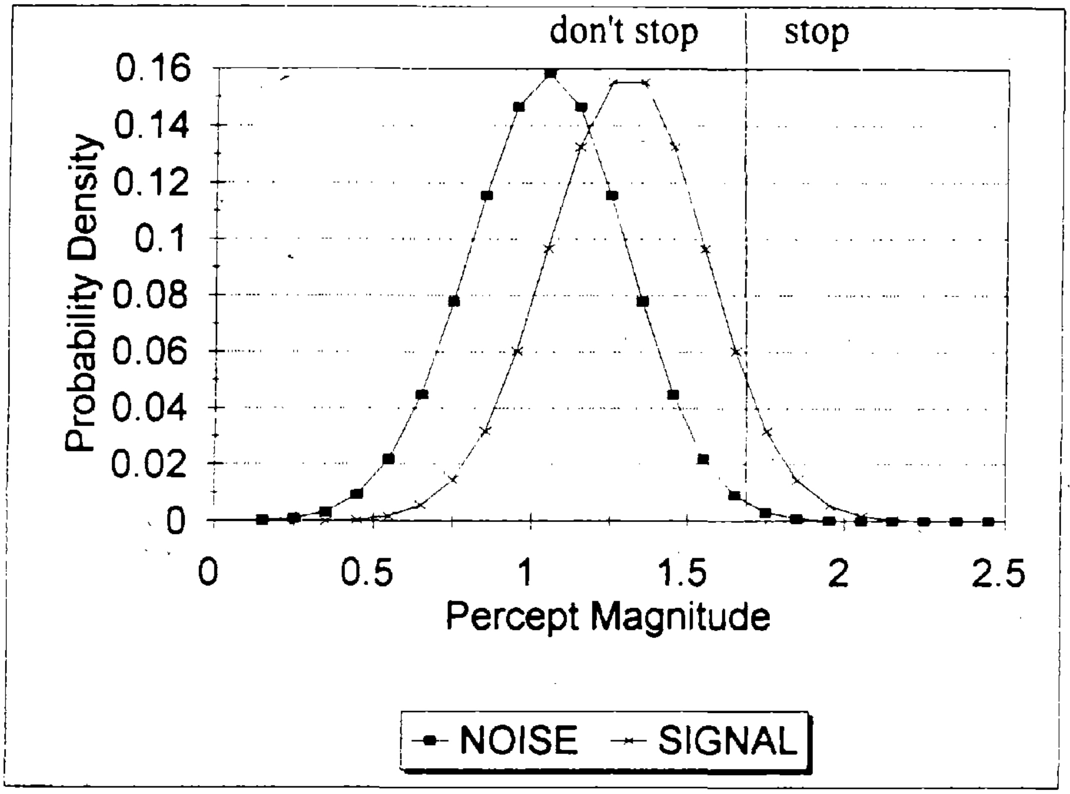

Figure 1. Noise and signal-plus-noise distributions. A criterion line is drawn to show how the probabilities of Table 1 are determined.

TABLE 1. STIMULUS AND RESPONSE MATRIX
FOR A MOTORIST AT A GRADE CROSSING.

	Yes, Stop.	No, don't stop.
Train is close	VALID STOP (motorist stops at crossing)	ACCIDENT (motorist doesn't stop)
Train is not close, or No train in vicinity	FALSE STOP (motorist stops unnecessarily)	CORRECT CROSSING (motorist crosses tracks safely)

If a train is close and the motorist decides not to stop, an ACCIDENT (AC) occurs. The decision to stop when a train is close is termed a VALID STOP (VS). The decision criterion divides the distribution of "train is close" percepts (signal distribution in Fig. 1) into VALID STOPs and ACCIDENTs. The criterion also divides the distribution of "train is not close" percepts (noise distribution in Fig. 1) into two parts: FALSE STOPs (FSs) and CORRECT

CROSSINGs (CCs). Since the two distributions are probability distributions, the probability of a VS (P(VS)) is the complement of the probability of an AC (P(AC)), etc. (i.e., P(AC) = 1-P(VS)). Moreover, since both distributions are divided by the criterion, only two probabilities are needed to totally describe the effect of changes in the criterion. In SDT these are usually P(VS) and P(FS).

The first point to note is that changes in the criterion do not change the detectability of the proximity of the train. The only aspect of this model which is capable of altering detectability is the separation of the signal and noise distributions. In this regard, there are three options: decrease the level of background noise, increase the level of the signal, and change the variance of one or both distributions. In a later section we will address the nature of the signal and the nature of the noise with a view to understanding safety issues. Changes in the criterion only change the probabilities of the outcomes, while changes in the distributions can effect a change in both detectability and the probabilities of the outcomes. Factors which affect the criterion are very important, especially if it is not possible to achieve an increase in detectability. These factors will also be addressed in a subsequent section.

To illustrate basic features of the SDT model, consider the criterion in Fig. 1 which is set at a percept magnitude of 1.65. As noted above, detectability is not influenced by the setting of the criterion, although the specific location of the criterion will determine the probability of accidents (P(AC). For example, the values of P(VS) and P(FS) in Fig. 1 at this value of the criterion are 0.055 and 0.0047, respectively. (It should be noted that P(VS) is the area under the signal curve to the right of the criterion, and that P(FS) is the area under the noise curve to the right of the criterion.) Because of the complimentary relationship between P(VS) and P(AC), the probability of an ACCIDENT is quite high with the criterion set at 1.65: P(AC) = 0.945. Leftward shifts in the criterion would increase P(VS) and decrease P(AC). For instance, if the criterion is set at a value of 1.35, then the values obtained for P(VS) and P(FS) are 0.34 and 0.08. A criterion set at 1.05 would cause P(VS) and P(FS) to have values of 0.79 and 0.42. Consequently, in these three examples the probability of an ACCIDENT (P(AC)) would change from 0.945 to 0.66 to 0.21. Note that these changes in the probability of an ACCIDENT have not involved changes in the detectability of the locomotive or train.

In SDT detectability is independent of the setting of the criterion. Mathematically, detectability (sometimes referred to as sensitivity) is defined as the difference between the means of the signal and noise distributions divided by their common standard deviation:

$$d' = \frac{\mu_s - \mu_n}{\sigma}. \tag{1}$$

In the example illustrated in Fig. 1, the mean of the noise distribution is 1.0 and that of the signal distribution is 1.25. Each distribution has been created to be normally distributed with a standard deviation of 0.25. As a result, the value of d' for the example in Fig. 1. will always be 1.0. In most practical situations, however, the means and standard deviations are usually not known. Under these circumstances detectability is often derived from outcome information, namely P(VS) and P(FS). Note that if the distributions are normal and of equal variance, then the formula for d' can be rewritten as the difference of two standardized (z-) scores. For instance, if a criterion c is selected, z-scores for the noise and signal distributions can be defined as:

$$z_n = \frac{c-\mu_n}{\sigma}, \tag{2}$$

and

$$z_s = \frac{c-\mu_s}{\sigma}. \tag{3}$$

By definition, z_s is the standardized score for HITS and z_n is the standardized score for FAs:

$$d' = z_n - z_s = \frac{(c-\mu_n) - (c-\mu_s)}{\sigma} = \frac{\mu_s - \mu_n}{\sigma}. \tag{4}$$

Because they are observable and can indicate the separation of the signal and noise distributions as well as the location of the criterion, P(VS) is often plotted as a function of P(FS) in a plot which is called a Receiver-Operator Characteristic (ROC) curve. Figure 2 illustrates this for the distributions shown in Fig. 1. Each point on a ROC curve corresponds to a particular criterion line. The line which connects the origin (0,0) with the upper right corner (1,1) corresponds to the ROC curve for identical signal and noise distributions (i.e., d' = 0). The ROC curve which is labeled "d' = 1" was generated from Fig. 1. The ROC curve labeled "d' = 2" was generated from the same noise distribution as that in Fig. 1, but with a signal distribution with a mean of 1.5 and a standard deviation of 0.25.

The ROC curve for d' = 2 illustrates the effect of an increase in detectability on the outcome probabilities. For a criterion value of 1.35, P(VS) = 0.725 and P(FS) = 0.08. Recall that for d' = 1, for the same criterion P(VS) = 0.34 and P(FS) = 0.08. Thus, an increase in detectability reduces the accident rate from 0.66 to 0.275 at a constant criterion.

Decision-Making: Setting the Criterion

Setting the criterion involves the process of decision-making. To this point we have not discussed how the criterion is set, or how a criterion can be changed. From the discussion above, it should be clear that the accident rate is directly influenced by changes in discriminability of the locomotive and by the setting of the criterion. Consequently, decision-making is an important aspect of the SDT model.

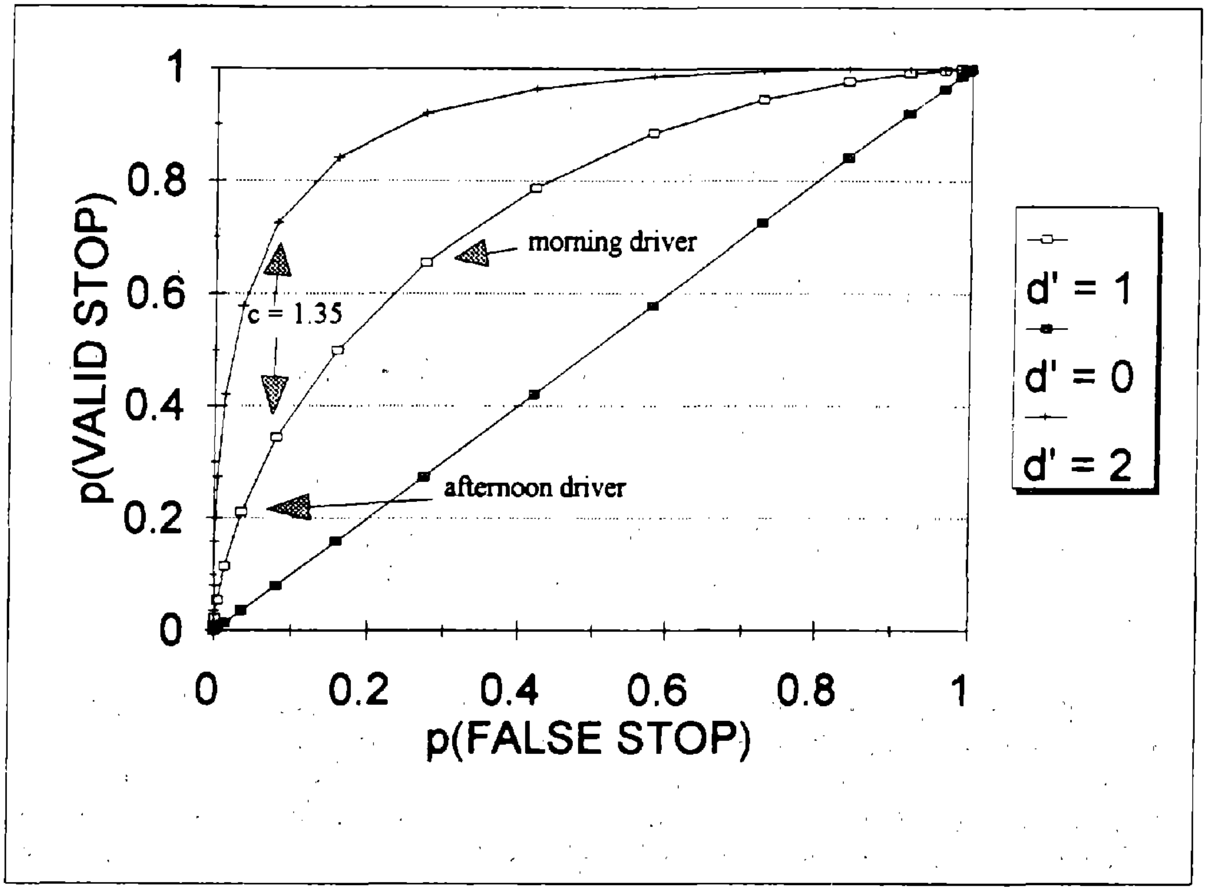

Figure 2. Receiver-operator characteric curves for Figure 1 and other conditions described in the text. The value, c = 1.35, indicates two points with a constant criterion.

As was noted above, the distributions of signal and noise are assumed to overlap. Suppose a perceptual event of magnitude x occurs which falls into the region of overlap. The probability that the event, x, came from the noise distribution is the conditional probability, $P(x|n)$. Similarly, the probability that x came from the signal distribution is $P(x|s)$. A rational decision concerning which distribution x came from can be made on the basis of these two conditional probabilities. The likelihood ratio (L), which is defined as $P(x|s)/P(x|n)$, indicates the likelihood that x arose from the signal distribution. Put differently, L indicates the strength of the evidence that the event was, in our example, a "train is close" percept. L is not a probability and can range from zero to infinity.

Signals and noise, however, do not always occur with equal probability. This is particularly true of trains at grade crossings. The probability of a signal P(s) and the probability of noise P(n) during any observation interval are important to the observer. In SDT these probabilities are called the prior probabilities. The observer has no control over the prior probabilities, but has knowledge of them based on experience, etc. If the prior probabilities are equal, then L provides a direct estimate of the odds that x arose from the signal distribution. The likelihood that the evidence was a signal or a noise is equal when $L = 1$. This occurs in Fig. 1 where the two distributions crossover. $L > 1$ for all perceptual magnitudes to the right of the crossover. Thus, the likelihood that the evidence was a signal is greater as the perceptual magnitude increases. If the prior probabilities are not equal, then the likelihood ratio does not provide an estimate of the odds that x arose from the signal distribution, and the posterior probabilities must be considered.

The posterior probabilities are the conditional probabilities of signals and noises given the sensory evidence, x: $P(s|x)$ and $P(n|x)$, respectively. Note first that since there are only two categories, s and n, $P(s|x) + P(n|x) = 1$. By definition the joint probability, $P(s,x) = P(x|s)\bullet P(s) = P(s|x)\bullet P(x)$. Consequently,

$$P(s|x)=\frac{P(x|s)\bullet P(s)}{P(x)}=\frac{P(x|s)\bullet P(s)}{P(x|s)\bullet P(s)+P(x|n)\bullet P(n)}. \tag{5}$$

The posterior probability, $P(n|x)$, can be similarly defined:

$$P(n|x)=\frac{P(x|n)\bullet P(n)}{P(x)}=\frac{P(x|n)\bullet P(n)}{P(x|s)\bullet P(s)+P(x|n)\bullet P(n)}. \tag{6}$$

The ratio of the posterior probabilities, $P(s|x)/P(n|x)$, is called the posterior odds and it indicates the likelihood that a signal was present given the evidence, x. The posterior odds are

$$\frac{P(s|x)}{P(n|x)}=\frac{P(s)}{P(n)}\bullet\frac{P(x|s)}{P(x|n)}=\frac{P(s)}{P(n)}\bullet L. \tag{7}$$

This last equation indicates that two sources of information are contained in the posterior odds: the relative frequency of occurrence of the two events, s and n, and the likelihood ratio. In this way the observer's expectations about the frequency of the events and the sensory information provided by the evidence are combined in the posterior odds. Decisions in SDT are made on the basis of the magnitude of the likelihood ratio, L, relative to some decision criterion. It is easily seen that L is a monotone function of the posterior odds.

Decision strategies come in many forms and may not even be rationally based. We will consider the most common strategy only. Decision strategies are usually the result of decision goals. A common goal in forming decisions is to maximize the expected value. Assume that the observer has a value (positive or negative) for each of the outcome cells in Table 1. Table 2 illustrates this.

TABLE 2. PAYOFF MATRIX.

	Yes, stop	No, don't stop
Train is close	V(s,Y)	V(s,N)
Train is not close	V(n,Y)	V(n,N)

In Table 2 each of the outcomes has a probability of occurrence as well as a value. The expected value of an outcome, by definition, is its probability multiplied by its value. The probabilities of concern here are the joint probabilities of signal and a "Yes" response [P(Y,s)], a noise and a "Yes" response [P(Y,n)], etc. By definition, $P(Y,s) = P(Y|s) \cdot P(s)$, $P(Y,n) = P(Y|n) \cdot P(n)$, etc. The expected value of the decision is the sum of all of the expected values for the outcomes. Hence the expected value, E(V), for Table 2 is

$$E(V) = P(Y|s) \cdot P(s) \cdot V(s,Y) + P(Y|n) \cdot P(n) \cdot V(n,Y) + P(N|s) \cdot P(s) \cdot V(s,N) + P(N|n) \cdot P(n) \cdot V(n,N).$$

The goal is to maximize E(V) which is accomplished by drawing the criterion line so as to achieve this. This is done by maximizing: $P(Y|s) - \beta P(Y|n)$. Green and Swets (1974) show that β is given by

$$\beta = \frac{V(n,N) + V(n,Y)}{V(s,Y) + V(s,N)} \cdot \frac{P(n)}{P(s)}. \tag{8}$$

The expected value is maximized by saying "Yes" whenever the likelihood ratio, L, is equal to or exceeds β. In short, β defines the location of the criterion line in Fig. 1.

If $P(s) = P(n)$, then β is only determined by the values of the outcomes. If all of the values of the outcomes are equal, β is only determined by the prior probabilities. When the values of the outcomes are all equal and the prior probabilities are also equal, $\beta = 1$. As was noted above, this is the value of L at the crossover of the signal and noise distributions in Fig. 1.

We are now in a position to examine the effects of bias on the decision-making of our motorist. In SDT bias is defined as the tendency of an observer to place his or her criterion anywhere except at the intersection of the noise and signal distributions (i.e., $\beta \neq 1$). Bias is independent of detectability (also called sensitivity or discriminability and measured by d' as noted above) and is determined by the observer's expectations (probability of signal, probability of noise), motivation (values of each of the decision outcomes), and other cognitive functions (e.g., memory, attention, decision strategy). For instance, a driver who is familiar with a particular grade crossing has an expectation regarding the frequency of trains at that crossing. We will use as an example a crossing where the frequency of trains varies markedly with time of day: on a railroad which carries only heavy morning and evening commuter trains. Drivers who use the crossing at different times of day will have markedly different expectations regarding the frequency of trains at the crossing. This is captured by the prior probabilities. Suppose trains are more frequent between 7 AM and 9 AM than they are between 1 PM and 3 PM, and that Driver #1 (the morning driver) uses the crossing to go to work between 7:30 AM and 8 AM and Driver #2 (the afternoon driver) uses the same crossing between 1 PM and 3 PM to visit a relative in a nursing home. If $P(s) = 0.62$ (62 out of 100 times the driver encounters a train at the crossing) for the morning period and $P(s) = 0.26$ (26 out of 100 times the driver encounters a train at the crossing) for the afternoon period, the ratio, $P(n)/P(s)$ for the two periods are $0.38/0.62 = 0.61$ and $0.74/0.26 = 2.8$, respectively. Hence, for the morning $\beta = 0.61$ and for the afternoon $\beta = 2.8$. Both drivers have a bias, because $\beta \neq 1$. For the morning driver, there is a bias to say "Yes, the train is close, stop" given the identical sensory information that the afternoon driver gets. This can also be viewed in terms of the perceptual magnitudes that each driver would require to indicate that he or she detects a close train (i.e., the "threshold" for detection). Referring to the distributions of Fig. 1, one can find the perceptual magnitudes which correspond to the values of β. Expected value is maximized by saying "Yes" whenever L is equal to or exceeds β. L is the ratio of the probability densities at each percept magnitude in Fig. 1. Thus, values of L map directly onto percept magnitudes in Fig. 1. Given the distributions in Fig. 1, a percept magnitude of 1.15 would be the "threshold" for the morning driver to say a train was close, and a percept magnitude of 1.45 would be the "threshold" for the afternoon driver. For the morning driver $P(VS) = 0.65$ and $P(FS) = 0.27$, while for the afternoon driver $P(VS) = 0.21$ and $P(FS) = 0.035$. Referring to Table 1, the probability of an ACCIDENT (P(AC)) is 0.35 for the morning driver and 0.79 for the afternoon driver, even though all other conditions are identical. It should be also kept in mind that for both drivers the train is assumed to be equally discriminable. This is shown in Fig. 2.

This observation may appear surprising, but it has been made previously with regard to the rail-highway grade crossing by Lerner et al. (1990, p. 3-12):

> A related principle from the area of signal detection theory is that the higher the perceived probability of an event, the higher is the likelihood that an observer will report having detected the event. If the driver assigns a low probability to the presence of a train at a rail-highway crossing, he will adopt a higher criterion for detecting the train, and this will increase his chances of missing the train. It is important to note that the criterion for detection is not consciously set, but rather corresponds to the amount of visual "evidence" required for detection.

SDT predicts that expectations play a major role in accidents at rail-highway grade crossings. All other things being equal, this analysis suggests that crossings with a lower frequency of trains should have a higher accident rate. Thus, for a particular type of crossing (active vs. passive protection, etc.), the frequency of trains should vary inversely with the accident rate at the crossing. This prediction will be explored in Section II.

Expectations also play a role with regard to signage at grade crossings. From the point of view of SDT, a role of signage is to inform the motorist that trains are frequent at the crossing. Personal experience with a crossing, however, is likely to be more important since a sign does not indicate the actual frequency of trains. Motorists who are unfamiliar with a grade crossing which has signage posted should assume that trains are highly frequent and exhibit a high degree of caution relative to motorists who are familiar with the crossing. This prediction of SDT is supported in the literature. Lerner et al (1990, p. 3-61) state that

> There is no question that familiar and unfamiliar drivers often behave differently at crossings, and that traffic is sensitive to the schedule of train operations. Sanders et al. (1973) found that driver looking and speed reductions were inversely correlated with the frequency of using the crossing. Expectancies based on familiarity have been implicated in accident causation research (Knoblauch et al., 1982). Sanders et al. (1973) also found that drivers were sensitive to the actual frequencies of trains. The correlation of looking with train frequency at the crossing was r = 0.66, and the correlation of speed at the crossing with train frequency was r = -0.85. Others have reported similar findings (e.g., Aberg, 1988).

Values associated with decision outcomes are also predicted to play a role in driver behavior at grade crossings. Again, the analysis assumes that all other aspects of the situation are the same, including the detectability of the train. Consequently, the distributions of Fig. 1 will again be used.

Recall that the morning motorist was driving to work and that the afternoon motorist was driving to visit a relative in a nursing home. For both drivers this is a daily trip. However, there are different values associated with the outcomes of decisions at the crossing for each driver. Moreover, the values are not necessarily monetary or even linear with dollar value. Thus, for the purposes of illustration, numbers indicating relative subjective value will be assigned to the outcomes in the payoff matrix so as to allow β to be calculated.

TABLE 3. PAYOFF MATRIX FOR MORNING DRIVER.

	Yes, stop	No, don't stop
Train is close	0.5	-20
Train is not close	-10	1

TABLE 4. PAYOFF MATRIX FOR AFTERNOON DRIVER.

	Yes, stop	No, don't stop
Train is close	1	-20
Train is not close	-1	1

Tables 3 and 4 present payoff matrices for the morning and afternoon drivers, respectively. For both drivers it is assumed that a very large negative value is associated with the error of saying "No" when in fact a train is close. Also, for both drivers there is a relatively small positive value associated with correctly saying "No". The drivers differ with regard to the values of the "Yes" responses. The morning driver is going to work, and saying "Yes" means that he will delay his arrival at work because of a necessary or unnecessary stop at the crossing. Consequently, a moderately high negative value is associated with stopping unnecessarily, and a very low positive value is associated with stopping for a train. By contrast, the afternoon driver has equally low values associated with the consequences of a "Yes" response.

If we assume that $P(s) = P(n)$ for each driver, the value of β for the morning driver is 0.54, while for the afternoon driver it is 0.095. In terms of thresholds, the morning driver requires a perceptual magnitude of 1.03 to cause a stop; the afternoon driver requires only a perceptual magnitude of 0.58. Because of the perceived negative consequences associated with stopping, the morning driver is much more willing to risk an accident.

It was previously noted that the frequency of trains differed substantially for the morning and afternoon drivers. When this is also included in the calculation of β, it is found that the morning driver now requires a perceptual magnitude of 0.8 ($\beta = 0.33$) and the afternoon driver requires a perceptual magnitude of 0.85 ($\beta = 0.27$). Thus the higher frequency of trains in the morning causes the morning driver to become more conservative, while the lower frequency of trains in the afternoon causes the afternoon driver to become less conservative.

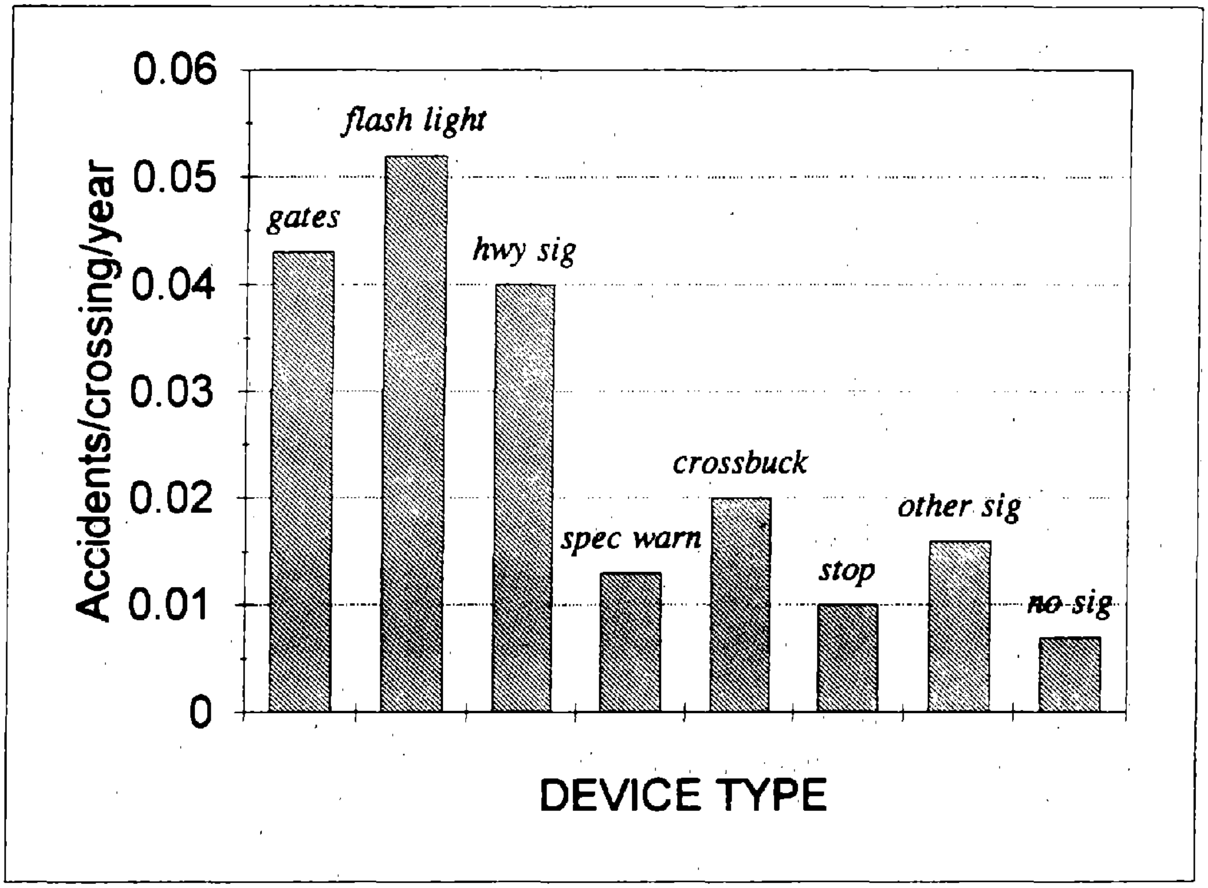

Figure 3. Accidents per crossing per year for the year 1986. See text for details.

SDT predicts an inverse relationship between train frequency at a grade crossing and the accident rate at that crossing. This prediction appears to be counterintuitive, since one would expect the highest accident rate to occur where the exposure is the highest. This section discusses accident rates and exposure.

<u>Accident Rates and Exposure</u>

Accident rates are usually reported so as to equalize differences in exposure. For example, the <u>Rail-Highway Crossing Accident/Incident and Inventory Bulletin</u> reports accidents as a rate (accidents per crossing per year) for each of the grade crossing protection device categories[2] rather than as accidents per year. This is because there are different numbers of crossings which are protected by the various devices, and the most common device will have more opportunities for accidents. However, this is not sufficient to equalize the accident exposure of different devices. For instance, as can be seen in Figure 3, the accident rate is much higher for categories 8 (gates), 7 (flashing lights) and 6 (highway signals, wigwags, or bells) than for any other device category. However, since device categories differ with regard to the number of trains per day and the number of cars per day that traverse the crossings at which they are placed, it is obvious that the device category with a higher amount of train and/or car traffic will have a higher accident rate. To reflect the true (equal exposure) accident rate for each device category the rate should be reported as the number of accidents per crossing per train per car per year (i.e., divide the reported accident rate by the average number of cars and by the average number of trains). The analysis of train frequency which follows uses equal exposure accident rates.

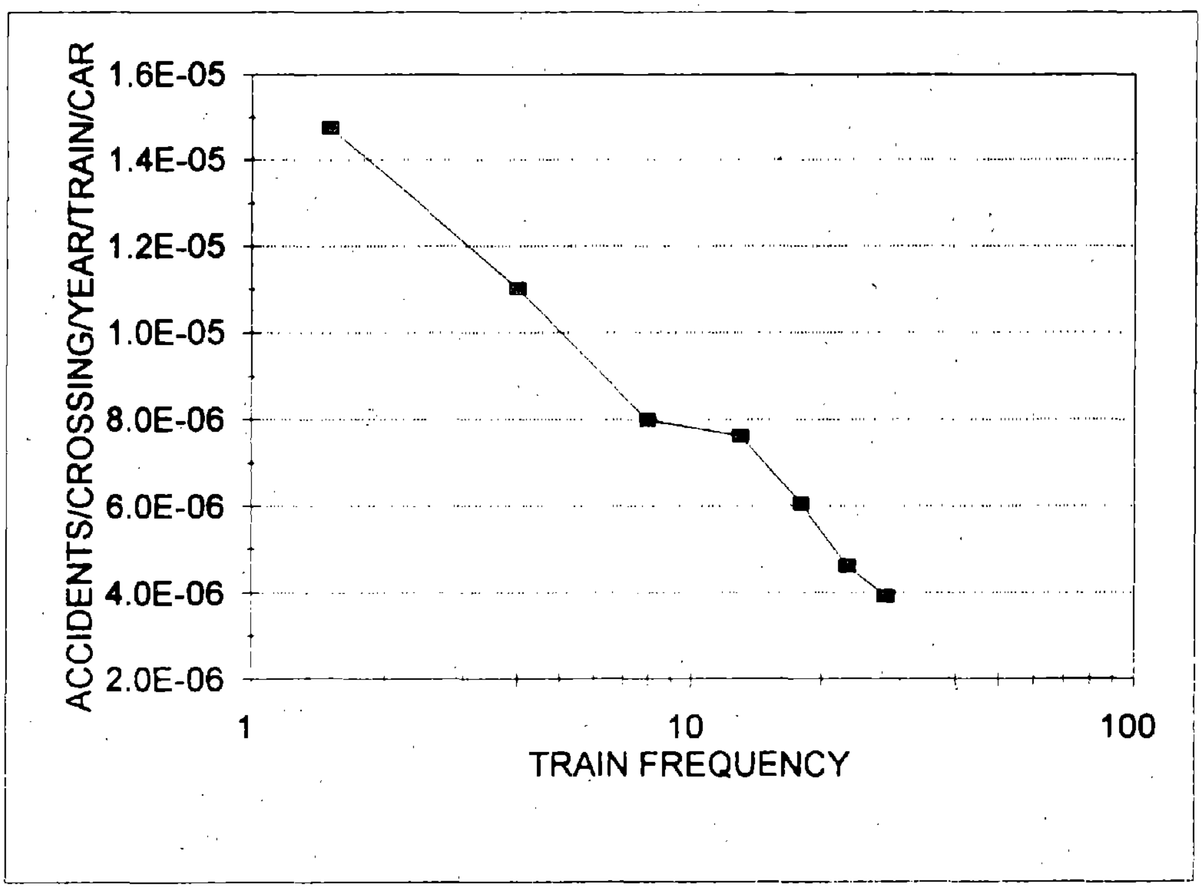

Figure 4. Accidents per crossing per year per train per car as a function of train frequency.

Train Frequency and Accident Rate

Based on data provided in the Rail-Highway Crossing Accident/Incident and Inventory Bulletin, Figure 4 plots accidents per crossing per train per year as a function of train frequency for 1986. From Fig. 4 it is clear that the prediction of SDT is correct. Per train, accident rates are higher for crossings with the lowest frequency of trains. This is a direct effect of the decision-making process at the crossing because P(S)/P(N) determines the setting of the criterion, as described in Section I.

Figure 4 plots accident rate as a function of train frequency averaged across device types. Protection devices are placed at grade crossings on the basis of the number of cars and trains at that crossing. In fact, the device categories noted above constitute a rank ordering of devices with respect to train and car frequency. Consequently, SDT also predicts that that rank ordering, to the extent that it reflects train frequency (which it only does partially), should be inversely related to equal exposure accident rate.

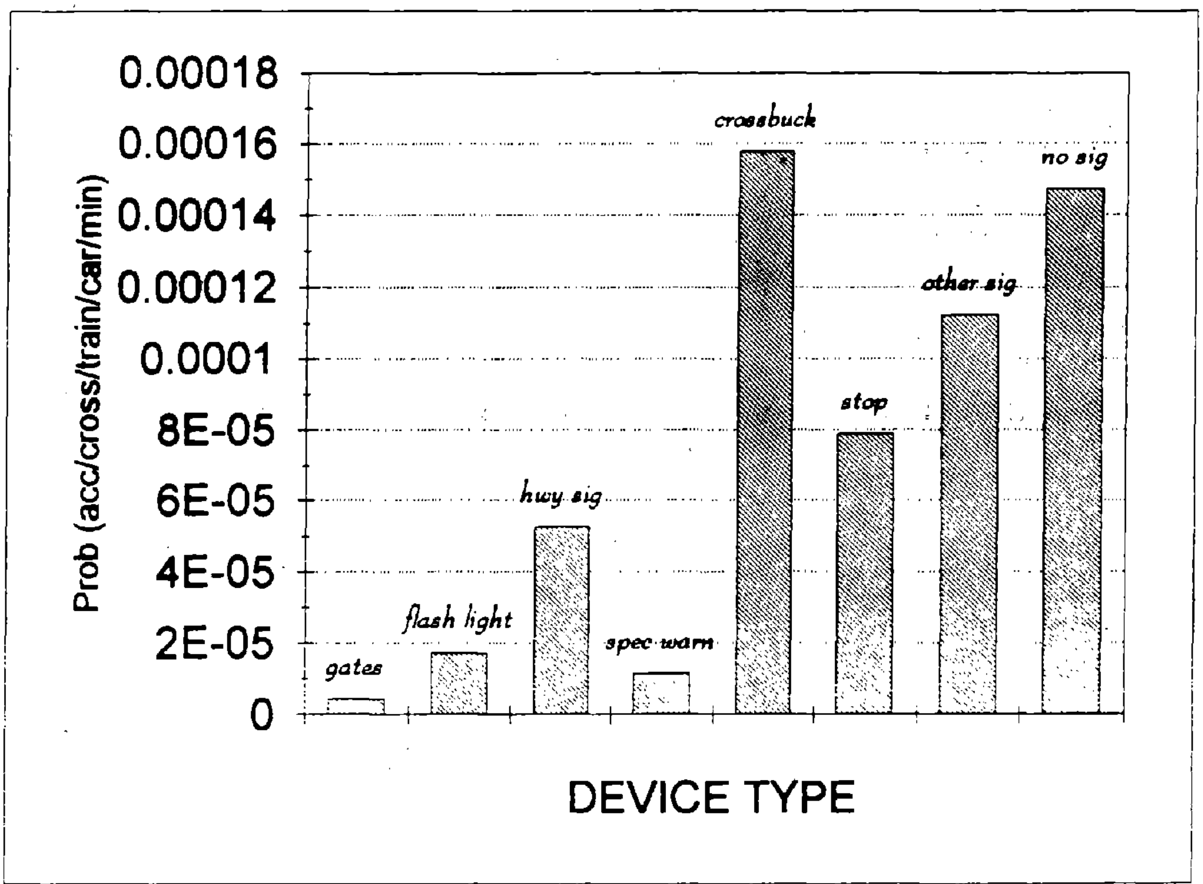

Figure 5. Equal exposure accident rates (accidents per crossing per train per car per minute) for the various device categories. See text for details.

Information on the frequency of trains and cars for different device categories is also provided in the Rail-Highway Crossing Accident/Incident and Inventory Bulletin. Tables 53 and 58 in the 1986 bulletin are typical. For easy reference, they are presented as Tables A1 and A2 in the Appendix.

There are two problems with the information that is presented in Tables A1 and A2. First, the frequencies are reported per day rather than per year. Obviously, all the units of frequency should be the same, and for reasons which will soon be apparent, all rates in this report will henceforth be expressed as the number of observations per minute. Second, a frequency distribution is provided for each category rather than a single measure of central tendency such as a mean. With regard to this problem, since the frequency distributions include bins for < 1 and > 25, a mean cannot be calculated from the information provided. A reasonable alternative, the median (which is also a robust measure of central tendency), can be easily calculated and is used to estimate the average number of trains and cars per min for each device category. This information is presented in Table 5.[3]

Figure 5 shows the equal exposure accident rate (accidents/crossing/train/car/min) for the various device categories. Given the normalization for traffic (cars and trains) exposure through different crossings, it can be seen that crossings with only crossbucks have the highest accident rate and crossings equipped with gates have the lowest rate. With the exception of crossbucks and special warning devices, the inverse relationship predicted by SDT holds well. As noted above this discrepancy could be due to the fact that the rank ordering of the devices also includes the frequency of cars.

TABLE 5. Median Train and Car Frequencies As a Function of Grade Crossing Warning Device Category.

Device Category	Median Trains/min	Median Cars/min
Gates	0.009	2.08
Flashing Lights	0.0028	2.08
Highway Signals	0.0028	0.52
Special Warnings	0.001	2.08
Crossbucks	0.0028	0.09
Stop Signs	0.0028	0.09
Other Signs	0.001	0.26
No Signs or Signals	0.001	0.09

The above analysis suggests that, in part at least, the accident rate at grade crossings is determined by decision-making processes based on the frequency of trains at the crossing. This aspect of the decision-making process (i.e., the aspect that relates to train frequency) is probably independent of the grade crossing device, unless the device also conveys information to the motorist concerning train frequency. In the absence of objective information concerning the frequency of trains at a crossing, motorists must be assumed to rely on the perceived and remembered frequency of trains. This could be problematic, because the heuristics that people use to estimate the probability of an event can lead to severe and systematic errors (Tversky and Kahneman, 1974). For instance, a motorist who normally travels over a grade crossing when there is light train traffic could wrongly conclude that the same is true at all times of day. Accurate information concerning the frequency of trains at a grade crossing could help to ameliorate the contribution of these effects to accidents.

Grade Crossing Protection Device Effectiveness

The above analysis begs the question of how effective different grade crossing devices actually are. At first glance one might suggest that the equal exposure accident rate speaks to this point, but careful consideration of Fig. 5 indicates that there is a problem with accident rate data. For instance, crossings protected by crossbucks have an even higher accident rate than crossings which have no signs at all. Since we would expect any sign to be more effective than no sign, this illustrates the problem, noted above, of using accident rate data as an indicant of device effectiveness. The accident rate confounds the reduction in accidents with the risk of accidents. Adjusting the accident rate for exposure does not unconfound these elements because we do not know how many accidents might have occurred if no device was in place. Two elements are required to determine the effectiveness of a device to prevent accidents: the accident rate (observed frequency of accidents) and the accident risk (how many accidents would have occurred if the device was not in place). In the previous subsection an equal exposure accident rate was developed. In this subsection we develope a metric for accident risk. In the following section (Section III), we use that information to ask a more complex question: do grade crossing devices achieve their effectiveness by enhancing the signal-to-noise ratio (S/N) or by changing the location of the criterion?

Accident risk

Accident risk is defined here as the probability that both a train and a car will be observed at a grade crossing during any one minute observation period. As noted above, the Rail-Highway Crossing Accident/Incident and Inventory Bulletin provides information on the frequency of trains and cars for the various device categories. The average (i.e., median) frequency of trains and cars for each device category was used to equalize exposure for the accident rate data. The same information can also be used to determine accident risk.

Two probabilities are required to determine accident risk for a particular grade crossing or a grade crossing category: the probability that in a one minute period one or more trains will be observed at the grade crossing and the probability that in a one minute period one or more

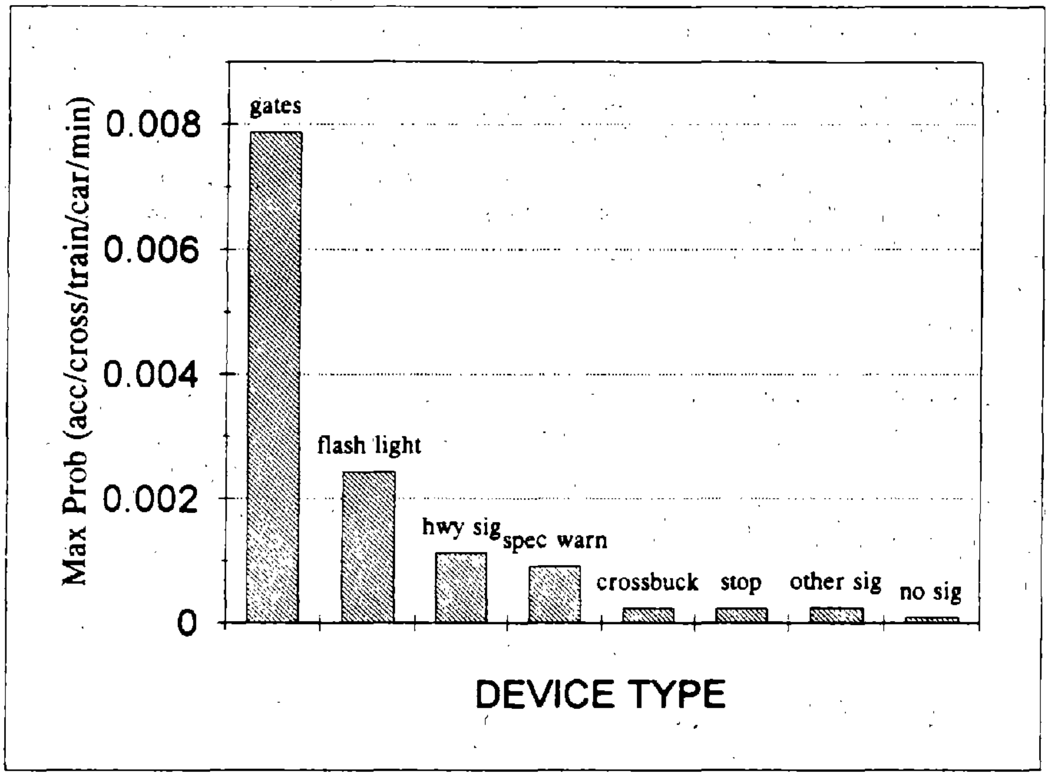

Figure 6. Maximum probability of an accident for various devices. See text for details.

cars will be observed at the grade crossing. If we assume that trains and cars are random events, equally likely to occur throughout the day, and that each occurrence of a train or a car is independent of the occurrence of other trains or cars, then the Poisson probability distribution can be used to model the situation (see Feller (1957), Parzen (1960), and Daniel (1974) for more detail on the Poisson distribution and its uses).

If x is the number of occurrences of a train (car) in a one minute[4] period of time, the probability that x will occur is

$$p(x)=\frac{e^{-\lambda}\lambda^{x}}{x!}. \tag{9}$$

The parameter λ is the mean rate of occurrence, and can be estimated by the average frequency of trains (cars) as described above[5]. The probability that one or more trains (cars) will occur in a one minute period of time is the cumulative Poisson probability distribution for $1 \leq x \leq \infty$, or $1 - p(0)$. This can be written as

$$p(1 \leq x \leq \infty) = 1 - e^{-\lambda}. \tag{10}$$

The product of the probability of one or more trains being observed in a one minute period and of the probability of one or more cars being observed in a one minute period at the crossing provides an estimate of the maximum probability of an accident (i.e., risk). This is presented in Figure 6 for the various categories of protection devices. Since the risk of an accident is based on the probability that one or more cars and trains will be observed at a grade crossing within a specified one minute period, and these probabilities are based on the frequency of trains and cars at grade crossings, it is not surprising that the greatest risk exists for those devices which have the greatest aggregate train and car traffic. This supports the validity of the procedure for estimating accident risk.

Device Effectiveness

Given an estimate of risk (accident probability) and an observed rate of accidents for various crossing devices, device effectiveness is easy to estimate. It should first be noted that since risk is defined as a probability, it is not necessarily directly comparable to the observed accident rate. However, at the low rates of occurrence observed in Fig. 5, the accident rate is the same as the probability of observing one or more accidents in a one minute period at a grade

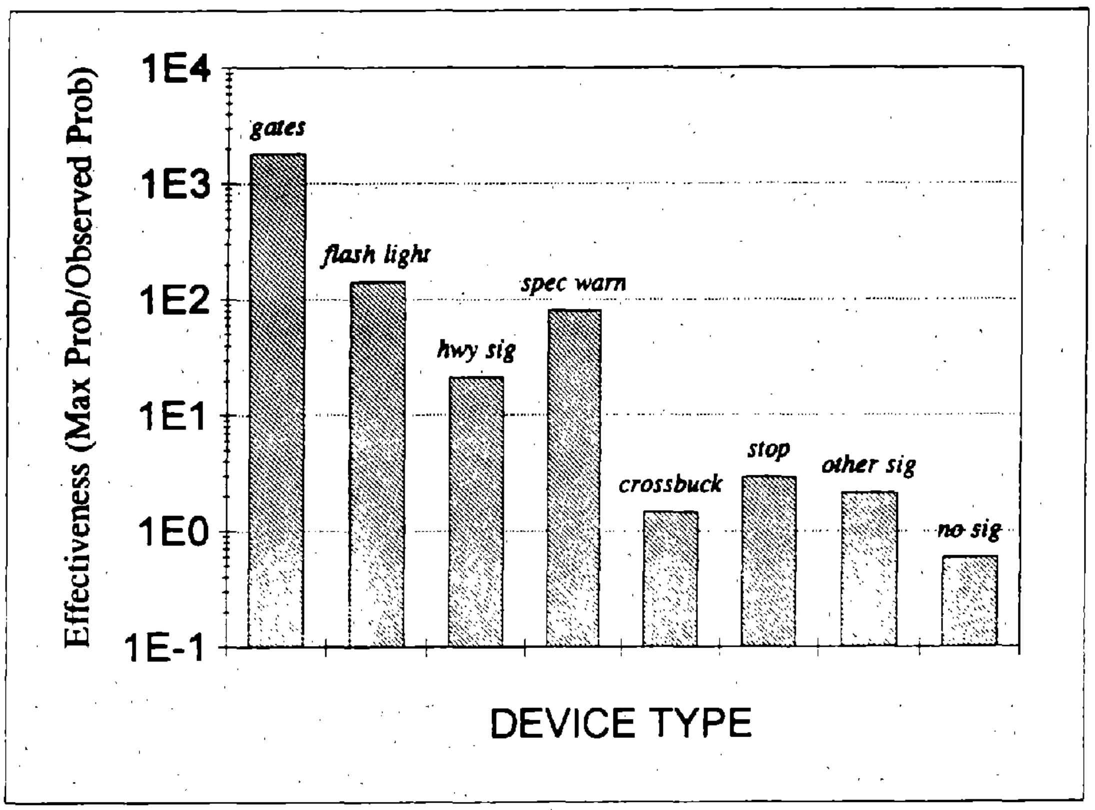

Figure 7. Device effectiveness for various grade crossing devices. See text for details.

crossing.[6] It should be noted that the abscissa in Fig. 5 is already labeled as a probability domain.

Device effectiveness is determined by comparing the risk of an accident (maximum probability) with the observed probability of an accident. Figure 7 shows the ratio of the risk to the observed probability for each device category on a logarithmic scale. If the ratio has a value of 1, the device has no effectiveness since the observed probability of an accident is the same as the risk. Ratios greater than 1 indicate increasing levels of effectiveness. Gates are the most effective devices, followed by flashing lights, special warnings, and highway signals. Passive devices are less effective than active devices by an order of magnitude. Finally, grade crossings without any protection (no signage) have a higher probability of accidents than is expected on the basis of train and car traffic.

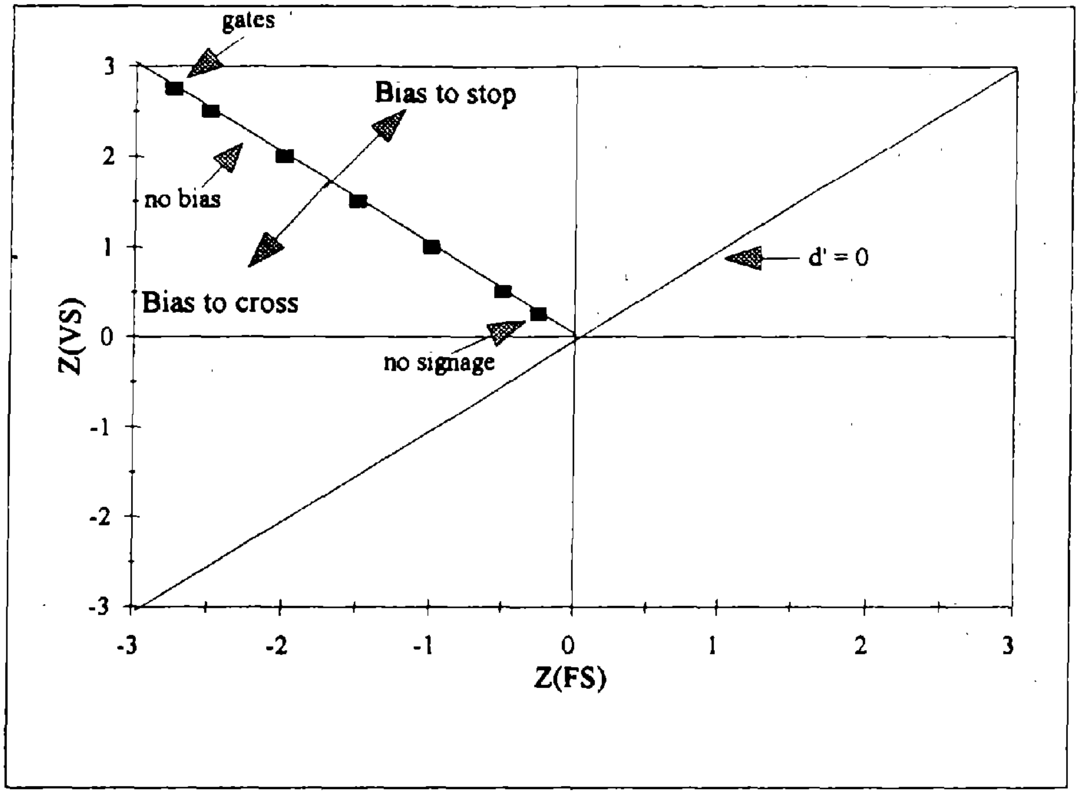

Figure 8. Hypothetical ROC plot demonstrating the possibility that grade crossing devices differ in effectiveness because of sensitivity differences. The major diagonal (lower left corner to upper right corner) shows zero sensitivity (d' = 0). The minor diagonal (upper left corner to origin) shows zero bias. Points which fall above the minor diagonal have a bias to stop, while points which fall below the minor diagonal have a bias to cross. The devices all have points along the minor diagonal (no bias) but differ in sensitivity. Gates have the highest sensitivity (d' ≈ 6), and no signage has the lowest sensitivity (d' ≈ 0.2). See footnote 7 for details concerning the use of different axes in this figure and in Fig. 2.

In the previous section we determined the relative effectiveness of the various categories of grade crossing protection devices. In this section SDT is applied to grade crossing devices to determine the source of that effectiveness. From the point of view of SDT, there are two major, independent classes of variables which can influence effectiveness. One is the separation of the signal and noise distributions. For a constant decision criterion, as the S/N ratio increases, the probability of an ACCIDENT (P(AC)) decreases. This factor involves the relative magnitudes of the signal (train) and the noise (everything else in the immediate vicinity of the grade crossing). Both signal and noise are multisensory stimuli, but SDT considers that each can be represented as a single perceptual magnitude. All other factors remaining constant, the "detectability" of a signal increases as the S/N ratio increases. This means that increasing

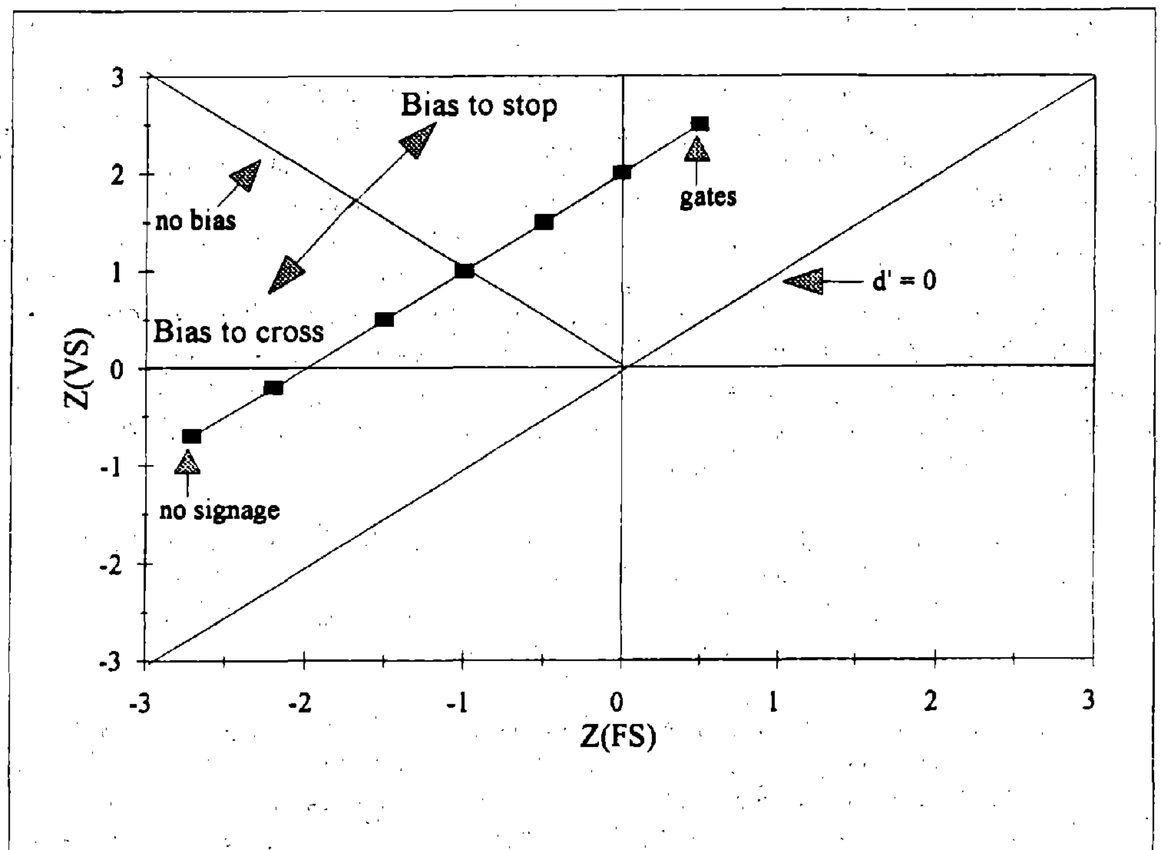

Figure 9. Hypothetical ROC plot demonstrating the possibility that grade crossing devices differ in effectiveness because of bias differences. The devices all have the same sensitivity. The line drawn through the points is an isosensitivity contour for d' =2. The devices all differ in bias. Gates have the highest bias to stop, while no signage has the highest bias to cross.

locomotive conspicuity, increasing the audibility of train horns, decreasing visual obstructions at grade crossings, etc., all increase the detectability of trains. The second factor involves human decision-making processes and the setting of the criterion. Expectations, attention, motivation, and decision goals constitute a short list of potentially important variables. In SDT these variables are independent of the S/N ratio, but affect whether the observer acts on a signal (i.e., stops at the grade crossing) or fails to act on a signal (does not stop). Since these variables are independent of the S/N ratio, they do not affect detectability. They do affect the tendency of the observer to report or to not report a signal, and therefore they are said to affect "bias". In SDT, bias and detectability are independent. Examples of what could alter bias at the grade crossing includes: train frequency (expectancy of signal), signage (expectancy of signal?), time of day (motivation; factory workers would have a higher cost associated with a delay at the crossing in the morning on their way to work, than they would at the end of their work day). The question asked in this section is: Do grade crossing protection devices achieve effectiveness because they increase the S/N ratio, or because they influence the setting of the criterion?

Estimating Valid Stop and False Stop Rates

One can determine the source of effectiveness of grade crossings by plotting the probability of a VALID STOP (P(VS)) vs. the probability of a FALSE STOP (P(FS)) for each device type in a Receiver-Operator Characteristic (ROC) plot similar to Fig. 2. If grade crossings differ in effectiveness because they increase the S/N ratio, then the most effective device (gates) should have the highest value of d' and the least effective device (no signage) should have the lowest value of d'. This possibility is illustrated in Fig. 8 [7]. On the other hand, if grade crossings differ in effectiveness because they influence the criterion (bias to stop), then the most effective device should have the highest bias to stop ($\beta <<< 1$) and the least effective device should have the highest bias not to stop ($\beta >>> 1$). This possibility is illustrated in Fig. 9. Note that in Fig. 8 β is constant, while if Fig. 9 d' is constant. The third possibility is that both d' and β will vary with effectiveness.

The primary problem in performing a quantitative SDT analysis of grade crossings is obtaining estimates of P(VS) and P(FS). P(VS) can be estimated from accident statistics. Recall that P(VS) = 1-P(AC). P(AC) is the equal exposure accident rate which was developed in the previous section, and P(VS) is easily calculated.

Accident risk was defined as the probability that a car and a train are simultaneously in the crossing. It was assumed that the car and the train cannot stop. Note that the situation in which a car and a train are at a crossing and the car does not stop also defines an ACCIDENT in SDT. Hence, accident risk defines maximum P(AC) [$P(AC)_{max}$]. If the car cannot stop, then the probability that the car won't have an accident is $1-P(AC)_{max}$. This can be taken as an estimate of P(CC). By definition $P(FS) = 1-P(CC) = 1-[1-P(AC)_{max}] = P(AC)_{max}$. Consequently, in the ROC analysis that follows, P(FS) is estimated from the accident risk associated with each device type.

Figure 10 is the ROC plot for the seven grade crossing protection device categories listed in the Rail-Highway Crossing Accident/Incident and Inventory Bulletin for 1986. The dashed line drawn through the seven points is the mean d' value. The points all fall in close proximity to the mean (dashed line), which indicates that there are very small differences in the S/N ratio between the different devices. The mean d' value is 7.13, which indicates that a train at a grade crossing represents an enormous signal relative to the background noise.

In Fig. 10, the solid line which has been drawn from the origin (0,0) to the upper left-hand corner is the equal bias ($\beta = 1$) line. Points which fall to the right of that line indicate a bias to stop ($\beta < 1$), and points to the left of the line indicate a bias not to stop ($\beta > 1$). The most effective device (gates) has the highest bias to stop, while the least effective device (none) has the highest bias not to stop. In addition, the bias to stop is higher for active devices than it is for passive devices. A statistically reliable correlation was found between device effectiveness (log(risk/probability)) and β across devices ($r = -0.77$, $p < .05$). This indicates that bias

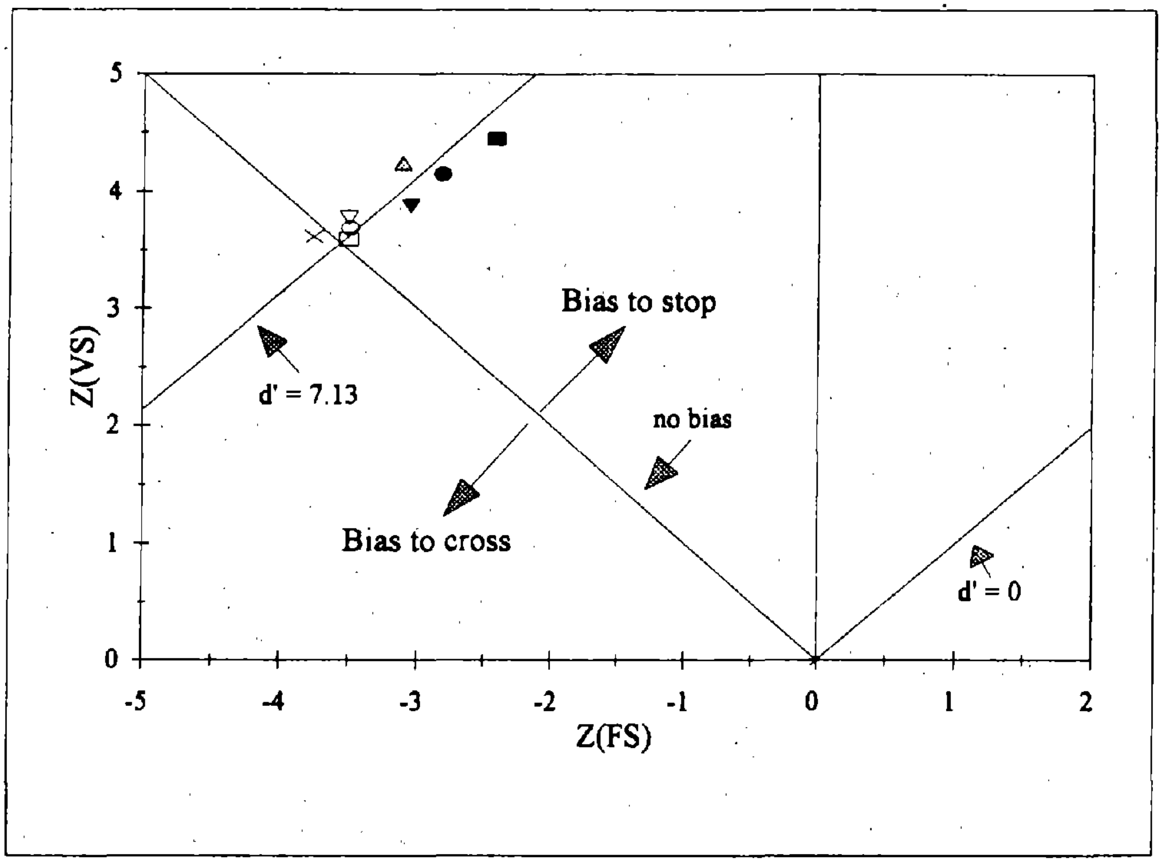

Figure 10. ROC plot for grade crossing devices (filled square, gates; filled circle, flashing lights; filled up triangle, special warnings; filled down triangle, highway signal; open square, cross bucks; open down triangle, stop signs; open circle, other; X, no signage). The line drawn through the points is an isosensitivity contour for d' = 7.13. See text for details.

accounts for almost 60% of the variations in effectiveness in the devices. By contrast, the correlation of effectiveness and d' was not statistically reliable ($r = -0.63$, $p > .05$).

Based on the correlations and visual analysis of the ROC plot in Fig. 10, it can be concluded that grade crossing devices achieve their effectiveness primarily because they affect the decision-making process. There is no strong evidence in this analysis that grade crossing devices enhance the S/N ratio. On the other hand, the correlation between d' and effectiveness, although not reliable, was negative which indicates a possibility that the devices actually degrade the S/N ratio. Since the grade crossing and its protective devices are not a part of the train per se, this makes sense: the auditory and visual stimulation produced by the devices must be adding to the noise, thereby degrading the S/N ratio.

IV. IMPLICATIONS

There are two classes of variables which can be manipulated to prevent accidents. First, there are those variables which increase the S/N ratio. Second, there are those variables which increase the bias to stop.

Measures to increase the S/N ratio

The analysis in section III indicates that the S/N ratio is already very large since the value of d' is approximately 7. This means that trains are highly detectable, which makes sense considering their visual and auditory properties. However, there are numerous strategies available to further increase the detectability of trains. This includes enhancing locomotive conspicuity, reflectorization of freight cars, altering the train horn, and improving line of sight (reduction in noise).

Since detectability is already high, how big a reduction in accidents could be expected by further increases in S/N? Conversely, what would happen to accidents if S/N were decreased? Because P(VS) = 1-P(AC), and P(AC) is the accident rate, these questions can be answered. From the theory of the ideal observer we know that the relationship between d' and S/N is

$$d' = \eta(S/N), \tag{11}$$

where η is the efficiency of a human observer relative to an ideal observer. The value of η is often assumed to be 0.4 (Potter et al., 1977). From equation (4) we also know that $d' = z(VS) - z(FS)$. Consequently, if bias is held constant, then we can relate changes in S/N to changes in d' and to changes in accidents.

Figure 11 shows the predicted number of accidents as a function of changes in d' for crossings protected by gates using 1986 data. The base value of d' is 6.86, β is held constant at .000927, and each change in d' of 0.25 units changes S/N by 0.625 units. In 1986 there were approximately 1000 accidents at crossings protected by gates. This corresponds to the 0 change in d' point in Fig. 11. Changes of one d' unit cause accidents to increase or decrease by almost an order of magnitude. On the basis of this analysis, it must be concluded that even small changes in the S/N ratio can result in dramatic changes in the number of grade crossing accidents. As a case in point, when Florida imposed a ban on night-time use of train horns a three-fold increase in accidents resulted. Figure 11 indicates that a d' change of about 0.75 units (1.875 units change in S/N) would produce a change in accidents of this magnitude for crossings protected by gates, under conditions of constant bias. If bias is not held constant (which would occur, for example, if P(FS) is held constant), then the same three-fold increase in accidents would result from a d' change of about 0.25 units (.625 units change in S/N). Obviously, eliminating the train horn reduces S/N, so this "natural experiment" is consistent with the prediction of SDT.

This analysis also has implications for the placement of horns at grade crossings instead of on the train. It was noted above that grade crossings with active devices had lower d' values

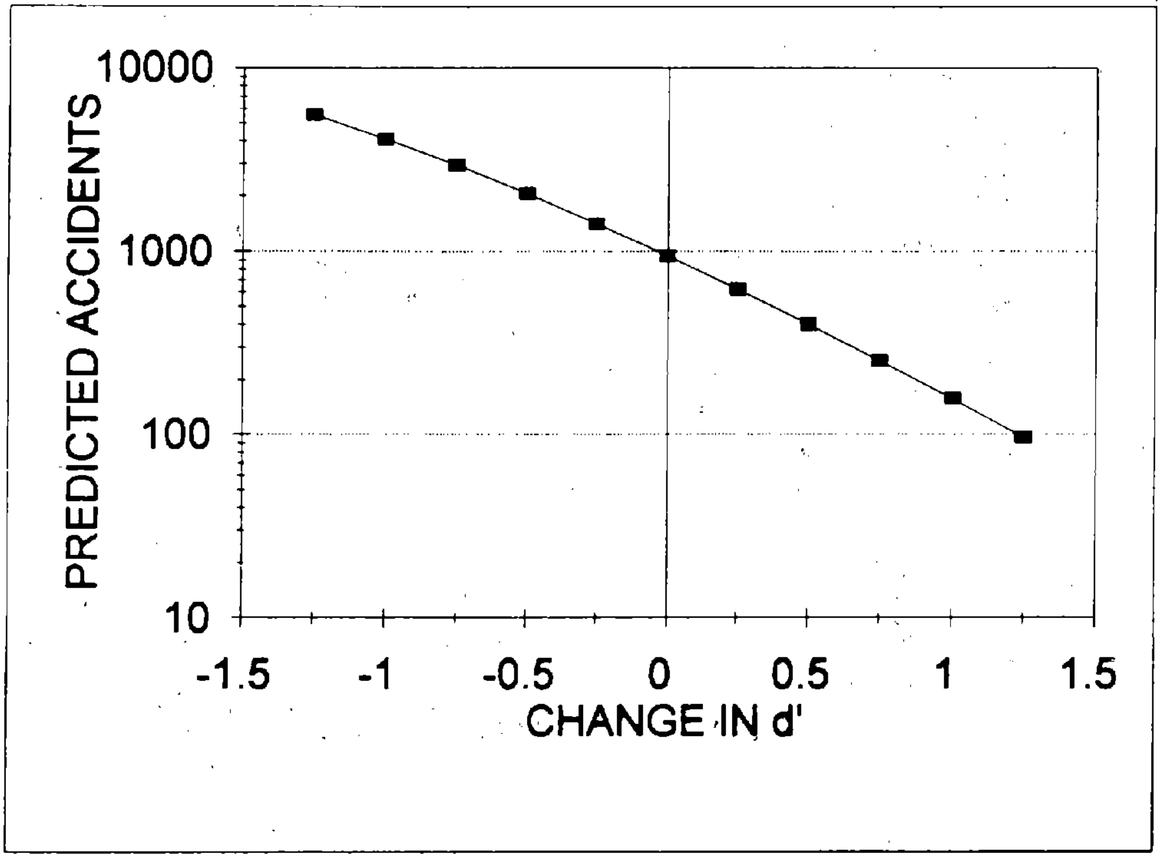

Figure 11. Predicted accidents as a function of changes in d' (sensitivity). See text for details.

than crossings with passive devices or no devices (see Fig. 10). This could be because the crossing is not part of the train, and consequently increases in light and sound at the crossing increase noise and decrease S/N. SDT accordingly predicts that automated horns should increase the accident rate at grade crossings, regardless of whether they sound like train horns or not.

The same argument can be applied to the illumination of grade crossings. To the extent that such illumination enhances train visibility (i.e., the train is in the crossing and the train rather than the pavement is illuminated), S/N will be increased, and accidents (particularly accidents in which the car hits the side of the train) should decrease. If illumination enhances the contrast between the train and its background relative to daylight conditions, accident rates should be lower than during the day (all other factors being equal). However, if the crossing is illuminated prior to the train entering the crossing, the noise level will be increased and more accidents (particularly those in which the car is struck by the train) should result.

Another obvious method to increase S/N, is to improve the line of sight of the motorist at the crossing and during the approach. In the absence of visual cues to the location of the

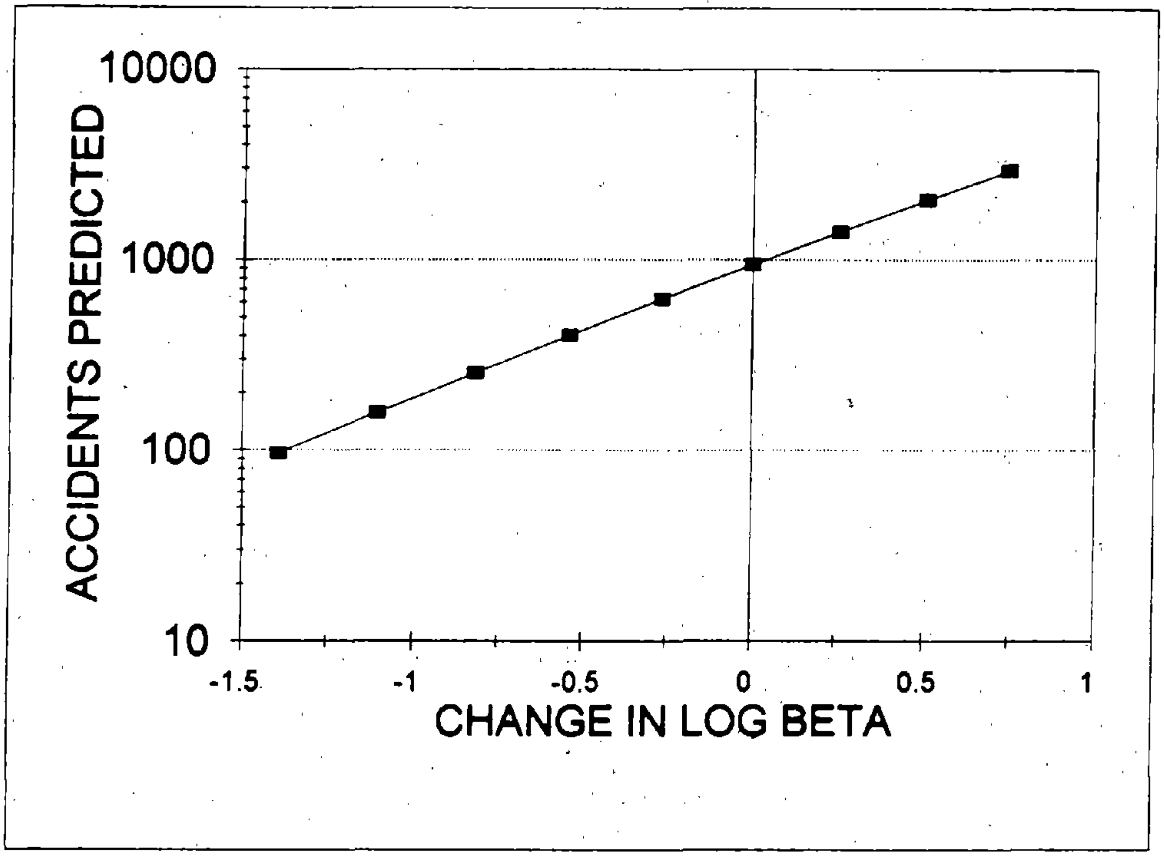

Figure 12. Predicted accients as a function of changes in log β. See text for details

train, the motorist must rely on a smaller signal which only consists of auditory and other non-visual cues. Improvements in the line of sight would increase the signal by adding visual cues and increase S/N.

Visual clutter (other traffic, traffic signs and signals, street lights, etc.) at crossings would tend to increase the noise and thereby reduce S/N. A reduction in visual clutter would increase S/N and reduce accidents. A recent FRA examination of 56 grade crossing with an average of more than one accident per year supports this conclusion. It was found that 97% of these crossings had visual obstructions, 95% had a large number of driveways and intersecting roadways, and 80% had visual clutter on the approach.

Measures To Increase the Bias to Stop

In Fig. 10, the changes in bias (β) between crossings without signage and those with gates were not specified. To correct that situation, it is here indicated that for no signage $\beta = 1.64$ and for gates $\beta = 0.000927$. β is calculated as the ratio of the ordinates of the standard normal curve corresponding to z(VS) and z(FS):

$$\beta = \frac{y_{VS}}{y_{FS}}, \tag{12}$$

where y_{VS} is

$$y_{VS} = \frac{1}{\sqrt{2\pi}} e^{\frac{-z(VS)^2}{2}}, \tag{13}$$

and y_{FS} is similarly defined.

Recall that there is no bias when $\beta = 1$. Values of $\beta < 1$ indicate a bias to stop and values of $\beta > 1$ indicate a bias to not stop. The data in Fig. 10, therefore, indicates that there are very large differences in bias between crossings with no signage and crossings protected by gates. Since gates produce such a large increase in the bias to stop, can a further change in accidents be expected for a change in bias with d' held constant? For the sake of comparison with Fig. 11, the 1986 data for gates is used as an example. Figure 12 shows predicted accidents as a function of the change in log β. To allow comparability, d' has a constant value of 6.86, the base value of β is .000927, and accidents range across the same values as in Fig. 11. Log β is plotted instead of β to allow a direct comparison with changes in d' in Fig. 11. From Fig. 12 it can be seen that an increase in log β of approximately .75 units results in approximately a three-fold increase in accidents. Accidents, therefore, are almost equally affected by changes in d' and log β. Moreover, just as was concluded for d', even modest changes in β are capable of producing large changes in the number of accidents.

There are several variables identifiable in SDT which can be manipulated to change bias. Recall the definition of β given in Equation 8:

$$\beta = \frac{V(n,N)+V(n,Y)}{V(s,Y)+V(s,N)} \bullet \frac{P(n)}{P(s)}. \tag{8}$$

The ratio P(n)/P(s) relates to the expectation of the motorist that a train will be encountered in the crossing. The ratio V(n,N)+V(n,Y)/V(s,Y)+V(s,N) relates to the motivation of the motorist with regard to the value of Valid Stops, Accidents, Correct Crossings and False Stops. Expectation and motivation are "psychological" variables, and in this context it should be emphasized that although the terms of Equation (8) are all capable of measurement at a physical level (e.g., P(s) as a Poisson probability based on the frequency of trains per minute at a crossing; V(s,N) as a dollar loss associated with an accident), perceived or subjective probabilities and values would be more appropriate. People tend to overestimate the probability of low frequency events and to underestimate the probability of high frequency events. Moreover, the subjective value of gains and losses is not a linear function of dollar value. In the discussion which follows, when estimates of probabilities (P) are available these are transformed to subjective probabilities using the relationship: $\Psi_P = P^{0.35}$, where Ψ_P is the subjective probability of P. Similarly, the subjective value of money ($\Psi_\$$) is related to the true value of money ($) by: $\Psi_\$ = \$^{0.5}$ (Stevens, 1975).

Section II has already confirmed the prediction of SDT that accident rates vary inversely with train frequency. It should be noted from Equation (8), however, that expectation is multiplied by the motivational factor to determine the value of β. In most situations, it is probably the case that both motivation and expectation are influential in determining β. This can be easily appreciated by assuming that $V(n,N)+V(n,Y)/V(s,Y)+V(s,N) = 1$ in Equation (8) and calculating β using the Poisson probability of a train that was developed in Section II.

In the case of gates, Table 5 shows that the Poisson probability of a train in the crossing is 0.009. The subjective probability of a train is then 0.19 ($0.19 = 0.009^{0.35}$). This defines P(s) and $P(n) = 1-P(s)$, so that $P(n)/P(s) = 4.2 = \beta$. Recall that if $\beta > 1$, there is a bias to not stop. Consequently, in the absence of motivation to stop, low train frequency predisposes motorists not to expect trains and biases them not to stop. In Section III, however, the value of β for gates was found to be 0.000927, which indicates a large bias to stop. Therefore, there must be a large motivational factor which is counteracting the bias not to stop. The motivation to stop can be calculated from Equation (8) given the value of $\beta = .000927$ and with $P(n)/P(s) = 4.2$. The calculation indicates that the motivation to stop is 4534.59 times the motivation not to stop (i.e., the motivation ratio is 1/4534.59). In terms of actual costs and benefits, if the subjective value of not stopping is 1 and subjective value of stopping is 4534.59, then the equivalent dollar amounts are $1 and $20,562,506.47 (because $\Psi_\$ = \$^{0.5}$, $4534.59 = [\$20{,}562{,}506.47]^{0.5}$). It should be kept in mind that the $20,562,506 includes the perceived cost of death, dismemberment, loss of property and grief due to an accident, so perhaps this dollar ratio is not unrealistic.

One method of increasing the bias to stop is enforcement of the law which requires motorists to stop when gates are lowered and lights are flashing. Considering that there is already considerable motivation to stop at lowered gates ($20,562,506), it seems questionable that a $50 or $100 fine would be effective in further increasing that motivation. However, there are other costs associated with fines which do not have a directly known dollar value. For instance, there is inconvenience and loss of time, especially if a court appearance is necessary. Embarrassment caused by publicly receiving a fine constitutes a social cost. If the act of non-compliance is considered a moving violation, points can be added to the driver's license and the license might be lost, which can have tremendous economic and personal consequences. Enforcement programs, such as the photo enforcement program in Los Angeles (Meadow, 1994), have been shown to decrease violations (which means that there is an increase in compliance), so the dollar value of the fine must not be the only perceived cost of receiving a fine.

The Los Angeles program found that photo enforcement decreased violations by 84%

(Meadow, 1994). In the SDT model this means that P(FS), which is compliance, has increased by 84%. If we assume that d' remains unchanged and that only β is changed, it should be possible to determine the change in the motivation ratio which a fine causes for the average gate-protected crossing. For a 84% increase in P(FS), the bias to stop increases ($\beta = 0.000138$ rather than 0.000927) and the motivation ratio becomes 1/30,532. The corresponding dollar value, which includes the dollar value of the fine, is $932,203,024. From this example it should be clear that human motivation is not limited to dollar-valued costs and benefits. A better understanding of the motivation for stopping and not stopping has the potential for generating innovative, cost-effective strategies for enhancing grade crossing safety.

Attention and Memory. Attention and memory have the capability to alter both β and d'. A primary function of crossing devices is probably attentional, and the variation in β with device type is consistent with a link between attention and β. In the psychophysical literature it is often found that attention to a signal does not affect d'. Instead, attention is found to enhance performance by causing a shift in the criterion. Recall that Fig. 10 showed that different devices differed in bias, but not in d'. Differences in β as a function of device type are probably, in part, the result of enhanced expectation of a train (i.e., the expectation ratio, P(n)/P(s), has been decreased). In this regard, the role that accurate information concerning train frequency could play in the further reduction of P(n)/P(s) remains unexplored.

Because attention also involves orientation towards a source of stimulation, attention may also serve to enhance the S/N ratio. Signage which indicates where motorists should look for trains would strengthen this function of attention, especially if active devices were used to indicate train direction. Note that knowledge of train direction assumes that the probability of a train is close to one. Signage which actively indicates train direction could function to enhance both d' and β. Signals and other changes in the sensory stimulation provided by grade crossing devices should be more focused on causing motorists to orient toward the train. This should enhance the bias to stop and ameliorate the previously noted decrement in S/N caused by the active devices (p. 26).

Memory has important functions for responding at the decision point and for stimulus recognition. Motorists at a grade crossing must remember what responses are appropriate given a particular device, the proximity of a train, and the consequences of the various outcomes. Regardless of whether the motorist is stopped or in motion, imperfect memory at the decision point can only bias the motorist to continue to remain stopped or in motion. Signage advising motorists of the appropriate actions at the crossing could relieve the motorist of this human limitation and enhance safety.

Memory can also affect S/N through the process of stimulus recognition. Imperfect memory in this instance degrades S/N primarily by enhancing the noise. Driver education and public service announcements that show motorists the appearance of locomotives and trains under different lighting conditions, angles, distances, etc. could improve stimulus memory and enhance S/N. Greater consistency in the pattern of stimulation which locomotives provide to motorists (position and number of lights, frequency and intensity of horns, etc.) would also aid to improve recognition memory, and thereby S/N.

Accident Prediction

The SDT model can be used for accident prediction in situations for which specific changes in S/N or β are under consideration. For instance, in the example where photo enforcement was discussed relative to motivation, the model indicates that a 84% increase in compliance at the average gate-protected crossing would also result in a reduction in accidents. The model predicts a 74% reduction in accidents at the average gate-protected crossing through photo enforcement based on the 1986 data. Crossing accidents were observed to decrease by 60% at the photo enforcement crossings in Los Angeles (Federal Railroad Administration, 1994).

As a perceptual and sensory information processing model SDT is particularly suited to evaluate a variety of sensory manipulations (e.g., improvements in line of sight) and psychological manipulations (e.g., dollar amount of fines) which are not captured by any other accident prediction model. Moreover, unlike other accident prediction models, SDT is based on clearly stated assumptions concerning underlying processes which have been systematically studied over a 30 year period. As a theoretical model, rather than an empirical model, SDT has the flexibility to incorporate new variables and can be used to extrapolate predictions beyond the empirical inputs. The unified view of accident causation at grade crossings provided by SDT allows an understanding of trade-offs between sensory and decision-making variables which is unavailable in other models. As a model of human behavior it can be used in both a descriptive (how do people actually perform) and a prescriptive (how would an ideal observer perform) mode. An SDT analysis of a grade crossing allows essential engineering data to be used within the context of human decision making. No other model of accident prediction has this capability.

However, for SDT to be fully useful as a model of decision-making at the grade crossing, there are a number of areas in which more information is required. Recall that it was necessary to estimate P(FS) from the maximum probability of an accident. P(FS) is an aspect of compliance and this had to be estimated because there is little good information on the average rate of compliance or of P(FS) for various grade crossing devices. Compliance rates have most frequently been studied in the past when particular crossings are noted to have an unusually high accident rate. Compliance at "normal" crossings is unknown. The accurate determination of d' and β requires knowledge of both P(VS) and P(FS).

Laboratory and/or field studies are also needed to determine basic relationships between sensory aspects of the train and d'. For instance, recent basic and applied research on perception of time-to-collision (e.g., Berthelon and Mestre, 1993; Bootsma and Oudejans, 1993; Kaiser and Mowafy, 1993; Wannm, Edgar and Blair, 1993) has not considered the special problems of the rail-highway intersection. While it is possible that some of this information is already available in the psychological literature, the sensory magnitudes which trains present are not ordinarily encountered in a laboratory setting. Consequently, verification of published relationships may be necessary. Of particular concern is the most appropriate rule for combining multi-sensory information into a single percept. Prediction of the detectability and/or proximity of trains having various combinations of lights and audible warning devices requires information on how people integrate sensory information.

Virtually no information exists concerning the motivation of motorists for stopping or not stopping, how this is affected by the type of device at the crossing, and effect of various enforcement programs. No information exists concerning the perceived frequency of trains at crossings and how that is affected by protection devices and signage. No information exists on the perceived risk present at crossings protected by different types of devices.

In the absence of quantitative information to specify the variables in the model, SDT will remain a useful heuristic model but will not achieve its full potential as an analytic and predictive tool. The basic model which has been presented here can be modified and refined to meet a variety of demands and needs. However, to do so it is necessary to have quantitiative information available to determine which aspects of the basic model are unsuitable. For instance, if it is determined that the assumption concerning gaussian distributions of signals and noise is not applicable, the theory can be adapted to other probability distributions such as the Gamma, Rayleigh, Chi-square, Poisson, and Binomial distributions (Egan, 1975). The theory has been adapted to the analysis of attention, conceptual judgment, learning, medical diagnosis, memory, personality, reaction time, recognition and vigilance (Green and Swets, 1974). Consequently, the current application of the theory has a wealth of resources on which to draw in order to improve our understanding of driver behavior at the rail-highway grade crossing.

IV. THEORY OF THE IDEAL OBSERVER: TIME TO COLLISION, VISUAL SEARCH, AND ACCIDENT PREDICTION.

The theory of the ideal observer is used in SDT to model the performance of the perfect, or ideal, observer. Such an observer uses all of the available information in a maximally effective fashion to reach a rational decision within the bounds of the model limits. Actual performance of less than ideal observers can then be compared with that of the ideal observer to determine if the model has validity in the search for underlying processes, or as a means to improve observer performance (Swets, Tanner and Birdsall, 1964/1988). In the present instance, we explore the possibility that the ideal driver bases decisions at grade crossings on subjective estimates of the arrival time of his/her own vehicle and of the train at the grade crossing. Visual search for and localization of the train consumes time during which the decision to stop can be safely made and directly affects accident probability. A quantitative description of these processes is presented below.

Sight Distance and Time to Collision

An important aspect of driving behavior at grade crossings is the visual search for a train, the localization of that train, and a decision to stop or not stop at the crossing given the location of the highway vehicle and train relative to the crossing. Figure 13 diagramatically presents the situation. The speed of the train and of the vehicle each determine the physical amount of time required to arrive at the crossing. The *Railroad-Highway Grade Crossing Handbook* (Tustin et al., 1986) defines two distances which are important for our analysis. The first, d_H, is the "Sight distance measured along the highway from the nearest rail to the driver of the vehicle which allows the vehicle to be safely stopped without encroachment of the crossing area..." (p. 132). The formula for d_H is:

$$d_H=1.47V_v t+\frac{V_v^2}{30f}+D+d_e, \tag{14}$$

where V_v is the vehicle velocity in mph, t is the perception reaction time in seconds, f is the coefficient of friction, D is the distance in feet from the stop line or front of the vehicle to the nearest rail, and d_e is the distance from the driver to the front of the vehicle in feet.[8] The second, d_T, is the "Sight distance along the railroad tracks to permit the vehicle to cross and be clear of the crossing upon arrival of the train..." (p. 132). The formula for d_T is:

$$d_T=\frac{V_T}{V_v}\left(1.47V_v t+\frac{V_v^2}{30f}+2D+L+W\right), \tag{15}$$

where V_T is the train velocity in mph, L is the length of the vehicle in feet, and W is the distance in feet between the outer rails.[9]

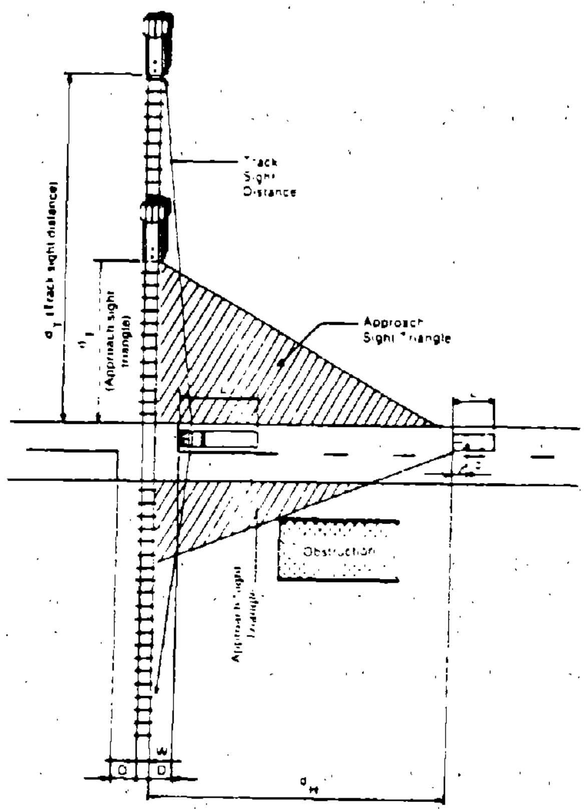

Figure 13. Definition of distances used in equations 14 and 15.

It is assumed that the highway vehicle and train are initially located at d_H and d_T, respectively. Consequently, the vehicle can either stop or cross without an accident if the driver knows at that instant the exact location of the train. However, the driver of the vehicle, as a human information processor, must first locate the train, calculate the distance and time to the intersection of both the train and the vehicle, and decide whether to cross or stop. Assume that this ideal driver has all the information required to accurately solve the equations for the two distances, once the train is located. Since he knows the distances and the velocities of both the train and the vehicle, he also knows the the amount of time he has to cross (Tc) and the amount of time to stop (Ts). His perception of these times, however, is not veridical. Estimates of the relationship between judged time to passage (TTP*) and actual time to passage (TTP) were obtained from Kaiser and Mowafy (1993, Figs. 7 and 8) and were used to adjust the values of Tc and Ts to reflect this aspect of human time perception:

$$TTP^* = 0.84375\ TTP + 0.84375. \tag{16}$$

It is typically found in the human time perception literature that short durations are overestimated and that long durations are underestimated. For instance, using the relationship above, a 4 s duration would be judged to take 4.22 s and an 8 s duration would be judged to take 7.59 s.

The driver decides whether or not to cross on the basis of the perceived difference between judged Tc (Tc*) and judged Ts (Ts*). The perceived difference between the two durations can be modeled as follows:

$$d' = \frac{\mu\,(Tc^{*} - Ts^{*})}{\sigma\sqrt{(Tc^{*})^{2} + (Ts^{*})^{2}}}, \tag{17}$$

where $\mu/\sigma = \gamma =$ a constant (Raslear, 1988). γ is the inverse of the Weber constant for time. An estimate of $\gamma = 57.47$ was obtained from a study of perceived time to collision by Bootsma and Oudejans (1993, experiment 1) for use in equation 17.

A value of d' can be determined for various vehicle speeds from equation 17. Train speed is not a factor in determining d' because of the use of equations 14 and 15 to determine sight distances. Once a value of d' is obtained, accident probabilities can be estimated for particular types of grade crossings. As an example, grade crossings with crossbucks are considered.

The previous analysis of grade crossing warning devices provides an estimate for each warning device of the probability of a false stop (P(FS)). For crossbucks P(FS) = 0.000231. SDT defines d' = Z(VS) - Z(FS). Converting P(FS) into Z(FS) and adding d' from equation 17 to Z(FS) yields Z(VS), and the corresponding probability, P(VS), is easily obtained. By definition P(AC) = 1- P(VS), so the probabiliity of an accident is obtained.

Figure 14 shows the probability of an accident as a function of highway vehicle speed. Note that the probability of an accident is low between 10 and 20 mph. Beyond 20 mph, the probability of an accident rises steeply and begins to asymptote at very high levels above 50 mph. For comparison, fatal crash data from Klein, Morgan and Weiner (1994) is also plotted in Fig. 14. The comparison should be considered tentative for several reasons: the Klein et al. data is for fatalities, for a 10 year period, for all crossings, and is aggregated differently; while the prediction from the SDT model uses accident data from one year for crossbucks. Nevertheless, there is a surprising degree of agreement between the model and the data. In particular, both the model and the data suggest that highway vehicle speed has a functional role in accident probability at grade crossings.

Visual Search

As was noted in a preceeding section, crossings with a higher than expected accident rate also tend to have a considerable amount of visual clutter. Visual clutter can be modeled by assuming that the prediction in Fig. 14 is for 0 items of visual clutter and that the 180° visual search requires no time. Thus, the driver scans the visual field over a 180° range,

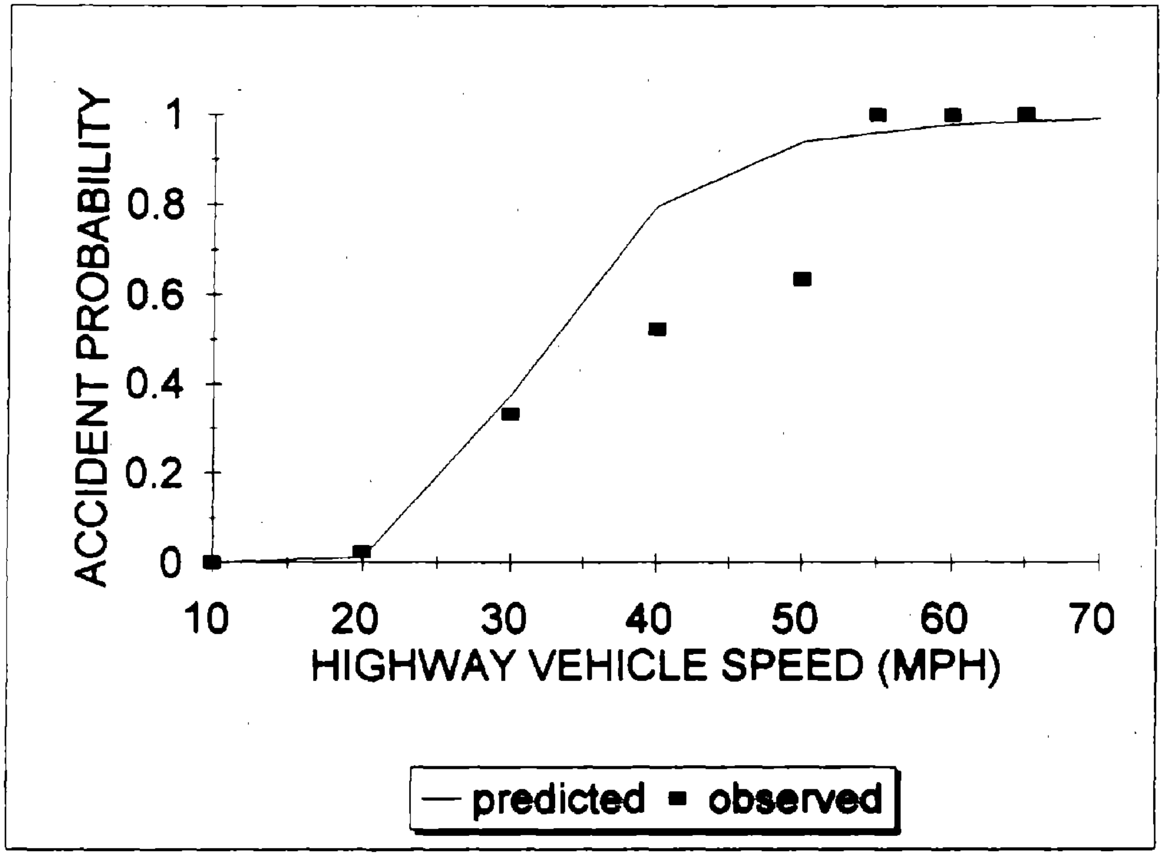

Figure 14. Accident probability as a function of highway vehicle speed. The predicted function is based on the model in equation 17. The observed data are from Klein et al. (1994).

instantaneously localizes the train and makes a decision. The process of visual search, however, requires time. Moreover, the average search time for a specific item (the train) increases with the number of items in the visual field. In addition, because visual search is a variable process (i.e., sometimes the target is found after examining one or two non-target items, and sometimes after examining all non-target items), visual search adds variance to the time-based decision-making process (i.e., equation 17). Visual search time has been extensively studied and an excellent summary of that work can be found in Luce (1986, p. 428). The average time required to search for an item is given by

$$S = \tfrac{1}{2}kM + r_0, \tag{18}$$

where k is the mean time per item, M is the number of items and r_0 is the residual time. The variance for visual search time is given by

$$\sigma^2 = \sigma_m^2 M + \sigma_r^2, \tag{19}$$

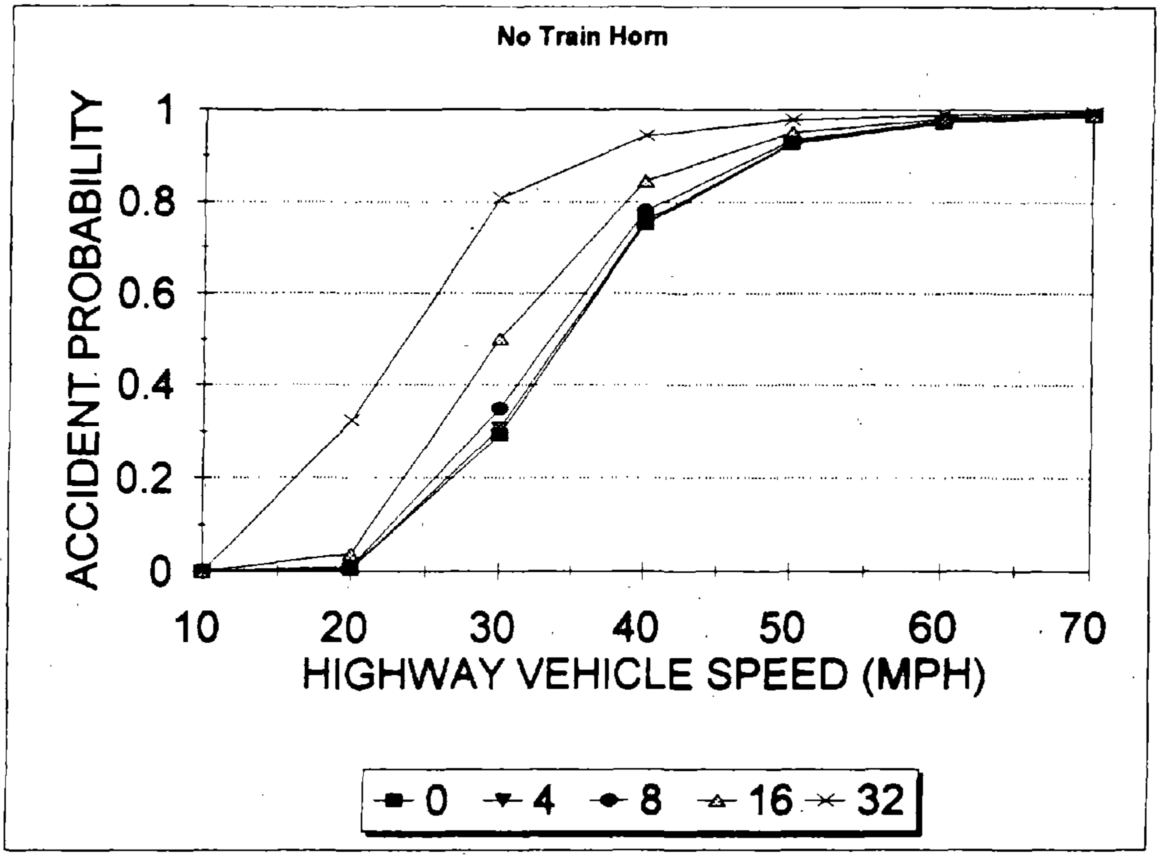

Figure 15. Accident probability as a function of visual clutter and highway vehicle speed without a train horn to indicate train location. See text for details.

where σ_m^2 is the per item variance and σ_r^2 is the residual variance. The modeling of visual clutter in the search for a train consists of reducing the values of Tc* and Ts* in equation 17 by the appropriate value of S in equation 18 and adding the variance obtained from equation 19 to the variance (demoninator) of equation 17. [10]

Figure 15 shows accident probability (based on crossbuck data) as a function of highway vehicle speed and amount of visual clutter (0,4, 8, 16 and 32 items). Note that as the amount of visual clutter increases, there is a corresponding increase in accident probability. The model clearly predicts that accidents should decrease as visual clutter is removed from a grade crossing.

<u>Train Horns and Visual Search</u>

If we assume that a horn has been placed on the train to aid in the localization of the train, we can model the change in accidents that results. The sound localization literature indicates that there is approximately a 10° error in localization of a sound source for pure tones (Licklider, 1951, p. 1026-1030). Since the motorist is searching a 180° field for the train, the inclusion of a horn on the train can be assumed to reduce the field of search to 10°. This means

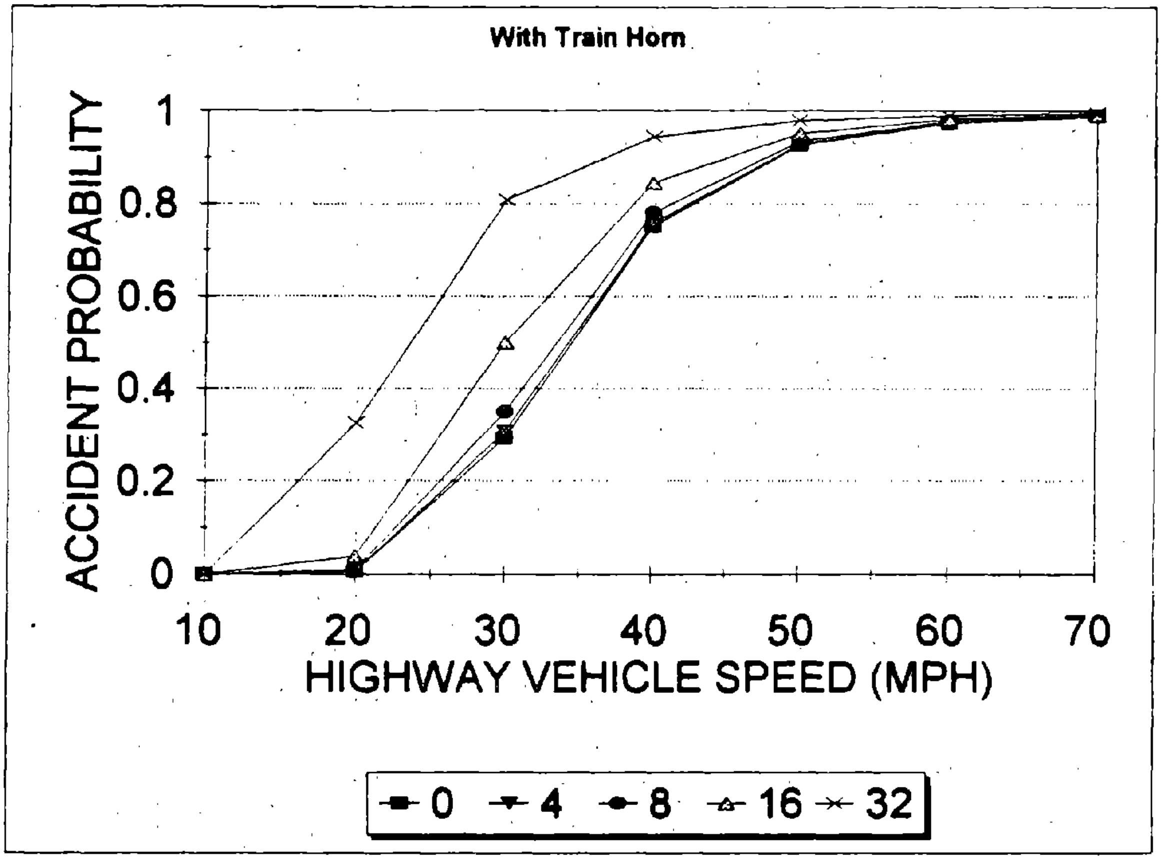

Figure 16. Accident probability as a function of visual clutter and highway vehicle speed with a train horn to indicate train location. See text for details.

that visual search time and variance have been reduced by a factor of 1/18. Figure 16 shows the effect of this change in the train by plotting accident probability as a function of vehicle speed and visual clutter. The train horn, by decreasing visual search time, also decreases the probability of an accident. Figure 17 provides a clearer picture of this by plotting the vehicle speed at which there is a 0.5 probability of an accident as a function of the number of visual distractors for a train with and without a horn. In all instances, if no train horn is sounded, the same level of accident probability occurs at a lower speed. A train horn, it must be concluded, enhances safety, and this conclusion is supported by the results of the Florida Train Whistle Ban study as noted previously.

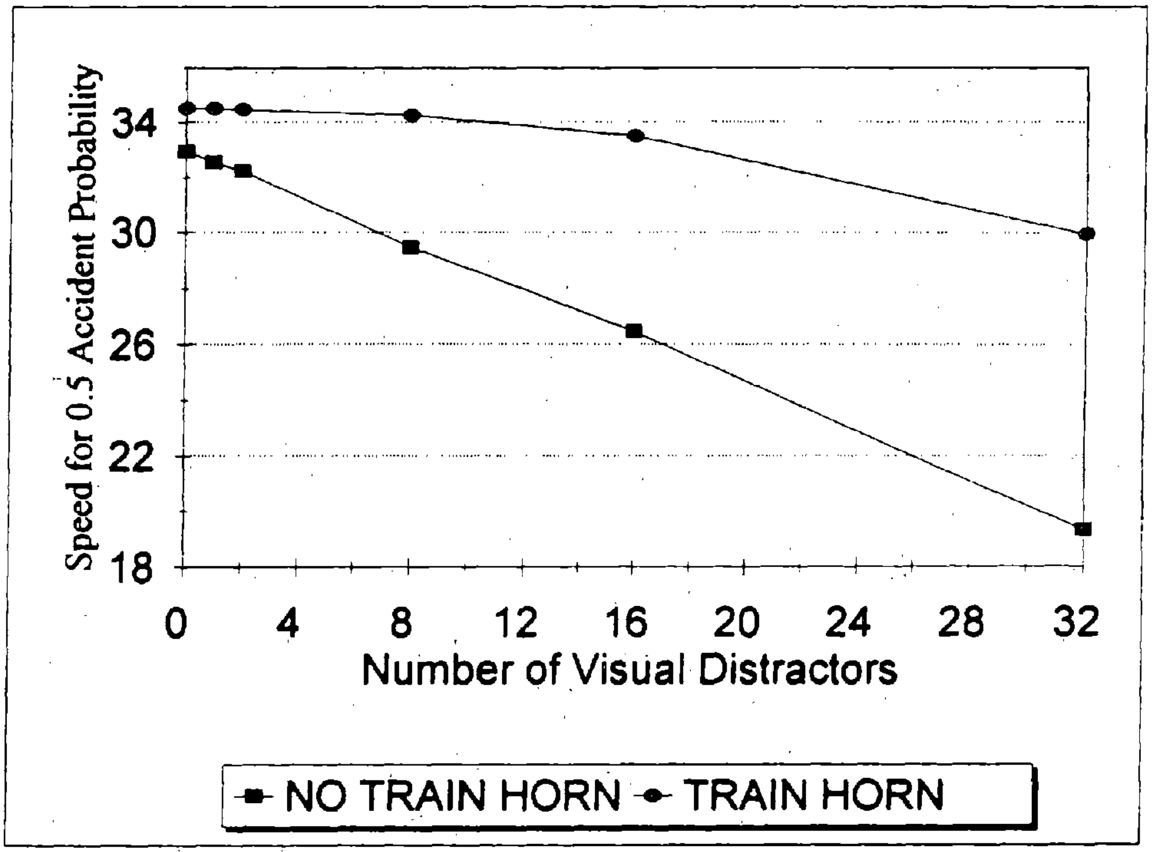

Figure 17. Highway vehicle speed at which there is a 0.5 probability of an accident as a function of visual clutter, with and without train horns.

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APPENDIX

TABLE A1. Total Crossings by Number of Trains Per Day And Warning Device Category (From Table 53 of the 1986 Rail-Highway Crossing Accident/Incident and Inventory Bulletin).

NUMBER OF TRAINS

Device	<1	1-2	3-5	6-10	11-15	16-20	21-25	>25	Total
Gates	807	2063	2231	4082	**2664**	3224	2308	4687	22066
Flashing lights	3491	7806	**6181**	7354	2880	2279	1068	1719	32778
Hwy. signals, etc.	291	689	**376**	425	181	128	71	110	2271
Special	2607	**2300**	781	465	234	189	49	137	6762
Crossbucks	19160	40967	**20185**	18697	6346	4741	2381	3621	116098
Stop signs	136	304	**239**	131	46	43	23	40	962
Other signs	210	**214**	89	88	29	20	2	29	681
No signs	3965	**3692**	1292	983	380	245	89	190	10836
Total	30667	58035	31374	32225	12760	10869	5991	10533	192454

NOTE: Cells which are emphasized contain the median for the device. The bin midpoint is the median. For instance, for Gates the median is 13 trains/day. This means that 50% of these crossings had fewer than 13 trains/day and 50% had more than 13 trains/day.

TABLE A2. Total Crossings by Annual Average Daily Traffic And Warning Device Category (From Table 58 of the 1986 Rail-Highway Crossing Accident/Incident and Inventory Bulletin).

ANNUAL AVERAGE DAILY TRAFFIC

Device	1-250	251-500	501-1000	1001-5000	5001-10000	> 10000	Total
Gates	2940	2167	2852	8025	3367	2715	22066
Flashing lights	4544	3671	4961	12386	4310	2906	32778
Hwy. signals, etc.	659	271	315	598	220	208	2271
Special	1508	844	871	2167	828	544	6762
Crossbucks	76318	13864	10182	12435	2254	1045	116098
Stop signs	489	134	122	172	30	15	962
Other signs	288	148	96	102	37	10	681
No signs	5836	1195	1122	1882	520	281	10836
Total	92582	22294	20521	37767	11566	7727	192454

NOTE: Cells which are emphasized contain the median for the device. The bin midpoint is the median. For instance, for Gates the median is 3000 cars/day. This means that 50% of these crossings had fewer than 3000 cars/day and 50% had more than 3000 cars/day.

FOOTNOTES

1. SDT terminology differs from what is presented here. In SDT, the names of the cells in Table 1 are as follows:

	Yes, Stop.	No, don't stop.
Train is close	HIT (motorist stops at crossing)	MISS (accident)
Train is not close, or No train in vicinity	FALSE Alarm (motorist stops unnecessarily)	CORRECT REJECTION (motorist crosses tracks safely)

In the terminology of SDT, an accident would be called a MISS, and the avoidance of an accident would be called a HIT. The use of alternative terminology seems advisable to avoid confusion.

2. Device Categories listed in the Rail-Highway Crossing Accident/Incident and Inventory Bulletin are: gates (category 8), flashing lights (category 7), highway signals, wigwags, or bells (category 6), special warning devices (category 5), crossbucks (category 4), stop signs (category 3), other signs (category 2), and no signs or signals (category 1).

3. It should be noted that several of the medians in Table 5 are identical. This is a result of the use of bins (ranges of values) in Tables A1 and A2. The median is located in the bin which cumulatively contains 50% of the observations. Since this is a range of values in Tables A1 and A2, the midpoint of the bin is used to represent the median. The inaccuracy which is introduced by this calculation is easily avoided by determining a mean based on train and car frequencies reported at each crossing.

4. A one minute observation period is suggested by the fact that the average freight train is approximately 67 cars long (AAR, 1993) and the average train speed through a crossing is 30 mph (Table 55, 1986 Rail-Highway Crossing Accident/Incident and Inventory Bulletin). At an approximate car length of 50 feet, such the average train would take approximately one minute to go through the average crossing.

5. It should be noted that the mean is the recommended estimator of λ in the present case. The median is used of necessity and with full knowledge that it is not the optimal estimator of the rate parameter of the Poisson distribution.

6. In Equation 10, as $\lambda \to 0$, $e^{-\lambda} \to 1$, and $p(1 \leq x \leq \infty) \to \lambda$.

7. Fig. 8, 9 and 10 plot z(VS) vs. z(FS) rather than P(VS) vs. P(FS). This has several advantages for analytic purposes. Because it is assumed that the underlying probability

distributions are normal and of equal variance, ROC curves which are plotted as normal deviates (z-scores) are linear rather than curvilinear (as in Fig. 2). As a result, isosensitivity contours (ROC curves for which d' values are equal) are all parallel to the major diagonal (d' = 0 contour) and have a slope of 1. Moreover, because z-scores, unlike probabilities, have no upper limit, high levels of sensitivity can be plotted and distinguished. This characteristic of z-scores also allows the effect of bias to seen at high levels of sensitivity.

8. In solving equation 14, $D = 15$, $d_e = 10$, $t = 2.5$, and f was obtained from Table 35 in Tustin et al.

9. In solving equation 15, $D = 15$, $L = 19$, $W = 5$, $t = 2.5$, and f was obtained from Table 35 in Tustin et al.

10. The following values of the parameters in equations 18 and 19 were used to apply the model: $k = 0.02$, $r_0 = 0.4$ (Sternberg, 1966), $\sigma_m^2 M = M^2/12$ (variance of a rectangular distribution of M items), and $\sigma_r^2 = 8.2944$ (Luce, 1986, p. 428).

THE HIGHWAY/RAILROAD INTERSECTION GRADE CROSSING SAFETY RESEARCH NEEDS WORKSHOP.

U. S. DOT
JOHN A. VOLPE, NATIONAL TRANSPORTATION SYSTEMS CENTER

APRIL 10-14, 1995

PRESENTATION BY: JOHN P. TOLMAN, LOCOMOTIVE ENGINEER AND
STATE LEGISLATIVE DIRECTOR FOR THE BROTHERHOOD OF LOCOMOTIVE ENGINEERS, MA, NH, RI.

GOOD AFTERNOON, I HOPE TO BRING TO YOUR REVIEW THE PERSPECTIVE OF THE LOCOMOTIVE ENGINEER AND SOME OF THE LEGISLATIVE INITIATIVES WE ARE WORKING ON. I HAVE A TWO MINUTE VIDEO FROM UNION PACIFIC RAILROAD, I WOULD LIKE YOU TO SEE. (ROLL FILM)

THIS IS WHAT IT ITS ALL ABOUT, HOW DO WE PREVENT THESE NEEDLESS TRAGEDIES? WHAT IF YOUR WIFE, HUSBAND, OR CHILD WAS ABOARD THAT BUS. I KNOW EVERY TIME I SEE THIS FILM, I GET HYSTERICAL, IT BRINGS CHILLS UP MY SPINE.

AS A RAILROAD ENGINEER I KNOW TO WELL WHAT ITS LIKE TO BE CONFRONTED WITH A ACCIDENT LIKE THAT.

IT IS EXTREMELY DIFFICULT, IT IS TRAUMATIC, IT IS DEVASTATING, ALL ACCIDENTS ARE DIFFERENT, SOME MORE TRAUMATIC THEN OTHERS.

WHAT ABOUT THE TRAUMA THE ENGINEERS GO THROUGH EVERY TIME AN INCIDENT LIKE THIS HAPPENS, EVERY 90 MINUTES THIS HAPPENS, A DRIVER FAILS TO YIELD TO THE HIGHWAY/RAIL INTERSECTION AND HAS A COLLISION WITH A TRAIN, WHAT ABOUT TRESPASSERS, WHAT ABOUT THE NEAR MISSES?

I AM HERE TODAY TO SPEAK ABOUT AN IMPORTANT SUBJECT, AND THAT IS THE LOCOMOTIVE ENGINEERS, AND WHAT HAPPENS TO THEM AFTER BEING INVOLVED IN SUCH AN INCIDENT. THE LOCOMOTIVE ENGINEERS ARE THE SECOND VICTIM IN ALL INCIDENTS. THESE INCIDENTS ARE NOT JUST HIGHWAY/RAIL INTERSECTIONS BUT TRESPASSES AND SUICIDES.

THE LOCOMOTIVE ENGINEERS INVOLVED IN THESE INCIDENTS ARE TREATED DIFFERENTLY ACROSS THE NATION, THERE IS NO RESEARCH, LEGISLATION OR PATTERN EXCEPT IN THE STATE OF RHODE ISLAND. THE BROTHERHOOD OF LOCOMOTIVE ENGINEERS IN 1993, WORKED TIRELESSLY FOR PASSAGE OF THIS LEGISLATION.

THE LEGISLATION READS LIKE THIS:
EVERY RAILROAD CORPORATION AND RAILWAY COMPANY SHALL PROVIDE OR MAKE AVAILABLE TO EVERY MEMBER OF AN OPERATING CREW INVOLVED IN A ACCIDENT ON ITS RAILWAY OR RIGHT OF WAY, WHICH RESULTS IN LOSS OF LIFE, OR SERIOUS BODILY INJURY, **COUNSELING SERVICES** OR OTHER **CRITICAL INCIDENT STRESS DEBRIEFING,(CISD)** SERVICES WITH IN 48

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HOURS, PROVIDED, THAT THE ENGINEER, OR OTHER OPERATING CREW MEMBER, INVOLVED IN SAID ACCIDENT **SHALL BE RELIVED** FROM DUTY WITH **COMPENSATION AND APPLICABLE BENEFITS AT THE SITE** OF THE ACCIDENT FOR A MINIMUM OF THREE DAYS; PROVIDED, THAT SAID LEAVE MAY BE WITHOUT COMPENSATION AND BENEFIT IF THE RAILROAD CORPORATION MAKES THE AFFIRMATIVE SHOWING THAT THE ACCIDENT WAS DUE TO NEGLIGENCE OF THE ENGINEER OR OTHER OPERATING CREW; PROVIDED THAT ANY PERSON WHO OTHERWISE IS ELIGIBLE FOR THESE BENEFITS AND WHO HAS BEEN FOUND TO HAVE NOT ACTED NEGLIGENTLY SHALL NOT BE GIVEN SAID BENEFITS.

ANY ENGINEER RETURNING TO DUTY FOLLOWING SUCH LEAVE SHALL, IF HE/SHE SO REQUEST, **SHALL BE ASSIGNED TO AN ASSISTANT ENGINEER OR OTHER QUALIFIED PERSON** WHO WILL ACCOMPANY THEM FOR SUCH A TIME AS MAY BE NECESSARILY TO GUARANTEE THE PUBLIC SAFETY, OR UNTIL RELEASED BY AN APPROPRIATE MEDICAL PRACTITIONER.

I WOULD LIKE TO PAUSE RIGHT HERE AND RELATE A FEW OF THE STORIES THAT ENGINEERS HAVE STATED.

GOING THROUGH A TRAUMATIC INCIDENT SUCH AS THIS ONE NEVER FORGETS ALL THE DETAILS. ALL ENGINEERS CAN RELATE EVERY DETAIL OF AN INCIDENT, THAT HAPPENED DURING THE CAREERS, BUT THEY COULDN'T TELL YOU WHAT THEY HAD FOR BREAKFAST, THIS MORNING.

W. J. C.; HAS BEEN INVOLVED IN THREE FATALITIES IN HIS 23 YEAR CAREER, HE TELLS ABOUT TWO TWELVE YEAR OLD BOYS PLAYING ON THE TRACK. "THE TRAIN STRUCK THE BOY AND TOSSED HIS BODY ONTO THE AIR. AFTER HE STOPPED THE TRAIN HE LOOKED BACK AT THE TWO BOYS. I CAN STILL SEE THE ONE BOY PICKING UP HIS FRIEND'S ARM. I CAN SE HOW HE FELL BACK DOWN AGAIN. AND HE RUNS UP TO ME AND SAYS, " I THINK MY FRIENDS DEAD."

N.N.; IN NY AREA WAS INVOLVED IN 13 INCIDENTS ALREADY. HE WAS HAVING A DIFFICULT TIME WHEN A YOUNG WOMEN PUT HER HEAD ON THE TRACK IN FRONT OF HIM AND HE THOUGHT IT WAS HIS DAUGHTER.

F. C.; IT WAS SNOWING OUT AS I APPROACHED THE CROSSING A CAR CAME UP TO THE CROSSING RATHER QUICKLY, I JUMPED UP THINKING THE AUTO

WAS GOING TO KEEP COMING WHEN HE STOPPED AT THE GATE. A GREAT RELIEF CAME OVER ME. I SAT BACK BLOWING THE WHISTLE, THEN HE LOOKED ME IN THE EYE AND PULLED OUT IN FRONT. AT THAT POINT, I KNEW THE ANSWER WHEN I HEARD THUMP, AND AT 75 MPH IT TOOK ALMOST ONE MILE WHEN THE TRAIN WAS PLACED IN EMERGENCY TO COME TO A STOP. AS WE WERE STOPPING ALL THE DEBRIS BEING PUSHED ALONG THE TRAP ROCK, WAS ALL FLYING TOWARDS THE LOCOMOTIVE WINDSHIELD AND SIDE WINDOWS. THE MOST FRIGHTING THOUGHT IN MY MIND WAS THAT THE AUTO WAS GOING TO EXPLODE THE 1500 HUNDRED GALLONS OF FUEL I WAS SITTING ON. THANKFULLY WE DID NOT EXPLODE, AND WHEN WE DID FINIAL STOPPED I CLIMBED DOWN OFF THE LOCOMOTIVE TO WITNESS A HORRIFYING SEEN OF A VEHICLE NO WIDER THAT THREE FEET WIDE, CRUSHED ON THE FRONT END OF THE LOCOMOTIVE AND THE KNUCKLE OF THE OF LOCOMOTIVE PENETRATING THE VICTIMS HEAD."

W. J.; WHEN WE CAME AROUND THE CURVE AND STRUCK THE SNOW MOBILE, I RAN BACK. PRAYING THAT THEY JUMPED CLEAR. WHEN I GOT TO THE LOCATION I SAW THE MANGLED BODY, I KNEW HE WAS DEAD. I FELT LIKE I WAS GOING TO VOMIT. WHEN I LOOKED UP, I SAW ALL HIS FRIENDS RUNNING TOWARD ME, I THOUGHT THEY WERE GOING TO KILL ME.
THIS WAS MY THIRD INCIDENT, IN TWENTY YEARS, I HAD NIGHTMARES WAS SICK AND COULD NOT SLEEP FOR WEEKS.

OTHER COMMON COMMENTS FROM TRAIN CREWS: "PRACTICALLY EVERY TRIP SOMEBODY TRIES TO BEAT A TRAIN."
"WHEN EVER I GO OVER THE CROSSING OR SITE I THINK OF THE VICTIM AND HOW THEIR FAMILY IS DOING."

J. T.; JUST BEFORE IMPACT, I SPOTTED THE TRACTOR CAB AND A PORTION OF THE SHINY, 9200-GALLON GASOLINE TANK FROM HIS RIGHT-HAND WINDOW. FOR A FLASH, HE HOPED IT WAS A MILK TRUCK. THEN HE CAME THE HORRIBLE REALIZATION THAT HE WAS ABOUT TO COLLIDE WITH A FUEL TANKER. IN AN ENGINEERS MIND, HE SAYS, HITTING A SCHOOL BUS IS THE ONLY THING WORSE THAN COLLIDING WITH A GASOLINE TANKER.

THE TRAIN TRAVELING AT 28 MPH, RIPPED THROUGH THE BODY OF THE TANKER, IGNITING THE GASOLINE AND SENDING FLAMES 50 FEET INTO THE AIR. THE BURNING GAS SPILLED ONTO THE LOCOMOTIVE CAB AND ROAD WAY SETTING FIVE AUTOS, STOPPED AT THE CROSSING, ON FIRE.

IN THE CAB, THE CREW WAS ON THE FLOOR, AND BURNING GAS HAD SET THE ENGINEER ON FIRE. SECONDS SEEMED LIKE HOURS. I LOOKED AT THE CREW AND STATED "THIS IS IT, WE ARE NOT GOING TO MAKE IT."

MIRACULOUSLY THE CREW DID MAKE IT, HOWEVER SEVEN OTHERS DID NOT, INCLUDING A SIX MONTH OLD CHILD.

HERE I COULD GO ON AND ON, THE POINT BEING THAT SOMETHING HAS TO BE DONE TO PROTECT THE CREWS FROM CHRONIC STRESS SYNDROME. THE OTHER VICTIM THE ENGINEER WHO IS THE LAST TO SEE THE VICTIM ALIVE. THE CONDUCTOR OR ASSISTANT CONDUCTOR WHO HAVE TO GO BACK TO HOLD A HAND OR IDENTIFY A CORPSE OR BODY PARTS. THIS IS NOT A NATURAL EVENT ITS IS UNNATURAL EVENT, BUT COMMON IN THE INDUSTRY, THERE IS MORE THAN ENOUGH RESEARCH DONE, THAT DEMONSTRATES THE NEED TO PROVIDE ASSISTANCE AND RELIEF FOR RAIL CREWS.

THE PURPOSE OF THE LEGISLATION IN RHODE ISLAND HAS FOUR ESSENTIAL STEPS:

RELIEF ON SITE OF ACCIDENT, SINCE 1989 WE IN THE STATE HAVE MADE EVERY EFFORT TO CONTACT ALL ENGINEERS THAT WORK IN MA, NH, AND RI TO PROVIDE FOR PEER CONTACT, OVER 95% HAVE STATED THEY NEVER SHOULD HAVE BEEN ASKED TO CONTINUE TO OPERATE THE TRAIN AFTER SAID ACCIDENT. THEY FELT THEY WERE IN THE STATE OF SHOCK AND SINCERELY DIDN'T REALIZE THIS, UNTIL LATER. WHAT USUALLY HAPPENS, IS A DISPATCHER, HUNDREDS OF MILES AWAY, WILL CALL THE ENGINEER AND ASK IF THEY ARE OK TO CONTINUE? WHILE THE TRAIN HAS BEEN SITTING FOR THE USUAL OF TWO HOURS OR MORE FOR THE CORONER TO INSPECT THE SITE AND LOOK FOR BODY PARTS. I DON'T MEAN TO SOUND CRUEL, BUT THIS IS REALITY WHEN A TRAIN MEETS A AUTO OR VICTIM THERE IS NOT MUCH LEFT BUT PIECES. MEAN WHILE THE ENGINEER IS LEFT UP IN THE CAB OF THE LOCOMOTIVE, TRYING TO DEAL WITH THIS UNNATURAL EVENT SOMETIMES CRYING, SHAKING, ETC. **IN THE RAILROAD ENGINEERS CAREER OF TWENTY FIVE YEARS ONE CAN EXPECT TO BE INVOLVED IN AT LEAST THREE INCIDENTS, THERE IS ONE IN SEVEN CHANCES OF BEING INVOLVED IN A TRAGEDY EVERY TIME THEY GO TO WORK. THERE NO STANDARDS**

COUNSELING SERVICES OR CRITICAL INCIDENT STRESS DEBRIEFING. (CISD) IS IMPORTANT BECAUSE. BY DEFINITION A CRITICAL INCIDENT IS AN EVENT OR SITUATION THAT CAUSES PEOPLE TO EXPERIENCE UNUSUAL STRONG

EMOTIONAL REACTIONS WHICH PUSH THEM BEYOND THEIR NORMAL COPING MECHANISMS AND HAVE THE POTENTIAL TO INTERFERE WITH THEIR ABILITY TO FUNCTION. ALL RAIL INCIDENTS COULD CLEARLY BE CLASSIFIED HERE.

WHEN INVOLVED IN A INCIDENT SUCH AS THIS, WHERE THE EVENTS ARE UNUSUAL OR THE SIGHTS AND SOUNDS SO DISTRESSING AS TO PRODUCE A HIGH LEVEL OF IMMEDIATE OR DELAYED EMOTIONAL REACTION, THIS IS AN EXTREMELY VIOLENT THING TO WITNESS, THE ENGINEER IS HELPLESS TO DO ANYTHING BUT PUT HE TRAIN IN EMERGENCY, BLOW THE WHISTLE AND HAVE FAITH, THAT THE VICTIM CLEARS OUT OF THE WAY. EMPLOYEES ARE NOT ADEQUATELY PREPARED TO HANDLE THIS EVENT. RARELY DOES A CARRIER CALL TO ASK IF THEY CAN ASSIST YOU. **THERE ARE NO STANDARDS.**

EVEN THOUGH THE EVENT MAY BE OVER, YOU MAY NOW BE EXPERIENCING OR MAY EXPERIENCE LATER, SOME STRONG EMOTIONAL RESPONSES OR PHYSICAL REACTIONS. IT IS VERY COMMON AND QUIET NORMAL, FOR PEOPLE TO EXPERIENCE EMOTIONAL AFTERSHOCKS, AFTER A HORRIBLE EVENT.

SOMETIMES THE EMOTIONAL RESPONSE OR STRESS REACTION APPEAR AFTER THE EVENT, FEW HOURS A FEW DAYS, AND IN SOME CASES THEY TAKE WEEKS OR MONTHS MAY PASS BEFORE STRESS REACTIONS APPEAR, IF LEFT UNTREATED.

THE SIGNS AND SYMPTOMS MAY LAST A FEW DAYS, WEEKS OR MONTHS AND SOMETIMES LONGER DEPENDING UPON THE SEVERITY OF THE TRAUMATIC EVENT.

COMMON SIGNS OF STRESS REACTION:

PHYSICAL: FATIGUE, NAUSEA, TWITCHES, CHEST PAIN, BREATHING DIFFICULTY, HEADACHES, WEAKNESS, CHILLS, SWEATING, ETC.

COGNITIVE: BLAMING SOMEONE, CONFUSION, NIGHTMARES, INTRUSIVE THOUGHTS, POOR ATTENTION, MEMORY LOSS, ETC.

EMOTIONAL: ANXIETY, GUILT, GRIEF, DENIAL, EMOTIONAL SHOCK, FEAR, DEPRESSION, APPREHENSION, FEELING OVERWHELMED, AGITATION, ETC.

BEHAVIORAL: WITHDRAWAL, EMOTIONAL OUTBURST, LOSS OF APPETITE, ALCOHOL CONSUMPTION, INABILITY TO REST, NONSPECIFIC BODILY

COMPLAINTS, STARTLED REFLEX, ETC.

WITHOUT SUCH DEBRIEFING PROCEDURES, AND ACCORDING TO OTHER STUDIES SUCH AS THE "EAP DIGEST" OF 1988. EXTREMELY SEVERE TRAUMATIC EVENTS WITH RAPID TREATMENT COST 40 TIMES LESS THAN LATER TREATMENT OR $5000.00, AS OPPOSED TO $200,000.00. WITHOUT PROPER INTERVENTION, THE PATIENT INVOLVED IN A CRITICAL INCIDENT WILL SUFFER FOR MANY YEARS ALONG WITH THEIR FAMILIES AND SOCIAL CIRCLES.

ANOTHER ASPECT OF THIS LEGISLATION IS <u>SICK LEAVE</u>, WITH COMPENSATION AWAY FROM THE WORK ENVIRONMENT. THE EMOTIONAL SCARS THAT BEFALL THE ENGINEER OR CREW SHOULD NOT BE COMPOUNDED BY NO COMPENSATION AND TIME OFF AFTER SAID ACCIDENT. MANY RAILROADS ACROSS THE COUNTRY AND CANADA PROVIDE COMPENSATION OF A FEW DAYS OFF. THE RAILROAD ENGINEERS IN THE STATE OF MASSACHUSETTS HAVE NO SICK DAYS, THIS IS QUITE COMMON THROUGH OUT THE INDUSTRY. THIS IS WHY IT IS NECESSARILY TO INCORPORATE SICK LEAVE, IN THE LEGISLATION. **<u>THERE ARE NO STANDARDS</u>**.

THE FINIAL PIECE OF THE LAW IN RHODE ISLAND, IS WHEN THE ENGINEER WHO IS THE IN THE MOST SAFETY SENSITIVE POSITION ON THE RAILROAD, IS READY T0 RETURN TO WORK FOLLOWING A CISD THEY CAN ASK FOR A RIDER, SOME ONE WHO IS QUALIFIED TO OPERATE THE LOCOMOTIVE. THE LOCOMOTIVE ENGINEER CERTIFICATION LEGISLATION, STATES WE WANT ENGINEERS AT 100% CAPACITY AT ALL TIMES YET THERE ARE NO SAFETY STANDARDS TO PROTECT WHEN THE SYSTEM FAILS. **<u>THERE ARE NO STANDARDS.</u>**

IF WE WORK IN THE AIRLINE INDUSTRY, CISD WOULD BE PART OF THE TRAINING, WITH TIME AWAY FROM THE ENVIRONMENT IF INVOLVED IN A INCIDENT. SAME AS FIREMAN, POLICEMAN AND MANY OTHERS IN SAFETY SENSITIVE POSITIONS.

IN 1993 THERE WERE 523 FATALITIES AND 509 SERIOUSLY INJURED TRESPASSING ON RAILROAD PROPERTY. ALSO IN 1993 THERE WERE 4892 COLLISIONS AT HIGHWAY/RAIL INTERSECTIONS, WHICH RESULTED IN 626 FATALITIES AND 1837 INJURIES. INTRIGUINGLY ENOUGH IN 1993, ALTHOUGH I DO NOT HAVE AN DATA TO SUPPORT A CORRELATION, THERE WAS 497 DECERTIFICATIONS OF LOCOMOTIVE ENGINEERS, I OFTEN WONDER HOW MANY

OF THOSE WERE INVOLVED IN A CRITICAL INCIDENT PREVIOUSLY AND DIDN'T RECEIVE PROPER ATTENTION?

THE POINT BEING THAT A TRAIN CREW JUST EXPERIENCE ITS WORST NIGHTMARE, THEY NEED RELIEF AND INTERVENTION. THIS IS A RAIL ORGANIZATIONS MOST VITAL ASSET, IT'S EMPLOYEES, THE TRAGIC EXPERIENCES THAT BEFALL ON A TRAIN CREW, EXEMPLIFIES THE NEED FOR INITIATED LEGISLATION TO ADDRESS THESE WORKERS, THEIR PROFESSION AND RAILROAD SAFETY. THIS CAN BRING ACCIDENTAL TRAGEDIES INTO THE DAILY WORK PLACE OR POTENTIALLY PREVENT FUTURE ACCIDENTS.

LAWS ARE MADE TO PREVENT THESE ACCIDENTS, BUT WHO CAN ENFORCE THEM, IN MOST STATES ONLY IF A POLICE, AND ONLY IF THEY ARE PRESENT TO WITNESS THE VIOLATOR, THEN THEY CAN CHARGE THE VIOLATOR. EDUCATION OF THE POLICE OFFICERS AS TO WHAT AN ENGINEERS GO THROUGH AFTER AN ACCIDENT, AND KNOWABLE, THAT A TRAIN DOESN'T STOP ON A DIME IS IMPORTANT.

FOR INSTANCE:
AN 8-CAR PASSENGER TRAIN GOING
60 MPH =2/3 OF A MILE STOPPING DISTANCE,
79 MPH = 1 1/8 MILES.
150 CAR FREIGHT TRAIN APPROXIMATE STOPPING DISTANCE
30 MPH = 2/3 OF A MILE.
50 MPH = 1 1/8 MILES.

WE MUST ALSO EDUCATE THE MEDIA, POLICE, CARRIERS AND PUBLIC. THAT ENGINEERS DONT HAVE TO BE DRUG TESTED, OR SHOW THEIR AUTOMOBILE DRIVERS LICENSE, AFTER SAID ACCIDENT. WE MUST REQUEST THE MEDIA LEAVE THE NAMES OF THE ENGINEERS OUT OF THE NEWS, SO THEY ARE NOT HARASSED BY THE VICTIMS RELATIVES.

OTHER HIGHWAY/RAIL INTERSECTION SAFETY LEGISLATION THE BLE IS WORKING ON IN THIS STATE AND OTHERS ACROSS THE COUNTRY ARE INCREASING THE FINES, PENALTIES, AND ENFORCEMENT OF THOSE WHO TRY TO BEAT THE TRAINS TO THE INTERSECTIONS. WE FEEL THIS EFFORT SHOULD BE NATION WIDE ITS A WAY TO EDUCATE AND DETER ABUSE.

WE ARE ALSO WORKING ON LEGISLATION THAT WOULD REDUCE A TRAINS SPEED TO RESTRICTING WHEN THE HEAD LIGHT OR WARRING WHISTLE FAIL

WHILE TRAIN IS ENROUTE. WE PUT MUCH EMPHASES ON THESE SAFETY WARNING DEVICES, BUT WHEN THEY FAIL, WE PLACE THE JUDGMENT IN THE HANDS OF THE LOCOMOTIVE ENGINEERS, WE FEEL COMPETENT TO THIS CHALLENGE, BUT THERE NEEDS TO BE SOME SAFETY STANDARDS NATION WIDE.

AS THE NEED FOR RAIL RIDERSHIP CONTINUES TO GROW, WE NEED TO ADDRESS CERTAIN SAFETY ISSUES AND NOT COMPOUND THE RESPONSIBILITIES OF RAILROAD EMPLOYEES.

THANK YOU FOR YOUR TIME AND ATTENTION.

Appendix G

Crossing Improvement (Engineering) Program Papers

Research on Highway/Rail Crossing Improvements:

A Practitioner's Perspective

By: Thomas R. Zeinz
Illinois Central Railroad

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Research on Highway/Rail Crossing Improvements: A Practitioner's Perspective

I have been asked to speak to you today on the history of grade crossing improvement research. I do so not as a researcher, but as an individual who has been practicing one or more aspects of railroad engineering for the better part of the last twenty-five years, the last eleven of those dealing almost exclusively with highway/rail intersection issues. While I've not had extensive direct exposure to much of the research that predates my direct involvement in this field, I have made every effort to acquaint myself with most of the relevant work that has been reported on since.

There are probably other persons here today who have a greater working knowledge of work that has been done in the past. Hoy Richards, who will speak later in this portion of the program, is frequently credited with having what is probably the most extensive annotated bibliography assembled anywhere on this subject, but even he readily admits it's far from complete. Trying to do so would likely entail thousands of man-hours of work.

At a recent TRB meeting, Bill Berg made the observation, if I may paraphrase him, that crossing research seems to have a shelf life of about 20 years. What he meant by that was that owing to the lack of coordinated efforts to preserve this information, whenever a new generation of researchers and practitioners comes along, what went before them is quickly forgotten. He further observed that many of the questions that confront us today are the same questions that were being asked by our predecessors 20 years ago.

While I submit that Bill may well be right, it has been my experience that past work which was deemed to be significant at the time *does* tend to get passed along. The fact that so little of it has been causes me to wonder if much of it was really all that significant in the first place; whether circumstances have sufficiently changed in the interim that it's still all that applicable to today; and if we're still asking the same questions now, then the work done 20 years or more ago apparently didn't provide many lasting answers.

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To understand the history of research in this field, one must appreciate the historical relationships between the players. Ever since the first pair of rails was laid across a road, or vice-versa, the relationship between the predominately privately owned railroads and public roadway agencies can be described as antagonistic and frequently acrimonious. The conflicts, which have been many, have generally revolved around a single, central issue: No one wants to admit responsibility for this intersection. The primary reasons are competition for resources (who should pay) and tort liability (again, who should pay). It's like a child's game of 'hot potato' where everyone stands in a circle and passes a potato, the object being to *not* be the person holding the potato when the music stops. After 150 years, the game still continues.

The other principle player is John Q. Public. Even before automobiles, the public in this country, it seems, has had a difficult time reacting to a vehicle that can't stop, can't even slow down very quickly and can't swerve so as to avoid colliding with them. Railroaders are equally nonplused that the public apparently has so little respect for something that's many times larger, and often faster. In feudal societies, people were conditioned to know their place and wait their turn. It seems one of the anomalies of a society based on personal equality is that people believe 'first come, first served' is one of their inalienable rights. The fact remains, no matter your cultural biases or the form of legal system in place, you can't repeal the laws of physics.

Quite honestly, the one significant thing that I can say about much of what I've seen passed off as crossing research is that a lot of it is of *little or no significance*. Much of it hasn't been field tested and even for that which has, the tests have frequently been so limited that they're either statistically irrelevant or inconclusive at best. The fact that we're still asking many of the same questions as were asked a generation ago is indicative of our not having found answers or, perhaps, maybe we're still asking the wrong questions.

From my perspective, the major problems that have historically impeded the conduct of meaningful research in this area have been and continue to be:

1) For the most part, we're dealing with relatively infrequent events which seemingly occur more or less at random. It's obviously quite difficult to measure something's effectiveness in reducing accidents when the expected frequency at any given location is only once every 15, 20 or 25 years to start with.

2) Researchers, railroaders and even highway interests are frequently reluctant to try anything which substantially deviates from the current 'norm' out of fear of the possible liability consequences should an accident occur while the test is still in progress.

3) The entities which sponsor and fund research, or the researchers themselves, often have a partisan interest in the outcome. All too often, the research is designed and undertaken by one party or another to justify or further their own agenda. Face it, would any of you, were you otherwise in a position to do so, fund a research effort *knowing* a reasonable expectation existed that the findings could undermine your own vested interests? Highway entities, railroads and researchers who double as expert witnesses are equally suspect in this regard.

4) All too much of the research that has been conducted has focused on the uniqueness of highway/rail intersections, rather than recognizing the similarities with highway/highway intersections. In my opinion there has been a general and sometimes deliberate failure on the part of traffic engineers to recognize and apply the same principals of highway traffic control engineering at highway/rail intersections as are customarily and routinely applied at comparable highway/highway intersections. The focus should be on fostering participant behavior that avoids collisions, irrespective of the engineering disciplines invoked.

If I may, I would like to spend the remainder of my time highlighting a half-dozen or so examples of some of the research I'm familiar with that I do consider significant and explain briefly why I consider it so. I suspect some of you may consider some of my selections somewhat surprising.

NCHRP Report 50, David W. Schoppert and Dan W. Hoyt, 1968. This report, which is the forerunner of the current *Railroad-Highway Grade Crossing Safety Handbook*, was the first real effort to compile in one place essentially all of then current collective wisdom about grade crossing safety engineering. However, while the authors did recognize certain synergies between rail/highway and highway/highway intersections, they, in my opinion, grievously erred by representing a rail/highway grade crossing as an Case I, or uncontrolled, intersection. In so doing, they discounted the warning devices at crossings as having any significance as traffic control devices, a position which most practitioners consider preposterous. Regrettably, both the 1st and 2nd editions of the *Railroad-Highway Grade Crossing Safety Handbook* have perpetuated this same error.

Rail-Highway Crossing Hazard Prediction Research Results, P. Mengert, 1980 - This research by USDOT let to the development of the DOT Accident Prediction Formula, now generally regarded as the best accident prediction model and hazard ranking formula available.

Effectiveness of Motorist Warning Devices at Rail-Highway Crossings, E. H. Farr and J. S. Hitz, 1985 - What I deem significant about this USDOT project is that it found there was no significant correlation between train speed and frequency of accidents at gated crossings. This finding was extremely instrumental in softening both Railroad and State Highway Department attitudes toward the use of gates on single track main lines in the latter 1980's.

Evaluation of Two Active Traffic Control Devices for Use at Railroad-Highway Grade Crossings, Daniel B. Fambro, K. W. Heathington, and Stephen H. Richards, 1989 - This field test, although quite limited, did indicate the potential benefit of using train activated standard 3-position highway traffic control signals at highway/rail intersections in lieu of traditional highway/rail flashing lights. It clearly demonstrated the majority of drivers respond better to standard traffic devices which they know and understand. Implicit in that, I think, is a greater perception on the motorists' part that they were more likely to be ticketed for violating a traffic light than a crossing signal. This report shows that we don't always need to search high tech extremes. Sometimes the answer may be right next door and 'off the shelf' to boot.

A Preliminary Laboratory Investigation of Passive Railroad Crossing Signs, Nancy Bridwell, Elizabeth Alacandri, Doug Fischer and Esther Kloeppel, 1993 - This is the so-called 'Turner-Fairbanks Passive Signing Study'. I find it significant in three respects. The first is that there's no good substitute for field testing proposed new signs. If you show people two signs out of context, one they're quite familiar with, and the other, one they've never seen before, it should be a foregone conclusion the one they're familiar with will score higher on recognition and comprehension. The second is that despite the fact that the standard R-15 crossbuck scored as high or higher than any of the alternate schemes, over half the subjects still didn't know the correct driver response. Thirdly, the conduct of and reporting of this study showed how easy it can be for FHWA to drag its feet on a study it really didn't want to do because it was afraid the results might tell it something it didn't want to hear.

FRA Florida Whistle Ban Study, Bruce F. George, 1990. Bruce, I've got to hand it to you. That's one of the best pieces of analytic homework I've ever seen. It simply doesn't pay to argue with the facts. I trust everyone here is familiar with this study, which, in itself, is quite a compliment. It took a subject which was very political, potentially very divisive, and reduced it to terms that humbled even the most outspoken detractors.

This last study, and the resultant FRA Emergency Order *saved lives*. That is what all our research efforts should try to do. Not to protect turf or partisan interests. Not to impress a judge or jury. But to *save lives*. That, in my opinion is what this workshop should be all about.

HIGHWAY-RAILROAD GRADE CROSSING SAFETY RESEARCH NEEDS WORKSHOP
CROSSING IMPROVEMENT PROGRAMS
CURRENT RESEARCH

John T. Sharkey, Illinois Central Railroad
Chairman, Communication and Signal Division
Association of American Railroads

April 11, 1995

Train Presence Detection Task Force

The first item I'd like to discuss this afternoon is the status of the AAR Train Presence Detection Task Force's work in the area of train shunt loss on the island circuit of crossing warning systems. Such losses of shunt occasionally result in gates lifting and/ or disruptions in the flashing lights while a train is occupying the grade crossing. The task force was formed as an multi-disciplined oversight committee in October of 1994. The task force consists of senior railroad officers in signal, track, mechanical, and grade crossing policy issues, AAR staff, as well as Federal Highway Administration and Federal Railroad Administration members.

The task force reviewed research performed by a C&S division task force and the AAR Research and Test Department. The following is a summary of the major findings:

- Shunt loss was observed at each of 14 field test sites, suggesting that the problem may be wide spread. However, it should be noted that the test sites were known "bad actor" crossings which had previous reports of loss of shunt. Of 42,000 trains observed, 120, or 0.3 percent exhibited shunt loss.
- The longest loss of shunt period observed was 17 seconds, and 72 percent were 2 seconds or less.
- Analysis of field data and laboratory investigations of the resistive films on wheels and rails indicate that the causes of shunt loss are contaminants such as iron oxide, sand, and possibly brake shoe material, in combination with light axle loads. No effect of rail lubrication was noted.

It must be pointed out that the island circuits that were experiencing loss of shunt problems were only a problem when integrated into the older models of Constant Warning Time devices or a Motion Sensing systems. The reason is that the CWT or motion sensing systems have an internal loss of shunt timing circuit built in when a train is approaching. That is why the gates stay down for ten or twenty seconds after the train stops. But in order to raise the gates after a train leaves the crossing, the loss of shunt timer is bypassed once the island circuit drops out and what is occurring on the approach is ignored. Therefore when the island looses it's shunt for a long enough period to pick up, the CWT relay picks up. The problem is not apparent on track circuit based systems because train wheel shunts are usually still shunting the approach circuit and the approach circuit holds the gates down.

Next the task force finalized a Request For Information which was sent to 40 potential suppliers of control systems which might mitigate the loss of shunt problem. The goal was to seek

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information on safe, reliable, cost-effective alternatives to detect trains occupying highway/ rail grade crossings. The intent was to select the most promising system concepts for test and evaluation at the test track and then possibly test them in revenue service at "bad actor" crossings. The RFI was sent out on November 30, 1994, and had a response deadline of January 16, 1995. We anticipated receiving five or six responses and were surprised when we received ten responses to the RFI.

After review of the information, seven suppliers were invited to make presentations to the task force on March 27th and 28th. The presentations made by these suppliers covered systems ranging from magnetic wheel detectors, rail strain gages, magnetic anaomoly detectors in conjunction with photoelectric detectors, island circuit shunt enhancers, and microprocesor based island circuits which use their processing power to differentiate between a receeding train and loss of shunt. At that point, the task force then selected first four of these technologies to test at the test track beginning in June 1995. The microprocessor based island will not be available until later this year. Up until this point the economics of the various solutions have not been considered because may of the proposed island technologies are part of a larger systems and the cost of a scaled down version solely for the island has not been determined.

The systems that survive the testing at the test track may then be selected for test in revenue service. Also at that time we may test the latest generation of constant warning time devices which have the ability to do processing on the island receiver input to distinguish between loss of shunt and a train leaving the island circuit. It is anticipated that testing on actual railroad crossings would begin in August of this year and be completed in January of 1996. At that time a final report will be made.

Other Highway-Rail Crossing Research Needs

The Association of American Railroads has identified other areas where it feels contiuing research needs to be made.

1. Low-Cost Active Warning Devices: Develop and evaluate low-cost active warning devices for low-density grade crossings. Such research could begin with the development of the functional requirements and performance specifications for such devices. These could be the basis for a request for proposal to manufacturers to develop prototypes. Manufacturers' prototypes could then be tested to determine their durability and effectiveness. Testing of effectiveness would require carefully controlled studies to determine whether the prototypes significantly influenced long-term driver behavior.

2. Improved Passive Warning Devices: Develop and evaluate improved passive warning devices for grade crossings. The approach could be the same as for the low-cost active devices. Such devices would incorporate the findings of highway driver response research.

3. Off-Track Train Detection Systems: Active crossing warning systems are now activated by track circuits that detect approaching trains. The advanced train control systems under

consideration do not rely on track circuits, however, because they constrain the use of more modern train dispatching systems. In addition, the increasing use of lighter-weight rail cars and specialized intermodal equipment will require increasingly more complex and costly track circuit systems for reliable detection, especially at grade crossings. These factors argue for the investigation of train detection devices for activation of grade crossing warning systems that do not rely on track circuits.

4. Four Quadrant Gates: There should be testing and evaluation of prototype crossing systems for four quadrant gates. Features of these systems include four-quadrant gates, and a crossing occupancy warning system that alerts the locomotive crew if a highway vehicle is on the tracks after the gates have been lowered. However, four quadrant gates are being considered by many highway authorities as an answer to all their problems. And they are not. The signal community is gravely concerned about the entrapment issue and the control logic problems that may result. The design of all gate mechanisms in use today on highway grade crossings, are designed to fail in the down position because that is the safe position to fail in. When we consider four quadrant gates, we now have a gate which is both an entrance gates to violators, and an exit gate to the law abiding citizen. It needs to be determined which way the gate is to fail if the power to it is lost. The design criteria must be determined by FRA and FHWA, rather then left up to the individual railroads or States.

Thank you for this opporunity to share what is being done in the industry, and more importantly share some of our concerns for the future.

ASSOCIATION
OF AMERICAN
RAILROADS

November 30, 1994

The Association of American Railroads is issuing a Request for Information (RFI), attached, to identify alternative reliable, cost effective systems for train presence detection. Selected systems identified through this process will be tested rigorously by the AAR to determine if these systems are suitable for detecting train presence at grade crossings.

If you have a system that can meet the requirements described in this RFI, I encourage you to respond, either individually, or as part of a larger consortium. As is decribed in the RFI, the potential market for improved train detection systems is substantial.

Those companies whose responses we consider promising will be asked to meet with the AAR Train Presence Detection Task Force, which is overseeing this project. At this meeting, these companies will be asked to make a presentation on their systems, and answer questions from the Task Force. Written questions may also be provided to you in advance of the meeting.

Complete information about responding to the RFI is included in that document. Responses are due by January 16, 1995. Any questions should be directed to Paul Kromberg at the AAR Research and Test Department [202-636-2278, fax 202-639-2285].

Yours truly,

John T. Sharkey

John T. Sharkey
Illinois Central Railroad
Chairman, Train Presence
Detection Task Force

Attachment

cc: Train Presence Detection Task Force

f ups

Research and Test Department
50 F Street, N.W., Washington, D.C. 20001 (202) 639-2240

up5f

Request For Information

Grade Crossing Train Presence Detection

Association of American Railroads

November 1994 -- Version 8

1.0 PURPOSE

On behalf of the North American railroad industry, the Association of American Railroads (AAR) is issuing this Request for Information (RFI) to identify and evaluate safe, reliable, cost-effective alternatives for train presence detection at highway-railroad grade crossings. Potentially, a reliable, cost-effective detection system identified through this process could also be used in other applications, such as approach circuits for grade crossings and track circuits for train control. Systems could be used for both retrofit and new installations.

Reliable train presence detection systems are essential to activate and control warning systems at grade crossings to warn highway motorists and pedestrians of trains approaching and occupying the grade crossing. There are approximately 60,000 grade crossings in the U.S. with active warning devices. Approximately 2,000 - 3,000 active crossing warning systems are newly installed or upgraded each year.

Shunting of track circuits has provided a means of detecting train presence since the basic DC track circuit was invented in 1872. It is still the principal means of train presence detection, and is used world-wide, with some variations to enhance performance. These variations include AC track circuits, and DC coded track circuits.

As other technologies, such as transponders, have become more reliable and less expensive, they are gaining increasing use internationally for detecting train presence in a variety of applications, including grade crossing warning systems. Such alternatives for detecting train presence may also be used to supplement track circuits to improve performance.

Refer to the Appendices for additional background information about crossing warning systems and train presence detection.

2.0 PERFORMANCE GOALS

The AAR is seeking information on safe, reliable, cost-effective alternatives to detect trains occupying highway/rail grade crossings. The intent is to select the most promising systems for test and evaluation. However, the AAR does not guarantee that any system will be selected for evaluation or testing.

Following is a description of the performance goals for these systems.

2.1 Functional Requirements

The train presence detection system shall be capable of detecting the presence of a train of any configuration in any situation, within the parameters of the operational environment, as described below. The system shall be capable of communicating the detected train presence to a grade crossing warning device. Further, the system shall be capable of determining when the train has left the specified area and communicating that information to the warning device.

2.2 Operational Environment

2.2.1 Detection Zone

Trains must be detected at least 50 feet from the edge of the pavement of the highway on both sides. The minimum length of the detection zone is 120 feet.

2.2.2 Track Structures

A wide variety of track is in service, which must be accommodated by the train presence detection system. Variations occur in types and quality of ballast, ties, rail, and associated hardware. These properties may affect the electrical resistance (impedance) of particular track. Variations in rail profile also affect the wheel/rail contact patch.

Contiguous multiple crossings may be present in an area where simultaneous operation is required. Proposed systems must be able to operate within four hundred feet of another crossing, equipped with either similar technology or conventional track circuits.

Multiple, parallel tracks may also be present, at track centers of as little as 11 feet.

Reference the American Railway Engineering Association's Manual for Railway Engineering for more detailed information on track structures. The Association of American Railroads Communications and Signal Division's Signal Manual provides additional details in Section 3.1.20 on related electrical issues.

2.2.3 Train Consist Characteristics and Speeds

Characteristics of trains or cars that need to be detected vary greatly. The trains range from long, slow bulk commodities trains to short high speed trains. Detection must accommodate freight trains operating as fast as 80 miles per hour and passenger trains operating as fast as 110 miles per hour. Additionally, the system must detect the presence of a single car standing or moving in the crossing. Train consists may accelerate or decelerate at rates up to 3.2 feet per second per second. Consists may enter the detection zone and leave the zone via the point of entry.

Trains may be as short as 40 foot single-unit switching locomotives or a cut of one or more cars. They may be as light as 5,000 pounds per axle for empty aluminum coal cars or innovative intermodal equipment. (These assumptions do not consider trends towards future lighter axle loads or the presence of hi-rail and similar maintenance-of-way equipment.)

Axles may be spaced as far apart as 70 feet. Some equipment may have split-axle designs, which may raise wheel-to-wheel shunting impedance substantially. However, in most cases, the wheel/axle/wheel DC resistance is a maximum of 50 micro-ohms. Any mix of equipment types may be found in any given train consist.

Variations in wheel profiles also occur, due to variations in both design and wear.

2.2.4 Highway Traffic Operational Requirements

While safety is the highest priority, delays to highway traffic due to activation of grade crossing warning devices must be minimized. In general, systems should not maintain activation of highway gate/signal operation more than two seconds after trains have cleared the presence detection circuit.

2.2.5 Environmental Conditions

The equipment detection system must operate in the range of conditions found throughout the North American continent. These include shock and vibration and extremes of weather (temperature, lightning, precipitation, ice formation, etc.). A wide range of environmental contaminants is also present at various roadbed locations, including spilled lading (e.g., coal dust, iron ore dust, taconite, chemicals, grain), leaves, sand, mud, diesel fuel, greases, iron oxides, and highway salt.

The Association of American Railroads Communications and Signal Division's Signal Manual provides additional details in Sections 3.1.20 and 11.5.1.

2.2.6 EMI Susceptibility

Installations may be subject to electromagnetic interference from radiated and conducted emissions. Guidelines for the limits on the electric field strengths encountered may be obtained from ATCS Specification 110, "Environmental Requirements," Revision 3.0, March 1993.

2.3 Interface with Grade Crossing Warning Devices

Not more than two seconds may elapse between the exit of the train/car and a signal sent to the warning device indicating no occupancy.

The ability to interface with existing grade crossing equipment is desirable. However, since there are multiple types of existing grade crossing devices, and no standard electrical or logical interface, this ability is not a requirement for responding to this RFI.

Current grade crossing warning systems are capable of operating using a backup low voltage power supply, since a backup power source of all systems is required by law.

2.4 Reliability

Reliability of the train presence detection system is critical to the reliable operation of the crossing warning system. The highest achievable reliability is desired.

Reliability in terms of occurrences may be expressed as failures to detect a train's presence per 1000 trains. However, the duration of failures is also significant and must be considered, since longer-duration failures are usually more critical than shorter ones.

2.5 Maintainability

The system shall be capable of being promptly maintained by railroad signal forces. Tasks included are fault diagnosis, fault isolation, removing and replacing necessary components, and performance verification testing. Built-in diagnostics may be helpful in meeting this requirement.

2.6 Costs

As is generally the case, systems that have a lower life-cycle cost will be preferred, other factors being equal. This is particularly relevant because of a desire to implement the solution at a maximum number of crossings in a relatively short time period.

3.0 INFORMATION REQUIRED

Suppliers with systems that will meet the requirements summarized above are requested to respond to this RFI by providing the following information.

3.1 Proposed Solutions

3.1.1 Description of Proposed System

Provide a summary functional description of how the proposed presence detection system will operate. This description should be no more than one page.

3.1.2 Current Status of Proposed Solution

3.1.2.1 Current Installations

Please state where your system(s) are installed (one or two examples only), and how long have they been in service (if applicable).

3.1.2.2 Operational Conditions

Please state what the volume of rail traffic is and what the operational conditions are at the site(s) described above (if applicable).

3.1.2.3 Current Performance

Describe the performance of the system(s) described above (if applicable). Include maintainability and reliability (mean time between failures (MTBF) and duration of losses of train presence detection) in your response.

3.1.2.4 Test Results

Include results of any testing that supports your statements describing your system's performance, or that would provide evidence of your system's ability to meet the performance goals discussed in Section 2.

3.1.3 Expected Performance

3.1.3.1 Reliability

Discuss the level of reliability that you project for your system, if different from the current performance indicated in 3.1.2.3, above. Quantify in terms of mean time between failures and duration of losses of train presence detection. Identify the differences between your proposed system and current operational systems that would contribute to the difference in MTBF, if applicable. Also address the tradeoff that is available between reliability and cost for your system.

3.1.3.2 Maintainability

Discuss the level of maintainability that you project for your system, if different from the current performance indicated in 3.1.2.3, above. What will be your system's maintenance requirements? (Specify frequency of repairs, mean time to repair, labor hours, skill level, built-in diagnostics, estimated annual cost per device.)

3.1.3.3 Interface

How will your system interface with existing warning systems (physical/electrical/logical interface) (if known)?

3.1.3.4 Assumptions

What conditions have you assumed that may affect the performance of your system (e.g. climate, train speeds, train frequency, maintenance)?

3.1.3.5 Susceptibility to Environmental Interference

What is the susceptibility of your system to environmental interference? Specific issues include electromagnetic energy generators, such as AC traction motors and electrical storms.

3.1.3.6 Other Advantages and Applications of Your System

Please address any other advantages or applications of your system. For example, could your system be used to provide train presence detection for grade crossing approach circuits, or could it support constant warning time devices? (Constant warning time devices provide the same, fixed amount of warning time regardless of the speed of the train that is approaching the crossing.)

3.1.4 Schedule and Costs

Indicate when you will be able to provide one or more prototypes for test and evaluation. Provide estimated costs for your system in production quantities. This estimate should clearly state what components it does or does not include.

Assume electrical power is available.

3.2 Capabilities to Develop Solution

Summarize your previous work in this field, including a list of references or customers, and the nature of the system developed for each.

Describe your ability to design and manufacture comparable systems and provide systems integration, and to provide technical support for tests and evaluation.

4.0 SELECTION PROCESS

Responses will be evaluated by the AAR based on its examination of the information provided. The AAR will compare the expected performance of each supplier's system with the requirements and performance goals that have been identified in this document.

The AAR will evaluate the suppliers' ability to meet the requirements of this effort according to the following criteria:

- Projected reliability of the candidate system;
- Projected maintainability of the candidate system;
- Supplier's adherence to schedule;
- Supplier's provision, installation, and maintenance of equipment for testing;
- Supplier's provision of technical support for testing.

Systems that already have undergone beta testing or have been demonstrated in service will receive preference in the evaluation process relative to those that have not.

5.0 TEST PROTOCOL

The following is a brief summary of the test protocol that will be used to evaluate candidate systems to detect train presence.

5.1 Test Procedure

Suppliers of selected candidate train detection systems shall each furnish a detection system, including a complete technical description, for preliminary testing at the Transportation Test Center in Pueblo, CO. (Suppliers would not need to furnish entire warning systems, but only the detection systems that would control the actual warning devices. Suppliers will also provide a means of detecting train presence in advance of the test zone in order to turn on the data collection equipment.) The output of the detection systems would be recorded during this preliminary testing. At this stage, the detection systems would not necessarily be used to control actual warning devices.

The data collected will be used to estimate each system's capability to consistently and reliably detect the presence of each car and locomotive in a section of track, and for train movements to be specified by the AAR.

If results of this preliminary testing are promising, more extensive testing at several different sites around the U.S. may subsequently be required for further evaluation. This second phase may encompass testing at sites with different climatic, train operations, train consist, and rail contamination characteristics. All sites would have significant traffic volumes so that each detection system experiences a large number of event recordings.

5.2 Data Analysis

Current industry standard track circuit detection systems that are in good functioning order will be used as the baseline for this experiment. The data collected from each candidate train detection system will be compared to this baseline system. The analysis will compare the candidate systems to the baseline system in several categories, such as operational and detection reliability.

The analysis will also examine system characteristics within sites and across sites. Standard statistical methods will be used to determine if site is a significant factor with respect to detection probability and other measurable characteristics.

In particular, the tests will estimate the following parameters of each detection system for each individual site and all sites together.

1. The probability of detecting a train when a train is present, and the system is said to

be functioning properly.

2. The probability of indicating a train is present when one isn't, and the system is said to be functioning properly.

3. The unconditional probability of detecting a train. This value is expressed as the product of the probability of detecting a train and the probability of the system functioning properly.

4. The probability the system is functioning properly, or system reliability. The probability the system is functioning properly is the fraction of time it is functioning properly.

5. The probability distribution for the time duration of loss of presence detection. The test will estimate the fraction of time a loss of presence detection occurs for each candidate system.

6. Mean and median times to failure of each candidate system.

6.0 ROLES AND RESPONSIBILITIES

This project is under the guidance of a joint government-industry task force comprised of representatives from the Federal Railroad Administration, the Federal Highway Administration, and the railroad industry. Task Force members are knowledgeable in such areas as railroad operations, communication and signal systems, train control systems, freight car and locomotive design, track system design and maintenance, and grade crossing safety.

6.1 AAR/Task Force Role

The AAR, under the direction of the Task Force, will select systems for test, specify test requirements, arrange for test sites, provide test management, collect and analyze test data, and write the final report.

6.2 Supplier Responsibilities

Suppliers shall provide the information that is requested. Those suppliers whose systems are selected for evaluation and testing shall furnish, install, and maintain test equipment. Additionally, they shall provide field engineering personnel during testing to ensure that systems have been installed correctly and are working properly.

It is the intent of the AAR to maintain the confidentiality of proprietary information. However, the AAR cannot guarantee confidentiality. Therefore, suppliers that wish to protect any proprietary rights, including but not limited to patents, trade secrets and copyrights, are advised that they must take all steps necessary to do so.

7.0 SCHEDULE

- Responses are due by January 16, 1995.
- Selection of prototypes for further consideration will be made by February 28, 1995.
- Tests will be completed in early 1996.

8.0 AAR CONTACT

Responses to this RFI and any questions about this project should be directed to:

Paul Kromberg
Senior Assistant Manager
Research and Test Department
Association of American Railroads
50 F Street, NW
Washington, DC 20001

phone 202-639-2278; fax 202-639-2285

9.0 REFERENCES

1. Moody, H., R. Reiff, and S. Gage, "Interim Report: Influence of Contact Patch Resistance on Loss of Shunt," August 1993.

2. Methods of Improving DC Track Circuit Shunting Sensitivity Report D21.3001, GRS, September 1937.

3. Appendix H, "The Rail-Wheel Interface" Proceedings of the C&S Division of the AAR, 1992.

4. "Elements of Railway Signaling," General Railway Signal, June 1979.

5. American Railway Engineering Association, Manual for Railway Engineering, 1994.

6. Association of American Railroads, Communications and Signal Division, Signal Manual, 1993.

7. Association of American Railroads, Advanced Train Control System Specification 110, "Environmental Requirements," Revision 3.0, March 1993.

APPENDIX A

A.0 BACKGROUND

A.1 Grade Crossing Signal Operation

The basic operation of a conventional DC track circuit provides for train presence detection when a train occupies the circuit. The train "shunts" or shorts out the circuit through the vehicle wheels and axles, deenergizing a track relay, which activates the signal or other control device. These circuits are low voltage devices - generally in the 2 volt range. This is required because the resistance of an alternative current path, the tie/ballast structure, is low -- on the order of two ohms per thousand feet. Normally, the wheel/axle/wheel resistance path is very low - on the order of 20 micro-ohms, making it well suited to shunt the circuit.

The signal-controlling track relay is normally energized to provide an indication of an unoccupied track. This provides the "fail-safe" feature of track circuits. If, for some reason, the circuit is interrupted or the power source fails, the relay "drops out," which causes the signal light or warning device to go to its most restrictive mode. A typical track circuit relay picks up (energizes) at 100 milliamperes and drops out at 50 milliamperes. A minimum "shunt" resistance of 60 milliohms must be detected as specified by FRA regulation.

The same principle applies to the grade crossing island circuit, except these circuits can be audio-frequency "overlay" track circuits instead of DC track circuits. This allows the circuit to be used on top of DC track circuits. Higher frequency AC signals attenuate rapidly in rail, eliminating the requirement for insulated joints at the boundaries of the circuit. These circuits are about 110 to 120 feet long, and overlap the highway crossing. The function of the island circuit is to keep the warning device(s), i.e. gates and flashers, active until the last car of the train leaves the island circuit. This allows for a very rapid deactivation.

Highway crossing warning systems also have an approach circuit. The long approach circuit, when shunted, activates the flashers and gates to provide suitable (a minimum of 20 seconds) warning of an approaching train in either direction. Once the train is in the island circuit, the island circuit controls the gates and flashers.

The performance of track circuits is dependent upon maintaining the circuit to prevent "wrong side" failures from occurring while also minimizing "right side" failures. A "wrong side" failure occurs when the track circuit is occupied but the control relay is energized, i.e., the warning system is not activated. This is opposed to a "right side" or fail-safe failure wherein the warning system is activated when no train is in the circuit. (See Appendix B for a discussion of fail-safe design concepts as applied to railroad signal systems.)

A.2 Loss of Shunt

Since track circuits operate at low voltages and currents, the effect of highly resistive thin films on wheels and the rail can affect their performance. As the film resistance increases, the likelihood of a loss of shunt increases. Thus, shunting sensitivity is dependent upon the ballast resistance, the rail and wheel surface condition (i.e., film resistance, wheel/axle/wheel resistance and contact pressure). Several European, North American and Japanese studies are referenced in the "Interim Report: Influence of Contact Patch Resistance on Loss of Shunt." These studies have identified the principal cause of the loss of shunt as films on the wheel and rail, which exhibit the characteristics of a semi-conductor.

These films are usually composed of various oxides of iron, either rust or magnetite (black iron oxide), sand, and small traces of other oxides and carbon. Other external materials such as leaves or lading are implicated in specific cases. Some laboratory tests have implicated films built up from brake shoe materials. At first, lubrication was thought to have contributed to the film make-up, but recent tests (see A.2.1) indicate that lubrication need not be present to have highly resistive films on the rail. However, there may be specific isolated cases where lubrication contributes to film resistance.

The wheel/axle/wheel resistance is negligible. Thus, within the limitations of the track circuit, the film resistance and how that resistance varies with contact pressure become the physical limiting factors for good shunting. This relationship has been known for years, and has resulted in not relying on track shunt for light axle load maintenance-of-way equipment.

The semi-conductor characteristics of these highly resistive films require the film to be "perforated" to allow appreciable current to flow.

An AAR Communications and Signal Division report of data taken from an Organization de Recherche d'Essais (ORE, now European Rail Research Institute) series of reports published in 1963 concluded:

1. The perforating voltage of the shunt path is the sum total of the perforating voltages occurring at each wheel/rail interface.

2. The perforating voltage of the wheel/rail interface depends inversely on the contact pressure.

3. The perforating voltage depends on the relative humidity of the air. In the ORE tests, the perforation voltage using a 50 hz sinusoidal current was cut in half in damp weather as opposed to dry weather.

4. When a wheel is moving, electrical contact between the rail and wheel is continually being created and destroyed.

The effect of humidity on the circuit performance may be countered by the overall circuit performance in wet versus dry conditions. As the ballast resistance goes up in dry conditions, the current in the track circuit goes up, potentially improving the shunting performance of the circuit. The effect of humidity may be an artifact of the circuit design, not any fundamental change in the perforating voltage requirements.

A.2.1 Findings to Date

A measurement program begun by the Association of American Railroads and the Federal Railroad Administration in 1992 and completed in December 1993 included a major data collection program with audio-frequency island circuits at several revenue service sites where loss of shunt was known to have occurred and at the AAR's Transportation Test Center. Auxiliary sites were established at some of these revenue service sites. These auxiliary island circuits were set up adjacent to the island circuit at the grade crossing, with all the functionality of an island circuit except they did not control any gates or flashers. These auxiliary circuits were placed within 100 ft. of the functioning island circuit. The purpose was to enable train-by-train comparisons of the responses of the two adjacent circuits.

Each field site was equipped with a data collection system. The data system recorded the output or receiver voltage and the status of the "island drive relay." The island drive relay controls the active warning devices, i.e., the gates and flashers. Severe loss of shunt resulted in the activation or "pick up" of the island drive relay, resulting in a momentary deactivation of the warning system.

Please refer to the "Interim Report: Investigation of Contact Patch Resistance on Loss of Shunt" for a detailed evaluation of the data collection.

A.2.1.1 Results

Results of the field tests showed some shunt loss at each of the field sites. A few of these events caused the island drive relay to pick up, indicating a possible deactivation of the warning device. Of 42,048 trains measured over the sites, 127 or .30% had an occurrence of island drive relay pick up. The number of occurrences and their duration varied considerably from site to site, suggesting that site specific conditions exist, either physically or electrically. Because loss of shunt was known to have previously occurred at these sites, these data are not necessarily representative of all in-service sites.

An analysis of the longest duration event in each of the 127 occurrences of island drive relay pick up was conducted. Approximately 72% of all occurrences were less than one second in duration, with the maximum duration event of 17 seconds.

Since the total shunt resistance includes the resistance of the wheel/axle/wheel resistance, wheel/axle/wheel resistance data were taken on 140 wheel samples. The wheel/wheel resistance data indicated that the actual resistance is at most 20 micro-ohms, negligible for this analysis.

A.2.1.2 Wheel and Rail Resistive Films

Rail samples and film samples were removed from the field sites for film analysis. The result of laboratory measurements showed that:

1. There was a presence of a highly resistive film on the rail surface, but no film at the "normal" contact patch in the center of the rail.

2. Material in the resistive films was sand and iron oxides. Small traces of other oxides and carbon were detected. There was little variation in the material makeup from site

to site. There was variation in the thickness and location of the films on the rail head.

These data suggest that the film on the rail head varies in extent and thickness across the rail head, and that wheels running off the normal contact patch may be more likely to cause loss of shunt. Also, the materials in the film are ordinary products: rust, magnetite (a normal byproduct of the contact between wheels and rails), and sand either from external sources or used to provide tractive effort. Sanders are required by Federal regulation on all locomotives.

A laboratory test was conducted to examine the relationship of axle load to film resistance. This test showed an inverse relationship between electrical resistance and load. This relationship could be expected as well in the field. The relationship appears to be log linear and monotonic.

APPENDIX B: EXPLANATION OF FAIL-SAFE DESIGN CONCEPTS

This appendix explains some of the major design concepts of safety circuits in "laymen's terms". The intent is to help those outside the signal industry understand the philosophy behind signal design.

FAILSAFE DESIGN, RELIABILITY, AND PROBABILITY

The theory behind failsafe design is to create systems and equipment in such a way that all possible failures will cause the system to be placed in its safest or most restrictive state. In the case of crossing warning systems, for example, if anything happens that would prevent the equipment from detecting an approaching train, the warning system should be activated to alert the public that the detection devices are not properly functioning. While it is recognized that in an imperfect world, nothing can be made totally failsafe, the concept of acceptance of any probability of a failure that could cause the warning devices to remain inactive (a "wrong side failure") and possibly allow the unsuspecting public to drive into the path of an approaching train has never been accepted. Every wrong side failure is investigated thoroughly. No matter how unlikely the probability of a second occurrence, if any design changes to the system or any component of the system can be made to prevent another occurrence, they will be. This policy has been in operation for over a century. Through it has evolved the remarkably safe equipment we use today.

Reliability of equipment is often mistaken for failsafe. If high quality devices with low probability of failure are used, it is assumed that the chance of a wrong side failure is very slim. It is accepted that reliability of equipment is important. A warning device that is often active even when there is no danger will, like the boy that cried "wolf" too many times, eventually be ignored. There is a constant battle to design a system that is as failsafe as possible without sacrificing reliability. Most of the sophisticated equipment in use today is constantly self-checking all of its components. If any single part is not functioning properly, the crossing will activate. In such a system, the reliability of proper operation is dependant on all of its parts.

In some systems, a "redundant" or backup warning device is designed to take over if the primary device fails any of its self-check tests. While this is done to increase the reliability of the crossing, it has nothing to do with its failsafe operation. The backup device will contain the same self-checking circuits as the primary device. If it also fails to work as intended, the warning system will be activated.

In spite of the use of high quality components, redundant equipment, extensive quality checks and periodic testing in the field, there are still many occurrences of crossing warning devices being falsely activated. The environment in which the equipment operates is very rugged. Lightning, water, vandals, and even vermin will sometimes cause problems. Most of all, though, there are thousands of crossings with warning systems. The more devices there are, of course, the greater the possibility that one or more of them will detect a problem and activate the warning system even though a train isn't approaching. Probably everyone has seen a crossing system operate when it shouldn't. However, very few have seen a crossing warning system not operate when it should. If only reliability and not fail-safety was a concern when the equipment was designed, probability would dictate that many of the false activations of warning devices that presently occur would be "wrong side" failures that would cause the equipment to not operate when it should. The resulting danger to the public would be intolerable.

As an example of non-failsafe signal design principles, assume that we need to provide a very simple crossing warning device. First, we take a section of track that is long enough to provide plenty of warning when the wheels of a train enter it and use insulated joints to electrically isolate it from the rest of the track (see Figure 1). Then, we take a battery and connect one terminal of it to one of the rails. Now, take a wire from the other rail and connect it to one side of the coil of a relay. Finally, we run a wire from the other side of the relay coil back to the other terminal of the battery. If an approaching train passes the insulated joints and runs onto our track circuit, its axles will short between the rails forming a path for the electricity to flow from one terminal of the battery to one rail, through the axles of the train to the other rail. It will then flow through the coil of the relay to the other terminal of the battery and energize the relay (see Figure 2). If the warning system is turned on by the contacts of the relay when it is energized, then the warning will occur whenever a train is coming near the crossing... Unless, of course, the battery goes dead, or one of the wires break, or a terminal or connection becomes loose or corrodes, or a rail breaks close to the crossing, or the relay coil burns out. If any of these things occur, then the warning will not be activated, and the flashing lights will remain dark as the train speeds across the highway.

Of course, we can do our best to "armor plate" the system to make it as reliable and safe as possible. We could use high quality and high capacity batteries with equally good battery chargers. We could use the best terminals and connections and cable and relays that money can buy. We could do all these things, but there would still be some risk.

Probability is accumulative. If the relay works properly 99.9999% of the time (fails after one-million operations), and there is equal reliability in the cable, battery and connections, the probability of the crossing failing is 0.0001% for the battery, plus 0.0001% for each of 6 connections, plus 0.0001% for each of three wires, plus 0.0001% for each rail. The total probability of a wrong side failure is 0.0012%, or about 1 failure every 83,000 operations. If we assume 10 trains a day, the probability is one failure every 8,300 days or every 23 years. This is an extremely reliable crossing. If we add the fact that due to the overlapping of many crossing approaches, timing circuits, cutout circuits to prevent the crossing warning system from continuing to operate as a train goes away from the crossing (tail-ring), as well as many other features that are needed at modern crossings, the 12 components of our simple warning circuit increases to dozens or even hundreds of separate components. This fact causes the probability of a wrong side failure to increase dramatically.

Obviously, merely using very reliable components will not make our crossing safe. To meet failsafe principles, a design change must be made. First, take the battery and connect one terminal to the end of one rail near the insulated joints, and connect the other terminal through a resistor to the other rail at the same end of the track section (see Figure 3). Now, go to the other end of the track section and connect a wire from one rail to one side of the relay coil. Finally, connect the other side of the relay coil to the other rail. Now, the current will flow from one terminal of the battery through the resistor to one rail. It then travels down the rail to the wire that is connected to the relay. It passes through the relay and back through the other rail and finally to the other terminal of the battery. The relay is now energized using the rails as if they are two wires. When a train comes into the track section, the wheels will short between the rails, as in Figure 3. (The resistor in the wire from the battery to the rail is to prevent the battery from being damaged when the rails are shorted by the train.) The energy to the relay will be cut off due to the short circuit caused by the train. If the contacts of the relay are wired opposite to the previous example then the crossing warning system will be activated when the relay is shorted out by the train.

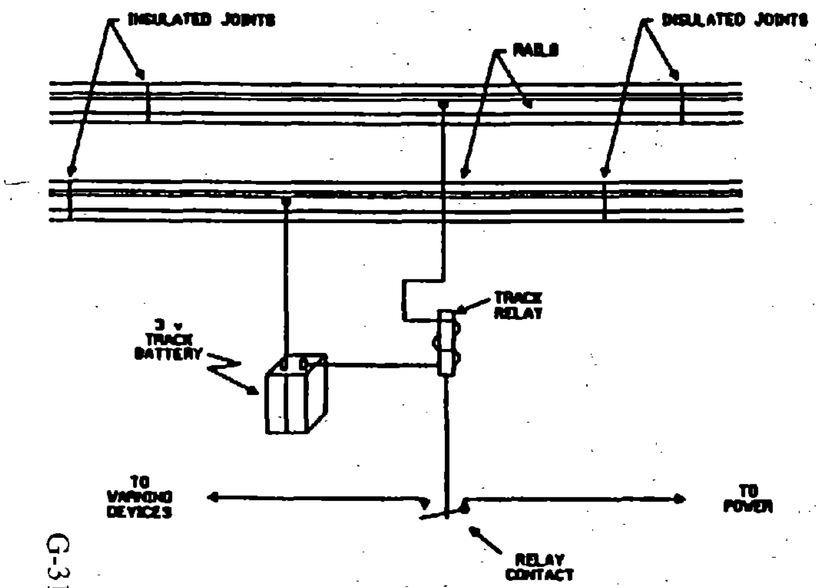
This circuit is designed according to fail-safe principles. If the battery goes dead, if a rail breaks, if any connections are loose or a wire is broken or cut, the relay will be turned off thereby activating the crossing warning devices. Now, the reliability of the components become an issue of reduced false activation of the warning system rather than probability that no warning will occur when it is needed.

While the above example of the "closed-loop" principle used in design of signal systems is very simplified, it shows the basic concept that is used in even the most complex, high-tech devices. All modern railroad warning systems are based on activation by absence of an expected electric voltage or signal. This way, if anything fails to perform correctly, the warning system will activate.

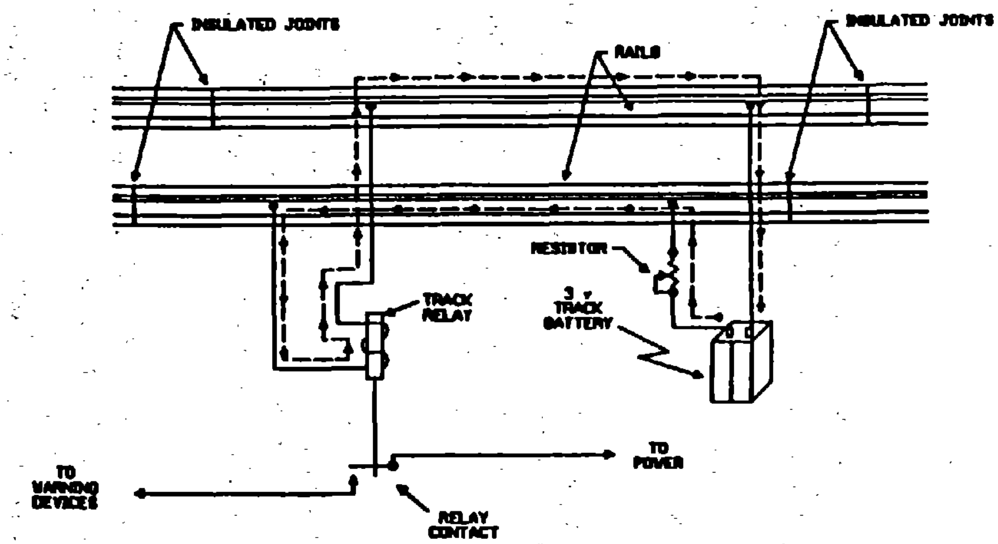
When electronic circuits are used that contain transistors and integrated circuits, the failsafe concept becomes a little more difficult. A transistor is basically like a relay. A small voltage applied to its base will cause it to conduct like a switch. The problem is, the failure mode of a transistor is not as predictable as a relay. The relay contacts will almost always close if it fails, especially if it is designed according to proper Association of American Railroads recommended practices. A transistor, however, can fail in either a conducting or non-conducting mode. Most signal equipment checks the transistors by constantly turning them on and off. If the output of the equipment stays constantly on or constantly off due to a failed transistor or any other component, then the crossing warning system is activated. Here, again, the absence of an expected signal is used to turn on the warning system.

Microprocessors, too, are checked in a similar manner. Whether two processors are constantly checking each other, or some external circuit is used to check the processor, absence of an expected pulse at the proper output at the proper time will cause the warning to be activated.

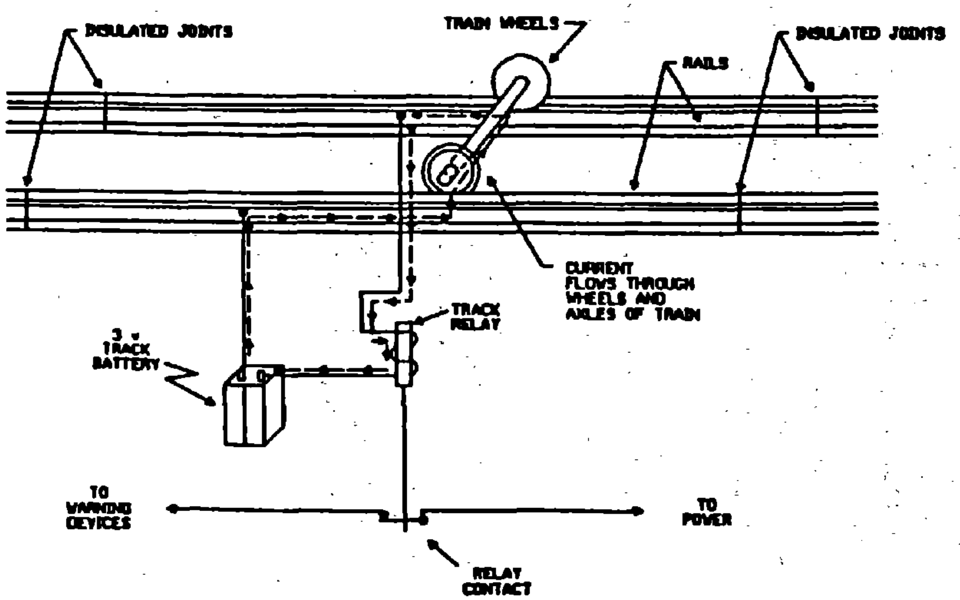
Once it is understood, the failsafe design concept is really not very difficult. Its foundation lies in doing everything possible to make sure that if any part of a circuit fails, it will activate the warning system rather than allow the possibility of no warning being given. Because railroad signal design follows failsafe design concepts, the occurrence of a wrong side failure is extremely rare even though millions of crossing operations occur every day.



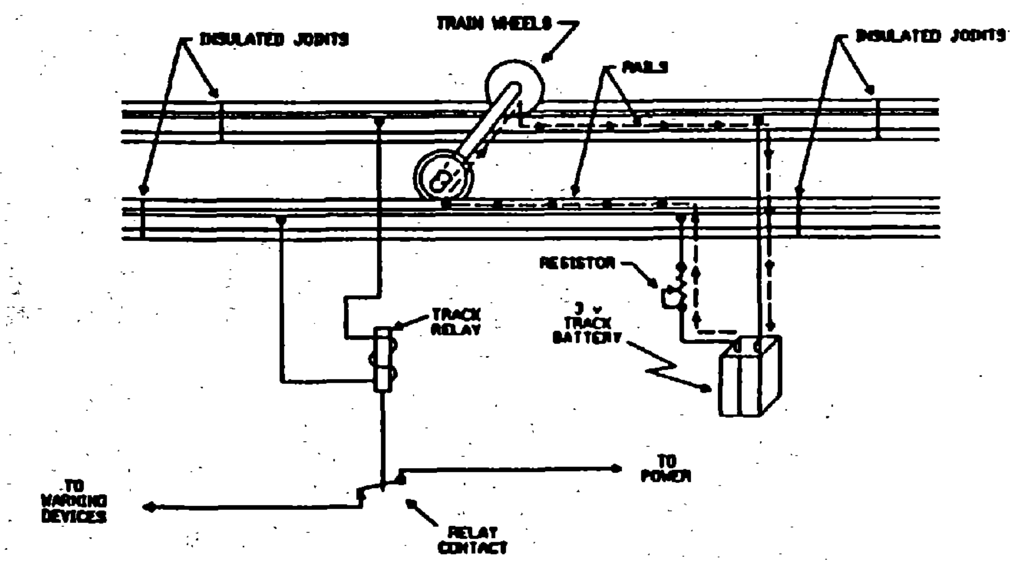
(FIGURE 1)



(FIGURE 3)



(FIGURE 2)



(FIGURE 4)

Mailing List
Track Presence Detection
Request for Information

Advanced Rail Technology Inc.
PO Box 304
Harrison, OH 45030
Attn: William Stillwell

KVH Industries, Inc.
110 Enterprise Center
Middletown, RI 02842
Attn: David H. Lane

Union Switch and Signal
5800 Corporate Drive
Pittsburgh, PA 15237
Attn: Ted Giras

Salient Systems
4140 Tuller Rd.
Dublin, OH 43017
Attn: Harold Harrison

Safetran Systems
Electronics Division
9271 Arrow Highway
Cucamonga, CA 91730
Attn: Glen Wilson

Harmon Industries
1300 Jefferson Ct.
Blue Springs, MO 64015
Attn: Robert Heggestad

ABB Signal AB
Box 42505, S-126 16
Stockholm,
SWEDEN
Attn : Jan Martensson

General Railway Signal
PO Box 20600
Rochester, NY 14602
Attn: Steven Blue

Siemens Transportation Systems
767 Fifth Avenue
New York, NY 10153
Attn: Bob Jahn

GEC Alsthom Signarail
9-T Place du Commerce
Brossard, Quebec J4W 2V6
Attn: Wagih Marcos

SEL Division
Alcatel Canada Inc.
725 S. Braddock Avenue
Pittsburgh, PA 15221
Attn: Michael J. Sukel

Amtech Systems Corporation
487 Sequoia Drive
Pittsburgh, PA 15236
Attn: Thomas B. Levine

Primetech Electronics Inc.
275 Kesmark
Dollard-des-Ormeaux
Quebec H9B 3J1
Attn: Jack McAllister

Honeywell Inc.
Valley Forge Corporate Center
PO Box 916
Valley Forge, PA 19482
Attn: Dick Gole

Rockwell International Corp.
400 Collins Road NE
Cedar Rapids, Iowa 52498
Attn: Dean Huntsinger

Ratheon Infrastructure
Services Incorporated
1015 15th Street NW
Washington, DC 20005
Attn: Ernest S. Lee

Vapor Division
Mark IV Transportation Products Group
6420 W. Howard Street
Niles, Illinois 60714
Attn: Keith N. Nippes

Hughes Aircraft Company
Corporate Offices
7200 Hughes Terrace
PO Box 45066
Los Angeles, CA 90045
Attn: Bernard Shatz

Advanced Railway Concepts Ltd.
264 Bronte St. South
Milton, Ontario L9T 5A3
Attn: William R. Mountain

AMCI
11819 Miami St.
Omaha, NE 68164
Attn : Curtis W. Pendley

American Systems Technologies
421 South Nine Mound Rd.
Verona, WI 53593
Attn: Wendy R. Oren

L&W Industries Inc.
3149 East Chestnut Expressway
Springfield, MO 65802
Attn: Herb W. Watkins

Quantum Engineering
352 Stowe Ave.
Orange Park, FL
Attn: Mark Kane

Railroad Signal Inc.
15110 East Pine St.
Tulsa, OK 74116
Attn: Eddie Burns

Serrmi Products Inc.
PO Box 43346
Atlanta, GA 30336
Attn: Robert M. Nielsen

CD&F Electronics
P.O. Box 2
Elm Creek, NE 68836

EDM Electronics & Manuf.
14112 Industrial Rd.
Omaha, NE 68144

EVA Signal Corp.
15309 Industrial Rd.
P.O. Box 268
Bennington, NE 68007

Shane Stoddard
3920 South 1915 West
Roy, UT 84067

Signal Systems Int., Inc.
P.O. Box 470
Lavallette, NJ 08735

Microwave Sensors
7885 Jackson Rd.
Ann Arbor, MI 48103

Scientific Technologies, Inc.
31069 Genstar Rd.
Hayward, CA 94544

Detector Systems
11650 Seaboard Circle
Stanton, CA 90680

Southwest Microwave, Inc.
2922 S. Roosevelt St.
Tempe, AZ 85282-2042

Vision Systems Ltd.
Innovation House West
Technology Park, The Levels
Adelaide S.A. 5095
AUSTRALIA

Gustafson Sales, Inc.
Rural Route 1
Red Wing, MN 55066

Turk Multiprox, Inc.
3000 Campus Drive
Minneapolis, MN 55441

Western Cullen Hayes, Inc.
2700 West 36 Place
Chicago, IL 60632

Tiefenbach Hyd. & Electronics
Neirenhofer Strasse 68
D-4300 Essen 15
GERMANY

SIFERDEC
100, Avenue Albert 1
92500 Rueil-Malmaison
FRANCE

GE Transportation Systems
2901 East Lake Road
Erie, PA 16531
Attn: Bret Begole

THE INTELLIGENT HIGHWAY-RAIL INTERSECTION INTEGRATING ITS AND ATCS FOR IMPROVED GRADE CROSSING OPERATION AND SAFETY

Hoy A. Richards

Richards & Associates

P.O. Box 10350

College Station, Texas 77842

(409)690-1408

FAX (409)690-6196

Richard T. Bartoskewitz

Engineering Research Associate

Texas Transportation Institute

Texas A&M University System

College Station, Texas 77843-3135

(409)845-9929

FAX (409)845-9761

DRAFT

FOR DISCUSSION ONLY

April, 1995

THE INTELLIGENT HIGHWAY-RAIL INTERSECTION: INTEGRATING ITS AND ATCS FOR IMPROVED GRADE CROSSING OPERATION AND SAFETY

INTRODUCTION

Motor vehicle/train accidents continue to occur at a rate of about 14 each day. In addition, it is estimated that twice that number of non-train motor vehicle accidents occur at highway-rail intersections each day. Statistics also suggest that approximately 60 percent of all grade crossing accidents occur at intersections equipped with train-activated warning devices. Several arguments are presented in defense of these statistics, notably that a majority of both highway and rail traffic is found at intersections having active devices, and that the problem is more one of driver behavior and not the technology employed.

It is not the purpose of this paper and presentation to evaluate either of these arguments as to their reasonableness or accuracy. This paper and presentation will, however, examine the future application of new technologies that may prove to be more effective in warning motorists of the approach or presence of a train at highway-rail intersections. Recent initiatives within the North American railroad industry to develop "Advanced Train Control Systems" (ATCS) and related technologies, such as Positive Train Separation/Positive Train Control (PTS/PTC), provide an opportunity to take a fresh approach to train detection systems for highway-rail grade crossings. The advent of Intelligent Transportation Systems (ITS), formerly referred to as Intelligent Vehicle-Highway Systems (IVHS), adds an even broader dimension to traffic management system research opportunities at highway-rail intersections.

Historically, interconnection and preemption of traffic control devices, specifically standard highway traffic signals, have been restricted to those devices at individual nearby intersections. Significant advances in traffic control systems that manage complex networks of streets and highways have been made, but the highway-rail intersection has largely been ignored in this evolutionary process. The problem is one of communication - railroads do not do a very good job of telling highway operators when and where to expect a train, and similarly, highway authorities fail to tell railroads where the traffic is and what it is doing. Given the current abilities of both railroad and highway operators to monitor their facilities

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and traffic in real-time or near real-time, it should be a relatively simple proposition to establish communication linkage between the two, to enable the "sharing" of relevant data and information.

KEY TERMINOLOGY

As with any endeavor to work outside a well-defined, designed, regulated and applied system, not only is it necessary that new technology be adequately defined and evaluated, but a working definition of relevant terminology is essential. This section will present and briefly define some of the key terms that will be used throughout the paper and presentation.

Intelligent Transportation System (ITS)

ITS is a group of applications, primarily technologies in the areas of information processing, communications, control, and electronics, that are being implemented in highway vehicles, within the highway transportation infrastructure, and in related control centers. The application of these technologies is intended to help realize goals for highway and transportation safety, congestion reduction, mobility enhancement, environmental impact mitigation, energy conservation, and economic growth.

Advanced Train Control System (ATCS)

ATCS is a microprocessor/communications/transponder-based system designed to provide both safety and business functions. Safety area capabilities are: (1) the digital transmission of track occupancy/movement authority to trains and an acknowledgment from the train crew via digital radio communications in lieu of voice communications, (2) provision of positive train separation control functions to preclude the train from exceeding its assigned limits of authority, (3) protection for maintenance-of-way and other workmen on track, (4) enforcement of authorized operating speed limits for trains consistent with civil engineering and other operating constraints, including temporary slow orders. In the business related function area, ATCS enables the transmission of work order activity related to pick-ups and set-outs of individual and drafts of cars, locomotive health reporting, and other functions. ATCS is a joint program of the Association of American Railroads (AAR) and the Railway Association of Canada (RAC). (Railroad Communications and Train Control)

System Architecture

The concept of "system architecture" derives from system engineering as applied to many large-scale defense and aerospace ventures, particularly in the evolution of computer and communications technologies. A system architecture is the framework that describes how system components interact and work together to achieve total system goals. It describes the system operation, what each component of the system does, and what information is exchanged among the components. Development of a system architecture is a common first step in the initiation of major new systems. (ITS Architecture Development Program: Phase I Summary Report)

User Services

User services define the capabilities that a system, such as ITS or ATCS, will provide to its customers. User services may be thought of as the "requirements" of the system architecture.

ITS SYSTEM ARCHITECTURE

Under the direction of the United States Department of Transportation (USDOT), a system architecture for ITS is in development. Phase I of this process recently concluded, with the number of competing consortia narrowed from four to two. Phase II is directed towards developing a national consensus architecture, combining the most promising elements of the various architectures identified in Phase I.

The system requirements of the ITS architecture are defined and described by 29 user services (in the current formulation of the architecture). To simplify discussion, these user services may be grouped into six "bundles," with each bundle consisting of two or more user services. The six bundles are: (1) Travel and Traffic Management, (2) Public Transportation

Management, (3) Electronic Payment, (4) Commercial Vehicle Operations, (5) Emergency Management, and (6) Advanced Vehicle Safety Systems.

For the purpose of this paper and presentation, only "bundle" number (6), Advanced Vehicle Safety Systems, will be considered in relation to the "intelligent highway-rail intersection" concept. (It may be appropriate to include other user service "bundles" in future research considerations, for example, (1) Travel and Traffic Management, is anticipated to have relevance to the highway-rail intersection.) This "bundle" includes the following user services: longitudinal collision avoidance, lateral collision avoidance, intersection collision avoidance, and vision enhancement for crash avoidance.

ATCS SYSTEM ARCHITECTURE

The ATCS architecture is comprised of five major sub-systems, including four information processing systems - the Central Dispatch System, the On-Board Locomotive System, the On-Board Work Vehicle System, and the Field System - plus the Data Communications System, which is the "backbone" or communications platform interconnecting the other four systems and other operation and business aspects of the railroad. Figure 1 illustrates the conceptual relationship between the five primary ATCS sub-systems.

These five sub-systems work together to handle requests for information, process data in real-time, ensure error-free delivery of data, and handle conflicts and equipment failures. System interconnection is accomplished through a combination of communication nodes and wireline and radio links. The ATCS Specification on System Architecture explains the functions of the five sub-systems:

> The function of the dispatch system is to manage the movement of trains throughout the rail network with the objective of guaranteeing safe operations without incurring train delays. The function of the locomotive system is to provide automatic location tracking and reporting, predictive enforcement, and automated transmission of movement authorizations and switch monitoring and control information via the data communication system. The primary function of the work vehicle system is to provide the capability for a track maintenance foreman to communicate with the central dispatch system and other vehicles via the data communication system. The ATCS field system is designed to provide remote monitoring and control of wayside devices.

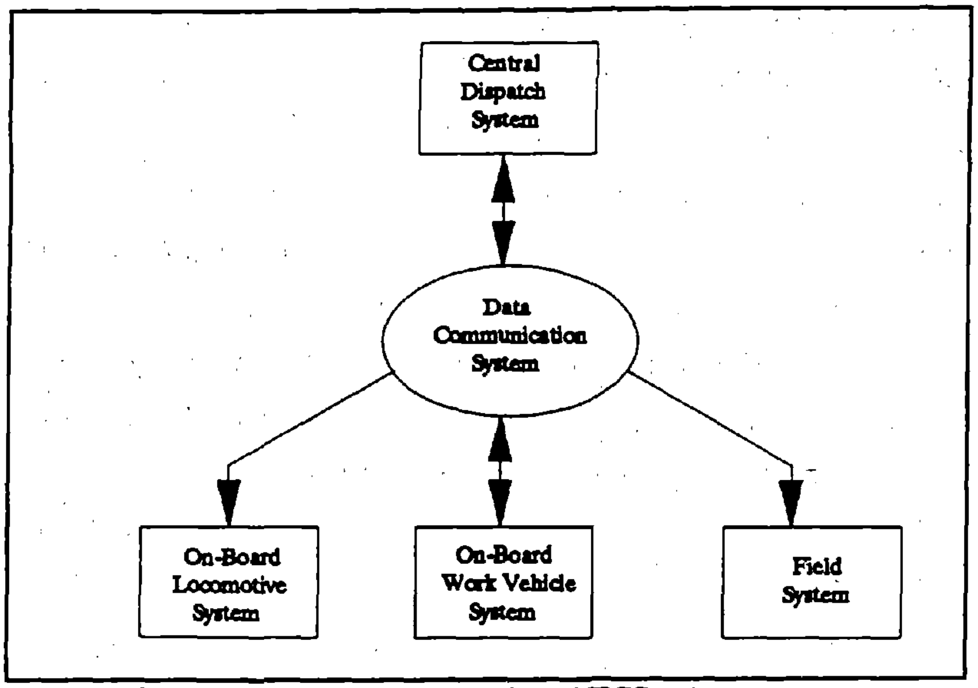

Figure 1. Relationship between the five ATCS subsystems.

INTEGRATION OF ITS AND ATCS ARCHITECTURES

In a recent letter to the Director of the USDOT's Joint Program Office for Intelligent Transportation Systems, Federal Railroad Administration (FRA) Administrator Jolene Molitoris requested modifications to the draft National Program Plan for the ITS System Architecture, to include the following regarding railroad safety:

> Include reference to safety issues involving rail safety such as road/railroad grade crossings and accidents between road vehicles and trains. **Examples: in the Intersection Collision Avoidance users service include prevention of collisions at grade crossings; in the Longitudinal Collision Avoidance and the Vision Enhancement for Crash Avoidance user services include prevention of collision between an automobile and a moving or parked train.**

The remainder of this section "walks through" an exercise to demonstrate how to properly address safety and operational requirements at highway-rail intersections in the development of an ITS national architecture.

Identify and Define "Modular Functions"

A "modular function" is a well-defined action that needs to be accomplished, but is implementation independent. The following are suggested modular functions of an "intelligent" highway-rail intersection:

(1) Determine location, direction, and speed of rail and highway vehicles;

(2) Determine locations and characteristics of highway-rail intersections (typically information characterizing the location and geometry of the crossing, thus expected to vary little or none over time);

(3) Monitor the status of the highway-rail intersection;

(4) Monitor the status of relevant traffic control devices; and

(5) Process information from functions above, to identify potential system failures (i.e., a malfunctioning traffic control device), to identify possible highway-rail conflicts (i.e., a vehicle stopped or stalled on the tracks), and to deliver appropriate information about train movements to individual drivers and highway operators.

Identify External Sources/Sinks for Information

An external source/sink is a person, organization, or adjoining system which acts to either provide inputs to a given user service (source), or to receive information or results delivered by the user service (sink). The following are suggested sources/sinks for an "intelligent" highway-rail intersection:

(1) "tags" or "transponders" on rail equipment,

(2) "tags" on highway vehicles (typically for automatic vehicle identification)

(3) wayside or roadside interrogators (to read tags)

(4) "traffic management center" or other highway traffic control center,

(5) railroad dispatching center,

(6) "intrusion detector" (camera or other sensor used at crossing),

(7) in-vehicle devices (aboard highway vehicles and/or trains),

(8) traffic control devices (highway), and

(9) spatially-referenced database containing fixed, constant data describing the highway-rail intersection (such as a Geographic Information System, GIS, or other useful data inventory).

Identify Information Flows from Sources to Sinks

For illustrative purposes, Figure 2 diagrams information flows for system design architecture. Others may be possible under many common circumstances.

(1) Status of warning system at the intersection (D1-d),

(2) Location, direction and speed of train and motor vehicle (D1-a),

(3) Status of motor vehicle and train at the intersection (D2-b),

(4) Status of track and roadway at the intersection (D2-f),

(5) Activation of in-vehicle (train) alerting system (D1 = D2-c)(D1 = D2-g), and

(6) Intervention with motor vheicle or train operation (D1 = D2-e).

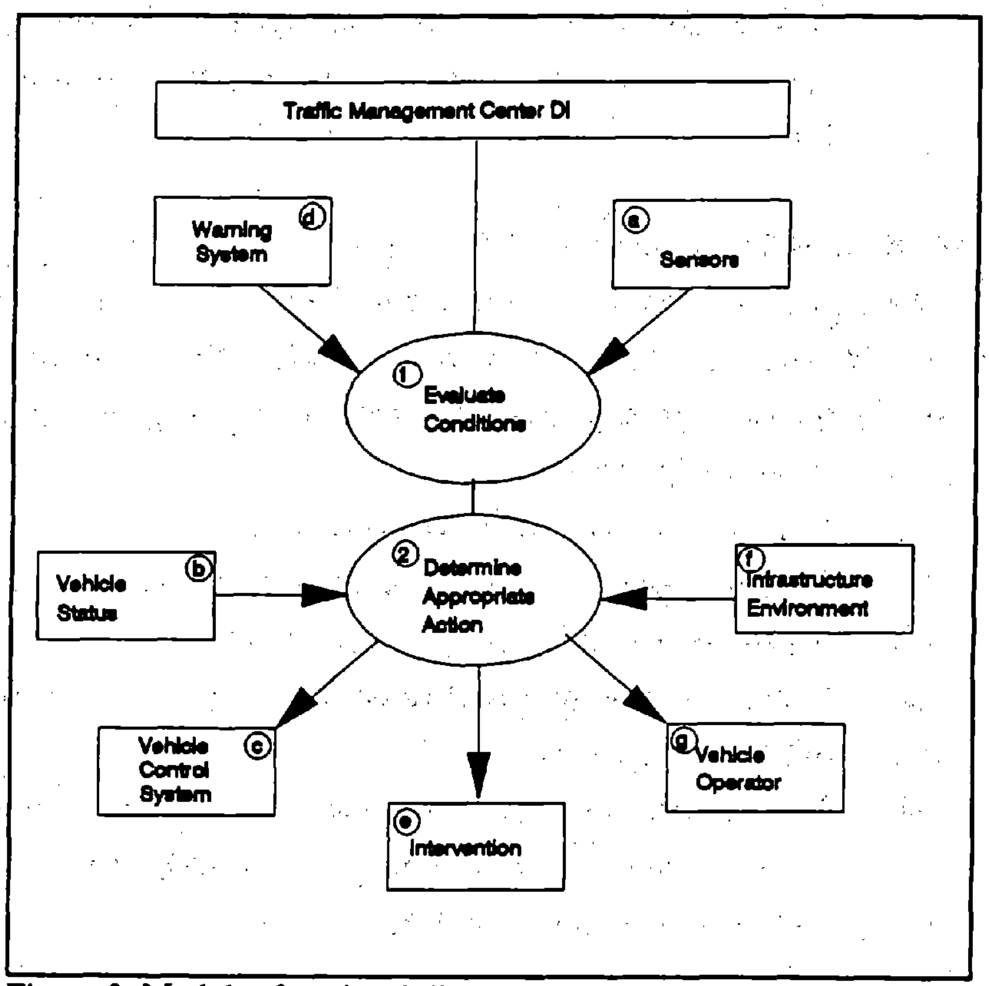

Figure 2. Modular functional diagram.

Identify Important Capabilities of the Desired Architecture

The following four capabilities are suggested as essential in the development and implementation of the "intelligent" highway-rail intersection:

(1) *Reliability*, approaching a fail-safe design, is essential due to the severity of motor vehicle/train accidents and the potential consequences of accidents involving special types of cargoes or loadings (i.e., passengers, haz-mat);

(2) Due to the involvement of two significantly different modes of surface transportation, the design will be subject to *regulation* by both highway and rail regulatory bodies;

(3) *Flexibility* to accommodate requirements of both highway (ITS) and rail (ATCS) traffic control systems; and

(4) Due to differing technology between rail and roadway signal and communication, systems must utilize both technologies for *deployment*.

The parallel development of ITS and ATCS technologies provides an opportunity to integrate current and future highway traffic control systems with current and future railroad traffic control systems. But first, three important questions must be addressed:

(1) How can the needs of the "intelligent" highway-rail intersection be met by existing communication architectures?

(2) How will the "intelligent" highway-rail intersection be integrated with non-ITS/non-ATCS technologies?

(3) Do architectures exist for these other non-ITS/non-ATCS services that might be adapted or modified?

CURRENT ACTIVITIES IN ATCS DEVELOPMENT RELEVANT TO THE HIGHWAY-RAIL INTERSECTION

This section briefly describes some of the key programs and technologies now being developed, and their relevance to the highway-rail intersection.

Positive Train Separation/Positive Train Control (PTS/PTC)

Some within the railroad industry advocate an electronic train monitoring and control system known as Positive Train Control (PTC) or Positive Train Separation (PTS). The two terms are often used interchangeably, though they refer to two distinct concepts. PTC, as defined by the FRA in reference to next generation train control, is "the application of technology in various subsystems that intervene to prevent trains from operating at a speed in excess of the maximum allowed, movement past any point of known obstruction or hazard, and movement beyond the limits authorized" (Railroad Communications and Train Control). The FRA defines PTS as the next generation of train control systems dedicated to the "application of technology to control the movement of trains in a manner that precludes the occurrence of collisions." In many respects, PTS is a scaled-down version of ATCS, designed with ATCS safety features but lacking the more extensive business-oriented features of the full ATCS implementation.

Demonstration of PTS in progressing, with a recent agreement negotiated between the Burlington Northern and Union Pacific railroads to test PTS on shared trackage in the Pacific Northwest region of the U.S. This pilot program will address the three primary safety objectives associated with PTS, namely prevention of collisions between trains, prevention of collisions involving trains and track maintenance personnel, and prevention of overspeed train operation. The Texas Transportation Institute, in cooperation with the Washington State Department of Transportation and both freight railroads, has proposed to develop and evaluate several grade crossing innovations in conjunction with this PTS test bed.

General Railway Signal Corp (GRS) Train Proximity System

The GRS approach to positive train separation begins with a "survey" of track and way-side infrastructure. Using GPS, the video survey provides a longitudinal/latitudinal data base for railroad facilities, including intersections of track and roadways. The data collection is based upon GPS components for location of the infrastructure component (e.g., a highway-rail intersection) and digital and video imagining recording devices. GRS proposes the development of an "intelligent grade crossing device." For Example, some of the work GRS has undertaken with the Burlington Northern, in the area of "train proximity," could have direct application to In Vehicle Warning Systems (IVWS), such as those now being tested by the Volpe Center.

Harmon Industries Train Control System

The Harmon Incremental Train Control System (ITCS) is currently in the conceptual design stage. The system use a "vital controller" to manage traffic over a limited area. It is designed to overlay Centralized Traffic Control. The system is a closed architecture that relies on "virtual signals" and "virtual" switches.

Rockwell Front-End Processor

The Rockwell/BN "front end processor" has a system architecture which can be described as a "black box". The system provides the locomotive engineer with a screen to monitor and manage the power unit. The ICE (Integrated Cab Electronic) system is more for diagnostics than train positioning and speed. The system may, however, prove vital to the development of control logic for specific Intelligent Highway-Rail Intersection system designs.

U.S. Switch and Signal (US&S) Train Inertial Positive Separation

The US&S approach is to use an open architecture system that is based upon an inertial navigation system. Train Inertial Positive Separation (TIPS), along with their positive tag reader, provides precise data to trains in CTC territory. The system may have application in the development of more precise highway traffic control device preemption control logic.

TESTING AND EVALUATION OF INNOVATIVE HIGHWAY-RAIL DEVICES

Researchers at the Texas Transportation Institute have developed a draft plan for a series of tests and evaluations of possible components of the "intelligent" highway-rail intersection. The first implementation series will focus upon the simplest systems in terms of estimated cost and technological sophistication. Each subsequent series will become successively more sophisticated. The following is a brief description of the test and evaluation plan proposed by the research.

Series A Systems/Technologies: Low Cost and Technological Complexity

Automated Horn System

The automated horn provides an audible warning of constant intensity to motorists when a train is approaching. One of three mechanisms may be employed to activate the device: (1) electric track circuits, (2) a radio signal transmitted from the approaching locomotive to a wayside receiver, or (3) information on train speed and direction, derived from the GPS train location system (or other technology), processed to determine activation time to furnish adequate warning to approaching motorists.

Crossing Illumination

Previous studies have investigated the use of illumination to improve nighttime safety at highway-rail grade crossings, especially crossings that lack signals or gates. To achieve this at the lowest cost possible, it is desirable that the illumination be activated when a train is approaching and deactivated after the train has passed. One difficulty is determining when a train is approaching such that the light may be activated. At crossings not equipped with train-activated warning devices (and hence track circuits), activation by track circuitry is not an option. TTI proposes the use of train position information derived from GPS to activate/deactivate the illumination at these crossings.

Integration With Advanced Traffic Management Systems (ATMS)

Interconnection and signal preemption represent the maximum degree of integration presently achieved between grade crossing safety systems and traffic control systems on adjacent roadway facilities. The effectiveness of such practices is limited by the available technology (electric track circuits). Traffic operations at intersections on adjacent roadways might be significantly improved if the highway "traffic management system" can be fed information about the location and time of arrival of a train. Given the train detection technology and warning system designs commonly employed at present, this is not feasible. Use of GPS to obtain real-time train positional information would permit this goal to be achieved. TTI is presently developing a "smart" intersection controller capable of adaptive signal operation to account for, among other functions, the presence of a train. Train "status" inputs to this system, primarily an estimate of train arrival time at the crossing, are lacking. The railroads' use of GPS to track train movements to achieve positive train separation represents an opportunity to improve the flow of traffic on congested roadways adjacent to railroad tracks.

Series B Systems/Technologies: Intermediate Cost and Technological Complexity

Vehicle Proximity Alerting System (VPAS)

Section 1072 of the 1991 Intermodal Surface Transportation Efficiency Act required the Secretary of Transportation to coordinate field testing of a Vehicle Proximity Alerting System (VPAS) and comparable systems in order to determine their feasibility as an effective safety warning device for "priority" vehicles. In July 1993, the Federal Highway Administration issued a request for proposals for VPAS. As presently envisioned, the VPAS would be installed only in special classes of vehicle - school buses, large trucks, hazardous materials haulers, and emergency vehicles. A VPAS could be used at both passive and active crossings, however, its greatest benefits would be realized at passive crossings where motorists receive no indication of the approach of a train. Two basic designs of the VPAS have been formulated, referred to as two-point and three-point systems. A two-point system provides direct train-to-vehicle communication, broadcast by a transmitter on the locomotive to a receiver on the approaching highway vehicle. With a three-point system, the warning message is broadcast from a roadside transmitter or beacon.

The simplest approach would be to inform the driver that a train is approaching, or that the crossing ahead is blocked by a train, but provide no further information as to the direction of travel or the speed of the train. An alternative would be to inform the driver of the train's approach, the direction from which it is approaching, and an estimate of its arrival at the grade crossing. This alternative would require three types of information: (1)

train position (variable) with respect to the crossing (a fixed point), (2) train speed, and (3) direction of travel of the train.

Based on the distance from the crossing and speed, an estimated arrival time for the train at the crossing could be calculated. It is expected that this information could be derived by processing train position information provided by GPS. TTI proposes to perform field testing of promising devices identified by the ongoing FHWA study.

Remote Monitoring

One proposed system combines sensor technology for remote monitoring with cellular communications to create a grade crossing health monitoring system. In the event of a malfunction, the cellular communications unit dials a pre-programmed sequence of phone numbers. For example, the unit could be set up to notify the railroad dispatcher, signal maintainer, local police, and the appropriate roadway authorities. Similarly, the signal maintainer would have the capability of calling the unit at any time and from anywhere to obtain a verbal status report for the equipment.

The current efforts by some railroads to perform continuous remote monitoring of grade crossing system health and status could provide secondary benefits to highway traffic operations personnel. A grade crossing monitoring system might provide two useful types of information to a highway traffic management center (TMC). The TMC would be able to determine the activation status of highway-railroad grade crossing safety devices. This information would permit the TMC to track train movements and their progress and take action to alleviate the effects upon traffic congestion on intersecting and adjacent roadways. Possible responses might include temporary adjustment of traffic signal phasing and timing and the implementation of lane use and turn restrictions through dynamic lane assignment and changeable message signs. The information could also be relayed to emergency services personnel - police, fire, and ambulance services - to facilitate routings which avoid blocked crossings and thereby optimize emergency response time. Similar actions could be implemented by the TMC in the event of grade crossing signal malfunctions.

Series C Systems/Technologies: High Cost and Technological Complexity

Intrusion Detection

Video image processing may offer the potential for early detection of obstructions at highway-railroad grade crossings. Early detection of stalled, disabled, or trapped vehicles blocking the crossing and in the path of an oncoming train would permit the train to be stopped or moved at restricted speed in anticipation of a track blockage ahead. The basic components of an image processing system include a video camera coupled to a computer processing unit through an analog-digital conversion system. An optical image from the camera is converted into an electronic form, from which the processor can extract various types of information.

The effectiveness of an intrusion detection system is in part a function of train stopping distance. The stopping distance defines the minimum distance from the crossing at which successful intervention in the train's operation may take place to avoid collision with a stopped, stalled, or disabled vehicle. For each grade crossing, a critical train stopping distance may be calculated based upon train operating characteristics and other factors. If the distance from the train to the vehicle exceeds the critical stopping distance, intervention in the train's operation will successfully halt the train before an accident occurs. If the distance from the train to the vehicle is less than this critical stopping distance, then a collision cannot be avoided, although intervention may reduce collision severity.

Dynamic Displays

A dynamic display would provide the minimum amount of information necessary for the motorist to determine if it is prudent to cross the tracks. Three modes of operation (analogous to highway traffic signal operation) are proposed:

(1) Proceed: signal displays green "clear" indication, changeable message sign is blank or displays "PROCEED" word message.

(2) Caution: activated approximately 60 seconds prior to arrival of a train at the crossing, signal displays yellow "caution" indication, changeable message sign

displays "TRAIN APPROACHING FROM RIGHT/LEFT" and "## SECONDS TO ARRIVAL" messages.

(3) Stop: activated approximately 20 seconds prior to arrival of a train at the crossing and upon termination of the caution phase, signal displays red "stop" indication, changeable message sign displays "STOP" message, remains in effect until the train has cleared the crossing (and other tracks are verified clear of trains if at a multiple-track crossing).

TTI proposes the development, installation and phased evaluation of a dynamic display device. The evaluation would include both laboratory and controlled field testing to assess motorist comprehension and acceptance of the device.

CONCLUSION

The next generation of highway-rail traffic control systems should include technology developed for both IVHS and ATCS. The on-board, self-locating systems, may prove to be a viable alternative to traditional train location and detection systems, which are based upon track circuits.

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3. Haakinson, E. J., W. Rust, M. Garrity, "An Evaluation of the North American Advanced Train Control System", U.S. Department of Transportation (Report to Congress), June 1994.

4. Progressive Railroading, December 1994.

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Appendix H

Data Papers

HISTORICAL PERSPECTIVE ON DATA ISSUES IN RAIL-HIGHWAY GRADE CROSSING SAFETY RESEARCH

by

William D. Berg
Department of Civil and Environmental Engineering
University of Wisconsin-Madison

presented at the

Highway-Railroad Grade Crossing Safety Needs Workshop

Volpe National Transportation Systems Center
Cambridge, MA

April 10-13, 1995

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Rail-highway grade crossing safety has been the subject of continuing research since the late 1930's. The fundamental issues have remained the same:

1. Why do accidents occur?

2. What countermeasures are cost-effective?

3. How can hazardous crossings be identified?

4. What constitutes a reasonable safety program?

The collection and analysis of data is fundamental to the task of developing solutions to these issues. Much has been learned in prior research, but we often seem to be unaware of that body of knowledge. This paper will present an overview of what we know (or should know) and how it relates to the definition of current research needs and the data issues associated with those needs.

Why Do Accidents Occur?

A human factors-based approach to improving grade crossing safety begins with the premise that a driver can be given sufficient information about a hazard to permit the driving task to be performed safely and efficiently. This concept has become known as positive guidance. Successful driver performance at grade crossings is dependent on the driver's ability to detect an approach train, recognize it as a hazard, decide on an appropriate speed and path, and act on the speed and path decision. A model of the driving process is illustrated in Figure 1. An understanding of this process is essential to an understanding of why accidents occur.

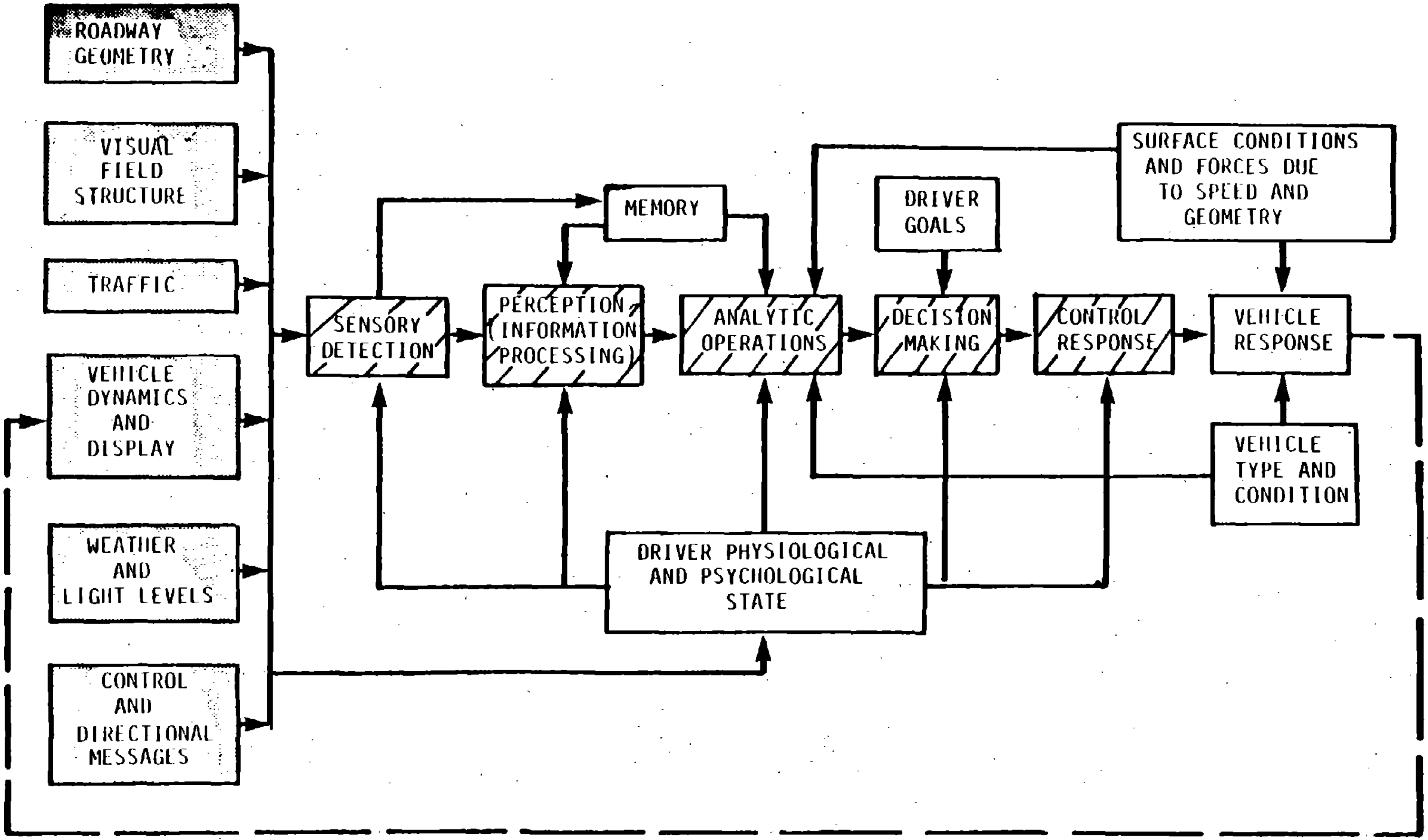
The ability of driver to detect the presence of an approaching train in the absence of automatic warning devices is dependent on many factors including the interaction between its visibility, its conspicuity, and the number and type of other information sources competing for the driver's attention. Also important in hazard detection are the driver's scanning behavior and expectancy regarding the possible arrival of a train.

The ability of a driver to recognize a detected train as a potential hazard is based primarily on prior knowledge or experience. The driver must be able to determine if the train will arrive at the crossing before the vehicle can safely traverse the tracks. This requires a judgement as to the train's speed and distance from the crossing. This can be a difficult task, especially during darkness when the train might only be identified by a single headlight.

Selection of an appropriate speed and path involves the identification of alternative courses of action, the evaluation of the probability of success of each alternative, and the selection of that alternative judged most appropriate for the given situation. Several factors can degrade a driver's opportunity to select an appropriate speed and path to avoid a collision:

1. Lack of time to choose between alternatives.

2. Inability to identify any suitable alternatives.



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

Figure 1. Operational Steps in Driving Guidance and Control.

3. Inability to choose among equally attractive or equally unattractive alternatives.

4. Insufficient information to make the right choice.

5. Being misled by conditions or cues that seem relevant but are not.

If a driver selects the wrong speed or path, a collision is likely. The task facing those involved in grade crossing safety is to design and implement information systems which can assist motorists in the selection of the appropriate speed and path under the prevailing combinations of roadway and environmental conditions. To this extent, it is important for the crossing safety specialist to develop programs and projects which respond to the needs of a "design driver" rather than the "ideal" driver. We must recognize the range in driver knowledge and attitudes, the patterns of driver behavior, and the relationship between these factors and accident causation patterns. The information needs of those drivers facing the most difficult combination of conditions must serve as the basis for the development of both long-run and short-run safety initiatives.

<u>What Countermeasures Are Cost-Effective?</u>

Research has shown that most motorists approaching grade crossings having passive warning systems do not expect to encounter a train. Even though motor vehicle regulations require that each motorist look for trains, it is known that about 70 percent do not. To offset this negative expectancy, measures must be taken to attract the motorist's attention. Over the long run, it may be possible to modify this behavioral trait through driver education programs such as Operation Lifesaver, or through enforcement activities. However, experience is the primary determinant of human behavior and motorists know that "anytime is <u>not</u> train time."

The principal impediments to attracting motorists' attention to a train are:

1. Sight obstructions.

2. Distractions and information overload.

3. lack of high train conspicuity.

The relative importance of each of the above factors is a function of the time-space relationships associated with a given encounter between a train and a motor vehicle.

With very limited sight distance and low train and traffic volume, any motorists on a collision path with a train faces a high probability of having a collision. The grade crossing tends not to be identified as a hazardous location because of the low exposure level, and detection of the unexpected train is severely hindered because of the restricted sight distance. This creates a situation where accidents are, in large part, chance events governed simply by the probability of the simultaneous arrival of a vehicle and a train.

Even with good sight distance, it is imperative that the train be as conspicuous as practicable. This means bright contrasting locomotive paint schemes, on-train lighting devices designed to alert motorists, and operation of the locomotive horn while within the critical track zone as defined by sight distance requirements. High train conspicuity will increase the likelihood of attracting the attention of the unalerted or distracted motorist. Similarly, the greater the sight distance, the more viewing time available to the motorist, and the more likely that the train will be detected. The provision of adequate sight distance may necessitate a reduction in vehicle and/or train approach speeds by means of speed regulations or stop controls. This requires an evaluation of the trade-off between crossing safety, and the delay and operating costs incurred by rail and highway traffic.

Active warning devices offer an improved means of satisfying motorists's information needs because the warning is presented only when a train is on the approach to a crossing, and the warning signal itself is positioned along the path of travel and within the normal field of view of a driver. The need for an upgrade to active warning devices increases if sight distance deficiencies cannot be improved and train conspicuity is poor. As the probability of a vehicle-train encounter increases with higher vehicle and traffic volumes, there is also an obvious increase in the need for active warning devices.

For those crossings which have a high traffic volume but a low number of low-speed trains, an alternative to active warning devices would be the flagging of all train movements. In this situation, the highway would be considered as the major transportation facility and therefore receives the right-of-way. From the motorists' standpoint, this type of operation would be consistent with the way in which intersections with minor streets are controlled, and would thereby reduce the expectancy problems described above.

Safety at grade crossings equipped with active warning devices is usually dependent in large part on the conspicuity and credibility of those devices. Conspicuity relates to the target value of the signal and is influenced by its configuration and placement. Credibility relates to the consistency and timing of the warning, the principal influencing factors being the type and design of track circuit.

To assure adequate signal conspicuity, careful attention must be given to the number, size, location, and alignment of signal faces. Under many conditions, the usual side-of-road, post-mounted signals will provide adequate conspicuity. However, with high vehicle approach speeds, a cluttered visual background, or a multi-lane highway, there probably exists the need for cantilevered signals and 12-in roundels. This will assure that a signal with a large target area is placed directly along the driver's principal viewing axis, and thereby increase the likelihood that motorists will detect an activated signal, even under adverse viewing conditions.

Where turning roadways and interactions are located adjacent to a crossing, it is essential to have side lights placed and aligned so as to be readily visible to motorists involved in turning maneuvers. These motorists are confronted with additional task loads and, as a result, have less time to detect and respond to the grade crossing warning devices.

Although signal conspicuity is important to crossing safety, human factors-based research has shown that signal credibility has a greater influence on accident causation. The credibility of a signal is directly related to the consistency and accuracy of the warning which is being provided. A substantial portion of the driving population do not reduce their speed when approaching an activated flashing light signal until the train comes into view. This is a result of the widespread lack of consistent 25-sec warning times. Drivers find that, although the warning devices are operating, there may be little hazard simply because the train is either far removed from the crossing, or completely stopped. At crossings equipped with gates, the gate itself removes the option of proceeding for most drivers, even with long warning times.

A fundamental cause of the often unnecessarily long warning times is an incompatibility between the track circuit design speed and the range of actual train approach speeds. In many cases this has resulted from a reduction in track speed without a compensating adjustment being made in the track circuit. Countermeasures which will permit consistent and accurate warnings under the full range of prevailing train operations will improve signal credibility and thereby increase safety. Examples include the provision of constant warning time circuits where train approach speeds are highly variable; shortening the track circuit where the maximum train speed has been lowered; and the installation of motion sensors where trains often stop within the track circuit.

Even with a well-designed track circuit and good signal credibility, there can be a compliance problem at crossings on high-volume arterials which are equipped with flashing light signals. Under these traffic conditions, drivers tend to be aggressive and attempt to minimize their delay. Traffic engineers recognize this driver goal and use it as the basis for designing intersections and timing traffic signals. Drivers approaching an activated flashing light signal can often be observed to follow one another in a caravan fashion over the tracks until the approaching train virtually reaches the crossing. Under these conditions, the installation of gates, even at single-track crossings, can be an appropriate and desirable countermeasure.

Although flashing light signals provide an effective countermeasure to the lack of good corner sight distance, a driver may still be confronted with inadequate sight distance when stopped at the tracks. Under these conditions, either gates should be provided to effectively remove the option of proceeding in advance of the undetected train, or the maximum train approach speed should be reduced. Special efforts should also be made to assure that trains which are stopped on a passing track or siding do not activate the signals, nor obstruct a stopped driver's required sight distance.

As discussed above, we do have a considerable body of knowledge regarding potentially effective safety measures. Nevertheless, we are continually confronted with the dilemma of which measures are truly cost-effective. Other relevant questions include:

1. Are new ideas worthwhile?

2. Are current programs useful?

3. Must a countermeasure's accident reduction potential be "measured" or demonstrated prior to implementation?

4. Can surrogate measures of safety effectiveness be used?

5. What constitutes a minimum acceptable level of safety?

How Can Hazardous Crossings Be Identified?

A significant amount of research has been devoted to the development of hazard index and accident prediction models which would be used to help identify hazardous rail-highway grade crossings. These models are beneficial, but lack sensitivity to site-specific conditions. Because the models are derived by applying statistical analysis procedures to a large data base of crossing characteristics, they can only measure trends in accident frequency which are associated with the variables in the data base. Correlations are measured, causal factors are not.

To make the models more sensitive to those conditions which have a significant impact on safety, more complete and accurate data will be required. The most glaring deficiency at the present time is the lack of sight distance data. This is time-consuming to collect, but it is behaviorally related to accident causation. In addition, variables which reflect the conspicuity or credibility of automatic warning devices need to be defined and incorporated in the models. For example, this could include signal configuration (mast-mounted versus cantilevered signals) and signal activation time.

The limitations of only using a 5-year accident history needs to be addressed. Good data exist beginning with the year 1975. All of this information should be utilized. It can be shown that the highest vehicle-train accident rate actually experienced at any crossing in the country is about one accident every 1-2 years. With the nation-wide average for all crossings (regardless of prevailing conditions) being about one accident every 30 years, it should be clear that a 20-year accident history of one accident every 5 years or less is an obvious indication of a problem. However, to identify the cause of the problem, it is necessary to go into the field and study the prevailing conditions. the relevant questions then become: do the prevailing conditions fail to meet accepted standards of practice, or are any of them causally related to the accidents which have occurred?

It is important to note that police officers, train crews, and claim agents are not generally trained or qualified to make these judgements. Although each may be involved in the collection of data used by researchers, these data need to be treated with caution as they often mischaracterize the actual prevailing conditions or behavioral relationships. Police tend to focus on what law was violated (i.e., failed to yield right-of-way). This has nothing to do with why the accident occurred or what countermeasure might be appropriate. Similarly, railroad employees tend to assess sight distance only in terms of a qualitative judgement of visibility from a stopped position at the crossing, with no consideration given to the available corner sight distance. They also tend to assume that the driver was trying to "beat" the train, the implication being that the driver knowingly accepted an unreasonable risk. This suggests that no countermeasure would have been effective. However, it also ignores the fact that the driver's detection and recognition of the train may have been delayed due to a lack of credible information being presented when it was needed.

What Constitutes a Reasonable Safety Program?

An understanding of the human factors considerations in grade crossing safety is an essential element in the development and implementation of programs for the reduction of vehicle-train accidents. These programs must recognize driver knowledge, attitudes, and behavior patterns, and use this information as a principal design control. Although it may be possible to modify these driver characteristics over the long run through various education and enforcement activities, the engineering improvements currently being implemented should be designed to accommodate today's driving population.

Program cost-effectiveness is difficult to evaluate because causal relationships are difficult to observe and measure. Easily developed indicators are often irrelevant. For example, the effectiveness of enforcement activities is often measured in terms of the number of traffic violations observed, or the relative change in rate of violations. Unless it can be shown that the frequency of traffic violations is highly correlated with the frequency of vehicle-train accidents, such an evaluation is neither useful nor appropriate.

Safety programs need to be focused on known problems (i.e., the target value of the crossbuck sign is not the problem, low target value of trains is the problem). What are the current problem areas? A high priority list should include the following:

1. Grade crossings with a low predicted accident potential (low exposure), but a high frequency of vehicle-train collisions.

2. Grade crossings with active warning devices, but devices which have poor conspicuity or credibility.

3. Grade crossings having low exposure, but severe sight obstructions.

4. Grade crossings with high train volumes and speeds, but low traffic volumes.

5. Grade crossings where sight distance is inadequate for drivers of large trucks due to the configuration of the truck and the angle of the crossing.

6. Low train conspicuity. At night, a large truck (18-wheeler) which can be steered and braked is many times more conspicuous than a train for which no evasive action is available.

Certainly, other problems could be added to the list, but the above represent those elements of the overall grade crossing safety problem which have not been adequately addressed or solved, and which may offer substantial opportunities for further research.

U.S. Department
of Transportation

National Highway
Traffic Safety
Administsration

DOT HS **808 196**

November 1994

NHTSA Technical Report

Rail-Highway Crossing Safety: Fatal Crash and Demographic Descriptors

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 808 196		

4. Title and Subtitle	5. Report Date
Rail-Highway Crossing Safety Fatal Crash and Demographic Descriptors	November 1994
	6. Performing Organization Code NRD-31
7. Author(s) Terry Klein, Tina Morgan, Adrienne Weiner	8. Performing Organization Report No.
9. Performing Organization Name and Address Mathematical Analysis Division National Center for Statistics and Analysis 400 7th St. SW Washington DC 20590	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Research and Development National Highway Traffic Safety Admin. 400 7th Street SW Washington DC 20590	13. Type of Report and Period Covered NHTSA TECHNICAL REPORT 14. Sponsoring Agency Code

15. Supplementary Notes
Adrienne Weiner, Co Author of Report, is a NHTSA Contractor employed by CAE-Link Corp.

16. Abstract
This report was prepared as part of the June 1994 Departmental Rail-Highway Crossing Safety Action Plan. Initiative V.B, Data and Research--Demographics, called for a study describing the circumstances under which fatal rail crossing crashes occur and characteristics of the drivers involved in such crashes. This report compares fatal motor vehicle rail crossing crashes with fatal crashes occuring at intersections and all fatal crashes. Data from NHTSA's Fatal Accident Reporting System, supplemented with information from Claritas, a commercially available geodemographic database, were used to provide the descriptive statistics.

17. Key Words	18. Distribution Statement
Crash, driver, Vehicle, Railroad	Document is available to the public through the National Technical Information Service Springfield, VA 22161

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

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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List of Exhibits

Executive Summary

In June 1994, the U.S. Department of Transportation published the Rail-Highway Crossing Safety Action Plan, encompassing support proposals from the Federal Highway Administration, Federal Railroad Administration, Federal Transit Administration, and the National Highway Traffic Safety Administration (NHTSA). The action plan presents a multi-faceted, multi-modal approach for improving safety at our nation's highway-rail crossings and for the prevention of trespassing on the rights-of-way of our nation's railroads. One of the six major initiatives identified in the plan was initiative V -- Data and Research.

The current report represents the culmination of crash and demographic data analysis, described in the action plan as initiative V.B -- Demographics. This report presents an analysis of fatal motor vehicle rail crossing crashes, describing the circumstances of occurrence and characteristics of drivers involved. Data from NHTSA's Fatal Accident Reporting System (FARS) and Claritas, a commercially available geodemographic database, were used to provide the descriptive statistics.

In this report, fatal rail crossing crashes are described and compared to all other fatal crashes, as well as other intersection fatal crashes. The following observations resulted from these analyses.

- In 1992, 388 fatal traffic-related rail crossing crashes resulting in 489 fatalities were reported to the FARS database.
- Fatal rail crossing crashes occur least frequently on Sundays, and increase daily through the week, reaching a peak on Fridays and Saturdays.
- With the exception of the 3 a.m. to 6 a.m. time frame (in which there are very few such crashes), fatal rail crossing crashes occur fairly regularly throughout the day. This is in contrast to all fatal crashes, which are much more frequent between the hours of 3 p.m. to 3 a.m.
- Almost 60 percent of fatal rail crossing crashes occur during daylight conditions, compared to less than 45 percent of all fatal crashes.
- While valid measures are not available to represent the exposure of motor vehicles and trains to potential rail crossing crashes, some observations are noted for calendar year 1992:
    - Fatal rail crossing crashes at crossings with crossbucks as the traffic control device comprised 42 percent of all fatal rail crossing crashes in 1992, the most frequent traffic control device present. At the same time, 52 percent of all crossings had crossbucks as the traffic control device. This apparent

"underrepresentation" of crossbuck locations could also be associated with lower exposure in terms of potential motor vehicle-train collision opportunities.

-- Crossings with flashing lights as the traffic control device comprised 24 percent of all fatal rail crossing crashes in 1992, the second most frequent traffic control device present. At the same time, 17 percent of all crossings had flashing lights as the traffic control device. Again, motor vehicle-train exposure could be a factor in relating fatal crash occurrence to the presence of this and other types of traffic control devices.

-- Crossings with gates and stop signs (the third and fourth most frequent traffic control device present, respectively) experienced the same percentages of all fatal rail crossing crashes as their representation at rail crossing locations.

- Over the period 1975-1992, over 30 percent of fatal rail crossing crashes occurred on roads posted 55 mph. The second most frequent occurrence of fatal rail crossing crashes was on roads with posted speed limits of 25-30 mph (over 25 percent).

- Over 60 percent of fatal rail crossing crashes occurred in rural areas, a greater percentage than either all fatal crashes or other fatal intersection crashes.

- In 1992, over 50 percent of all fatal rail crossing crashes occurred in eight states: Texas, Ohio, Indiana, Michigan, Louisiana, Illinois, Oklahoma and California. The next eight states add an additional 25 percent of all fatal rail crossing crashes. Due to the small number of fatal crashes in some states (the top 16 states for 1992 ranges from a high of 36 to a low of 9), state-level estimates are subject to relatively high year-to-year variability.

- The most frequently involved motor vehicles were passenger cars (63 percent), followed by light truck and vans (25 percent).

- Drivers 25-34 years old (a ten-year span) comprised the greatest percentage (24 percent) of fatal involvements, followed by drivers 16-20 years old (a five-year span at 17 percent).

- Male drivers comprised approximately the same percentage involvement in fatal rail crossing crashes (77 percent) as in all fatal crashes and fatal intersection crashes.

- Drivers in fatal rail crossing crashes exhibited rates of alcohol involvement (a BAC of 0.10 percent or greater) approximately twice as great (24.4 percent) as drivers in other intersection crashes (12.8 percent), but at about the same rate as drivers in all fatal crashes (26.1 percent).

- The five Claritas-defined social groups most involved in fatal rail crossing crashes comprise approximately 65 percent of the drivers involved. Three of the five social groups represent rural populations, while the remaining two represent town populations. The locations of these populations are likely to result in the greatest exposure to rail crossing opportunities, contributing greatly to their population-based overrepresentation.

- The five Claritas-defined social groups least involved in fatal rail crossing crashes comprise approximately 8 percent of the drivers involved in these crashes. Three of these social groups represent urban populations, which may have the least exposure to rail crossing opportunities, while the remaining two represent the most affluent city or suburban populations.

- A larger percentage of drivers involved in fatal rail crossing crashes have no college experience (60.9 percent) compared to both fatal crash-involved drivers (58.5 percent) and the U.S. population as a whole (54.5 percent), with the greatest differences observed for the 4+years of college category (15.7 percent for fatal rail crossing-involved drivers, 17.7 percent for other fatal crash-involved drivers, and 20.6 percent for the U.S. population).

- The median household income for fatal rail crossing-involved drivers ($27,667) is lower than both other fatal crash-involved drivers ($29,649) and the U.S. population ($31,900).

- There are only minor differences in the family type (single vs. married, with or without children) among the three populations.

- One of the largest differences among the three populations is in the area of occupation, with fatal rail crossing-involved drivers coming from households in which 32.8 percent report blue-collar occupations, close to the 31.2 percent for other fatal crash-involved drivers, and greater than the 26.6 percent reported for the U.S. population. While the service sector appears equally represented across the three populations, there are fewer professional/manager and other white-collar occupations for both fatal crash-involved groups and more reporting of farm/ranch/miner occupants than in the U.S. population.

- In terms of race/ethnic origin, fatal rail crossing-involved drivers come from areas with a greater percentage of white households (85.0 percent), slightly higher than for other fatal crash-involved drivers (83.3 percent), and higher than the U.S. population (80.1 percent). This is also likely a function of geographic location (the higher propensity for involvement by rural and town populations).

- There is essentially no differences among the three populations with regard to household size.

- *Field and Stream* and *Outdoor Life* were listed in the top magazines read by households that comprise 65 percent of fatal rail crossing-involved drivers. This was followed by two other outdoor-oriented magazines (*Sports Afield* and *Hunting*). These magazines could be an important delivery mechanism for reaching and educating the population of drivers most likely to encounter and become involved in rail crossing crashes. Informational messages on the potential dangers related to rail crossing maneuvers could be effective if focused on these populations.

Fatal Rail Crossing Crashes

INTRODUCTION

In June 1994, the U.S. Department of Transportation published the Rail-Highway Crossing Safety Action Plan, encompassing support proposals from the Federal Highway Administration (FHWA), Federal Railroad Administration (FRA), Federal Transit Administration (FTA), and the National Highway Traffic Safety Administration (NHTSA). The action plan presents a multi-faceted, multi-modal approach for improving safety at our nation's highway-rail crossings and for the prevention of trespassing on the rights-of-way of our nation's railroads. One of the six major initiatives identified in the plan was initiative V -- Data and Research.

This report represents the culmination of crash and demographic data analysis, described in initiative V.B -- Demographics. This report describes the circumstances of occurrence and characteristics of drivers involved in fatal rail crossing crashes based on available information. The ultimate goal of this report is to provide descriptions of fatal crashes and involved drivers to effectively focus countermeasure efforts on appropriate target populations.

In 1992, there were 388 fatal traffic-related rail crossing crashes and 489 associated fatalities. Both the National Highway Traffic Safety Administration and the Federal Railroad Administration maintain statistics on rail crossing crashes. However, NHTSA collects information only on traffic-related crashes, and thus, the fatality totals reported by FRA are generally greater than those reported by NHTSA.

CRASH DATA

NHTSA's Fatal Accident Reporting System (FARS), which became operational in 1975, contains a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico (although Puerto Rico is not included in national totals). To be included in FARS, a crash must involve a motor vehicle on a public trafficway and must result in the death of an occupant of a vehicle or a nonmotorist within 30 days of the crash.

A motor vehicle crash is a transport accident that:

(1) Involves a motor vehicle in transport,
(2) Is not an aircraft accident or watercraft accident, and
(3) Does not include any harmful event involving a railway train in transport prior to involvement of a motor vehicle in transport.

The third criteria means the collision between the railway train and the motor vehicle must be the first harmful event for the railway train to be a motor vehicle traffic crash. If the train struck an object laying on the tracks, derailed, and collided with a motor vehicle, this would not be considered a motor vehicle crash. However, if the train struck the motor vehicle first, then the event would be considered a motor vehicle traffic crash. This does not mean that the first harmful event for the vehicle must also be a collision with the train. The motor vehicle may strike the train as a subsequent event and still be classified as a motor vehicle crash as long as the subsequent event for the vehicle was the first event for the train.

The resultant fatality can be a vehicle occupant, a pedestrian if the train struck a vehicle first, or a train occupant, as long as the fatality occurrs within 30 days of the crash.

In this report, data for FARS calendar years 1975-1992 were used. Fatal rail crossing crashes are fatal crashes where the first harmful event was a collision with a railway train. Several fatal crashes, where a motor vehicle first collides with something other than a train, followed by a collision with a railway train are included in FARS but were not included in the analysis, because the first harmful event was not a collision with a train. There were 11 of these fatal crashes out of the over 9,500 included in this analysis.

Most figures in the report show, in addition to fatal rail crossing crashes, fatal intersection and all fatal crashes for comparison purposes. Intersection crashes were used as a comparison because rail crossings are a special type of intersection and a comparison of rail crossing to other intersection fatal crashes could be enlightening.

Fatal intersection crashes are defined as fatal crashes where the relation to junction was identified in FARS as the intersection in 1975 to 1990, and intersection in both interchange and non-interchange areas in 1991-1992 (the variable relation to junction was revised in FARS in 1991). The revised variable contains the same information as earlier, but also identifies whether the junction was at an interchange or non-interchange area. In this report, fatal intersection crashes do not include fatal rail crossing crashes; thus, these two groups do not overlap. The all fatal crashes comparison group represents all crashes in FARS.

CLARITAS

NHTSA subscribes to a commercially available market research tool, Claritas, which utilizes geodemographics to characterize different population segments. Geodemographics link demographic and lifestyle data with different geographic units. All population segments are classified by zip code. Claritas is a useful tool to gain information about households of drivers involved in certain types of crashes. By using the driver's zip code, Claritas can help determine: who the target population(s) are, where they live, what they read, which television programs they watch, and what their consumer habits are like. Starting in 1987, driver zip code was added to the data collected by the Fatal Accident Reporting System. Therefore, driver zip codes from FARS are available for merging with the information from Claritas, to conduct the analysis of demographics.

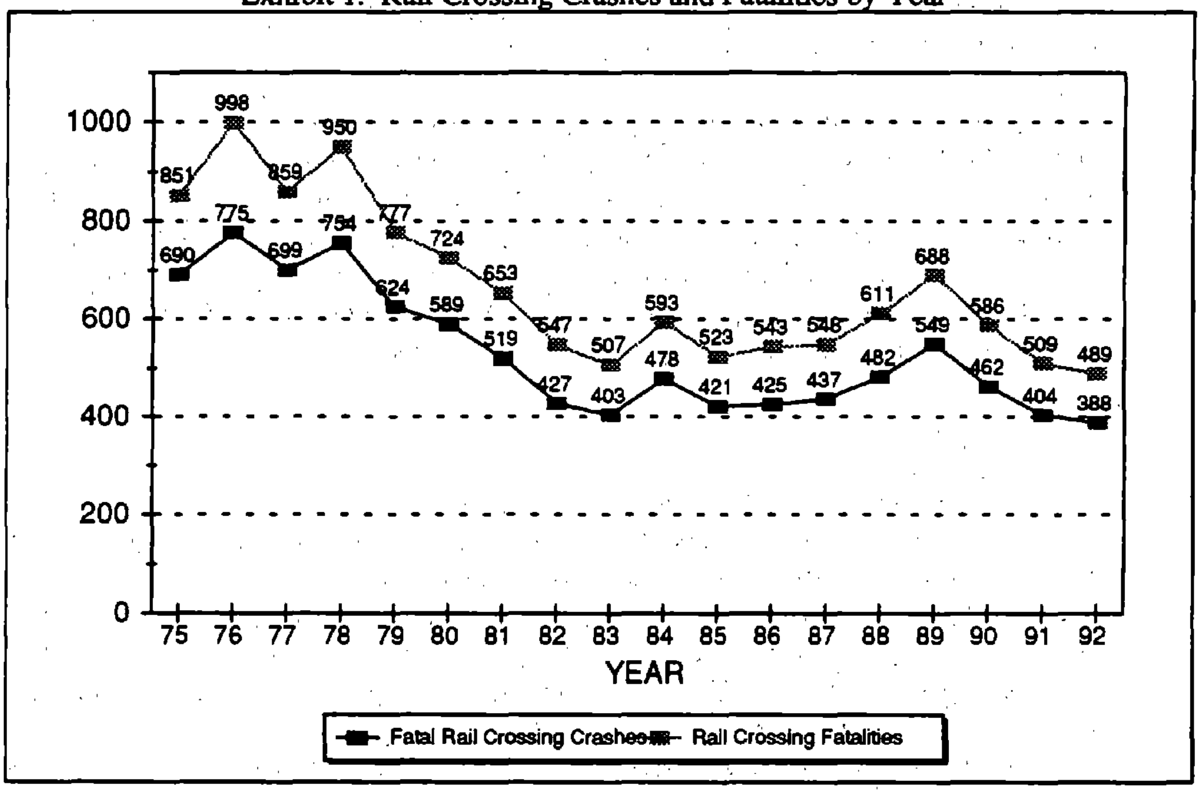
Claritas classifies each of the more than 3,500 zip codes in the United States into one of 62 cluster groups. Each cluster groups represents a unique set of demographic, socio-economic, and lifestyle characteristics. The 62 cluster groups all fall into one of 15 Social Groups with three to four clusters each. The 15 Social Groups are organized by urbanization (neighborhood density) and socio-economic status (income, occupation, home value, etc). Each of the 15 Social Groups fall into one of five broad geographic types: Suburban Populations (S), Urban Populations (U), Second City Populations (C), Town Populations (T), Rural Populations (R).

ANALYSIS

Fatal Crashes

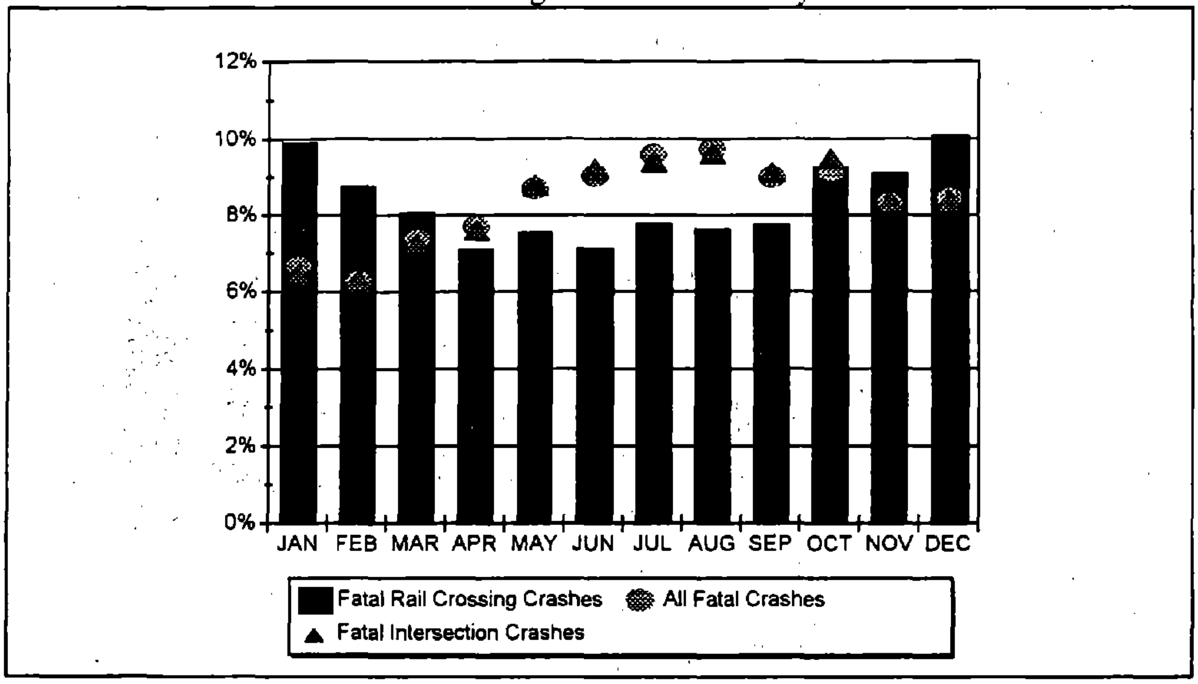
Exhibit 1 displays the number of fatal rail crossing crashes and the number of fatalities in rail crossing crashes over the past 18 years. From 1976 to 1982, there was a gradual decline in the number of fatal rail crossing crashes and their associated fatalities. The trend was relatively flat between 1982 and 1987, increasing slightly from 1987 to 1989, followed by a decrease from 1989 to 1992.

Exhibit 1. Rail Crossing Crashes and Fatalities by Year*



*Source: FARS 1975-1992

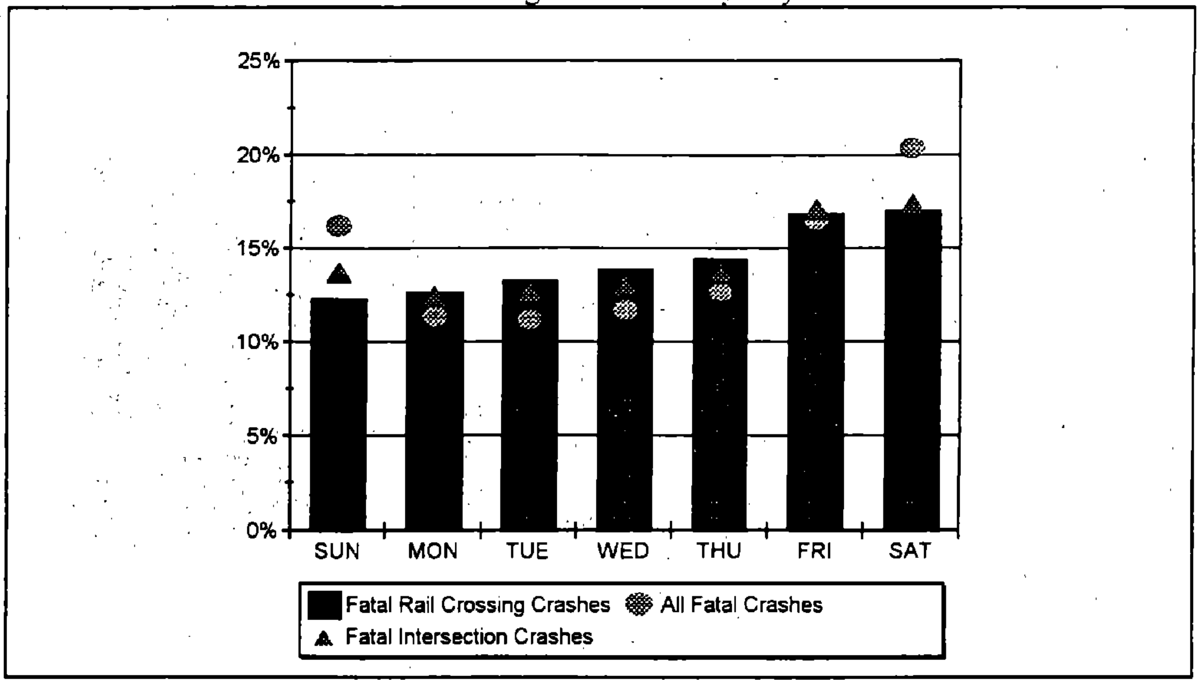
Exhibit 2. Percentage of Fatal Crashes by Month*



*Source: FARS 1975-1992

Exhibit 2 shows the percentage of fatal crashes by month. The chart indicates that the percentage of fatal rail crossing crashes is slightly greater during the winter months of October through March. In contrast, the percentages of all fatal crashes and fatal intersection crashes are greater during the summer months of April to September, when fatal rail crossing crashes are less frequent.

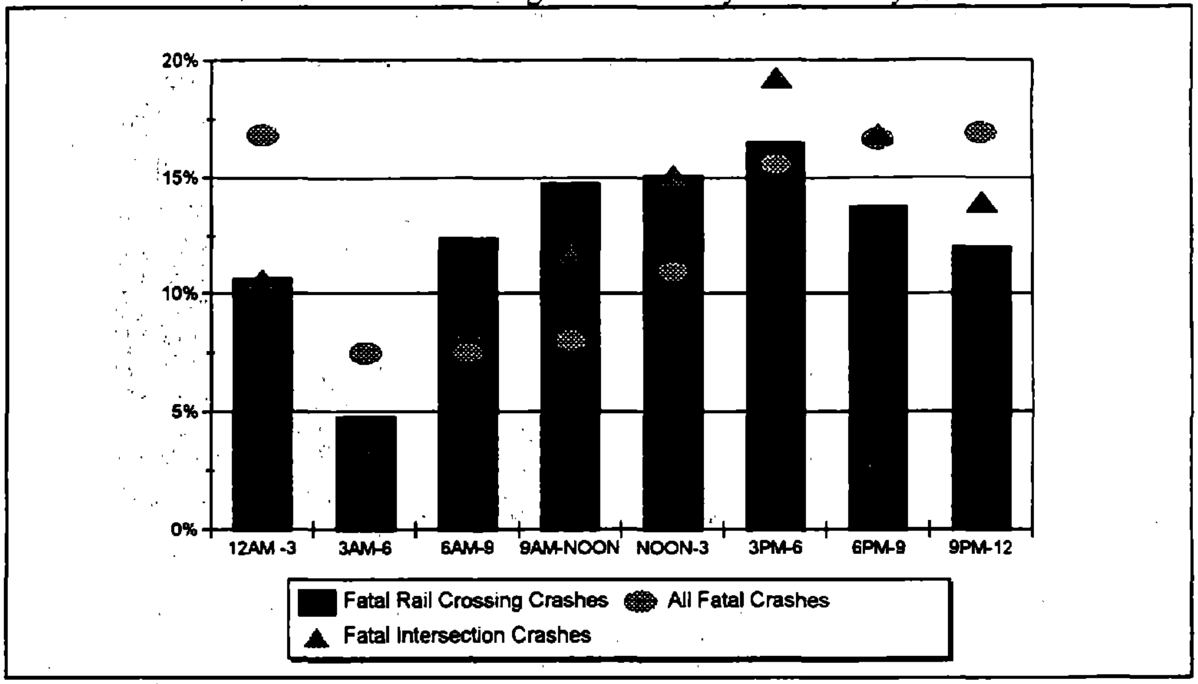
Exhibit 3. Percentage of Crashes by Day of Week*



*Source: FARS 1975-1992

Exhibit 3 shows the percentage of fatal crashes by day of the week. Fatal rail crossing crashes follow a pattern that closely resembles fatal intersection crashes, which are highest during Friday and Saturday (approximately 17 percent each day), and lower during Sunday through Thursday (approximately 13 percent each day). In contrast, the pattern for all fatal crashes shows a greater percentage during Friday, Saturday and Sunday, and a lesser portion occurring during Monday through Thursday.

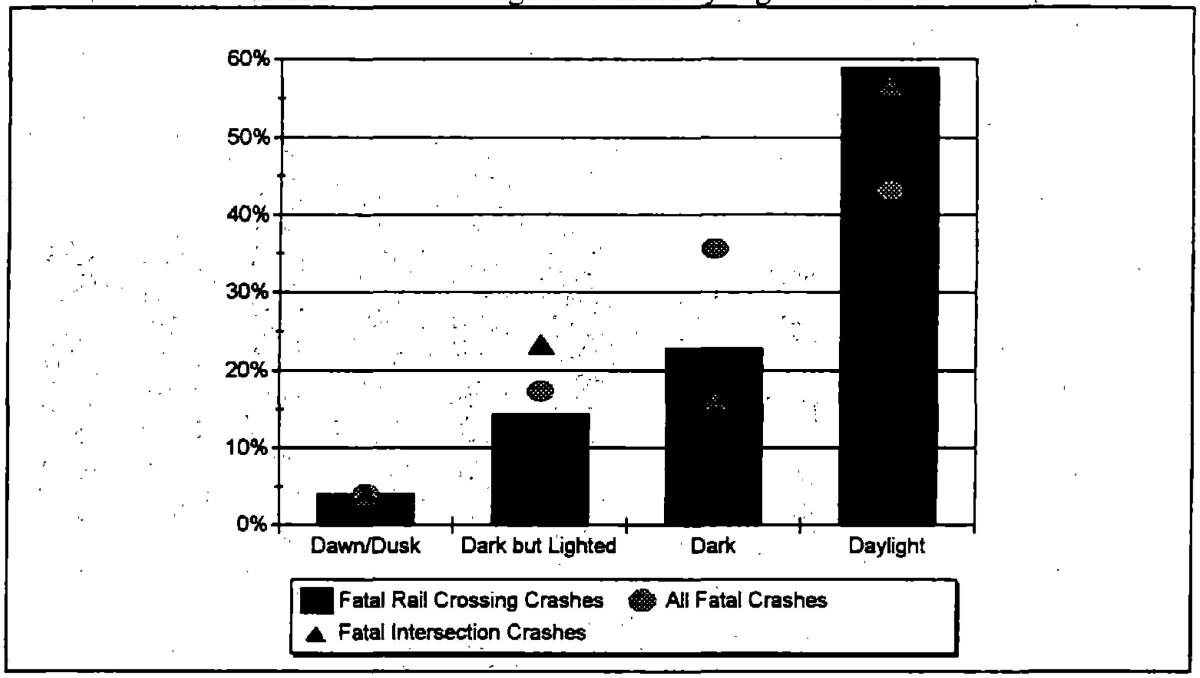
Exhibit 4. Percentage of Crashes by Time of Day*



*Source: FARS 1975-1992

Exhibit 4 shows the percentage of fatal crashes by time of day. Fatal crashes are more frequent between the hours of 6:00 p.m. and 3:00 a.m. The fewest occur between 3:00 a.m. and noon. After noon, there is a steady increase in the number of fatal crashes until the peak hours. Most fatal intersection crashes occur during evening rush hour, 3:00 p.m. to 6:00 p.m. The fewest occur between 3:00 a.m. and 6:00 a.m. From 3:00 a.m. until 3:00 p.m., there is a steady increase in fatal intersection crashes. The percentage of fatal rail crossing crashes is lower than both fatal intersection and all fatal crashes between 6:00 p.m. and midnight, and greater between 6:00 a.m. and noon.

Exhibit 5. Percentage of Crashes by Light Condition*



*Source: FARS 1975-1992

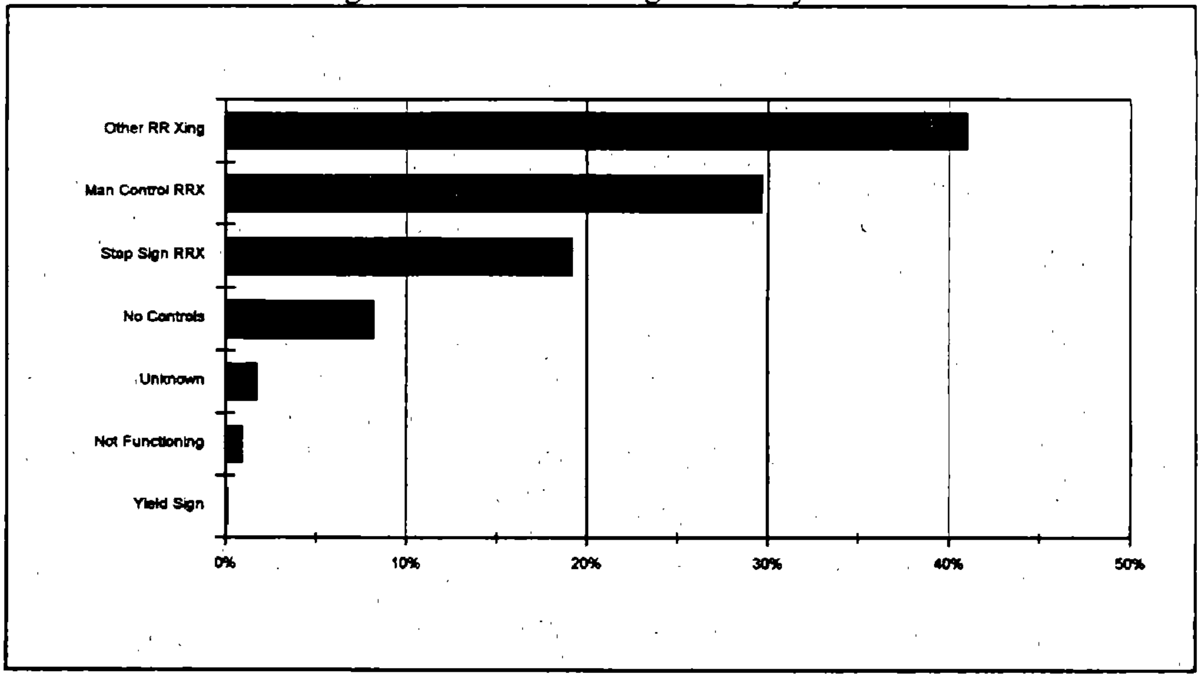
Exhibit 5 shows the percentage of fatal crashes by light condition. More than one-half of all fatal rail crossing crashes occur during daylight, which is greater than the percentage of all fatal crashes (a greater percentage of which occur during dark conditions), but about the same as fatal intersection crashes. The difference between fatal intersection and fatal rail crossing crashes during dark and dark but lighted conditions may be due to the possibility that more traffic intersections are lighted than are rail crossing intersections.

Traffic Control Devices

In 1982, the FARS variable reporting the traffic control device was revised. Exhibit 6a shows the percentage of fatal rail crossing crashes by the old traffic control device variable in FARS during 1975-1981, and Exhibit 6b shows the percentage of fatal rail crossing crashes using the revised traffic control device in FARS 1982-1992. From 1975 to 1981, 8 percent of fatal rail crossing crashes occurred at crossings with no controls. This percentage dropped during 1982 to 1992 to only 2 percent. This may be attributable to more crossings receiving traffic control devices during the more recent years.

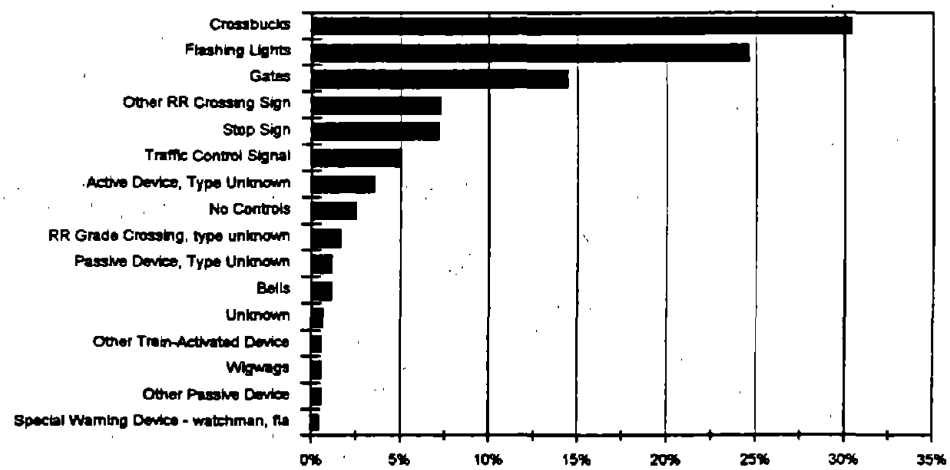
From 1982 to 1992, 30 percent of fatal rail crossing crashes occurred where a crossbuck was posted. Crossbucks are black and white signs in the shape of an X that say RAILROAD CROSSING. They are passive control devices. Passive control devices are controls which do not change when a train is present, they simply warn that trains might be present all the time. Another example of a passive control device is a stop sign.

Exhibit 6a. Percentage of Fatal Rail Crossing Crashes by Traffic Control Device#



#Source: FARS 1975-1981

Exhibit 6b. Percentage of Fatal Rail Crossing Crashes by Traffic Control Device+



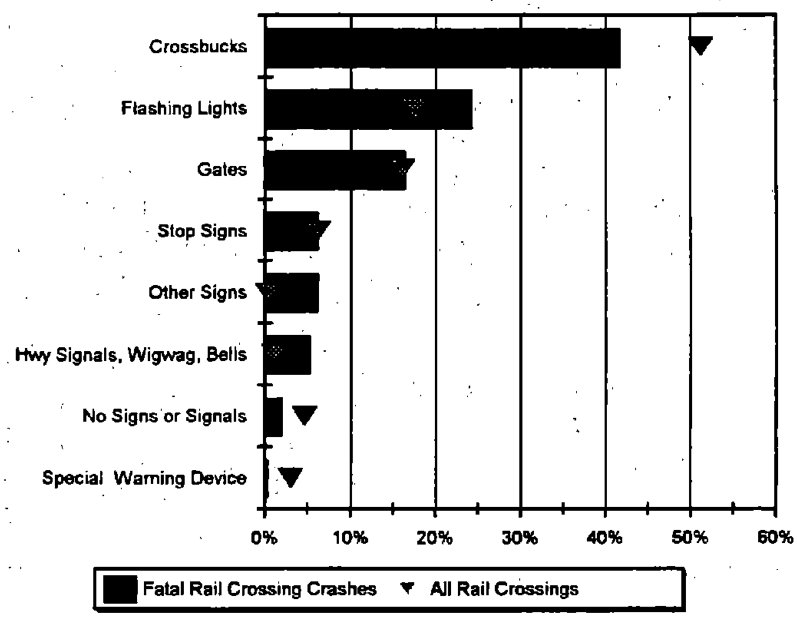
+Source: FARS 1982-1992

From 1982 to 1992, 24 percent of the fatal rail crossing crashes occurred where there were flashing lights and 14 percent occurred where there were gates. These are active control devices, which are those that signal when a train approaches; for example, flashing lights, gates, bells, wigwags, and traffic control signals are active devices.

FARS codes traffic control devices on a hierarchical scale. When more than one device is present, the highest is coded. The hierarchy is, from highest to lowest, gates, flashing lights, signals/wigwags/bells, special warning device, other active device, stop sign, crossbucks, other signs, other passive device, no controls.

In 99 percent of the fatal intersection crashes with traffic control devices present in FARS 1982-1992, the traffic control devices were functioning properly. However, only 95 percent of the fatal rail crossing crashes in FARS 1982 to 1992 had properly functioning traffic controls devices.

Exhibit 6c. Percentage of Fatal Rail Crossing Crashes and Rail Crossings by Traffic Control Device**



**Source: FARS 1992, Federal Railroad Administration "Highway-Rail Crossing Accident/Incident and Inventory Bulletin" No. 15 Calendar Year 1992

Exhibit 6c shows the percentage of fatal rail crossing crashes in FARS 1992 and the percentage of rail crossings present in the United States in 1992 by traffic control device. These estimates serve to contrast the presence of devices and occurrence of fatal rail crossing crashes. These estimates do not reflect measures of exposure, such as the number of trains and motor vehicles passing at each traffic control device. These data are available within the Federal Railroad Administration databases, and could provide fruitful information for further investigation. Twenty-four percent of all fatal rail crossing crashes occur where flashing lights are the traffic control device and 5 percent occur where highway signals, wigwags and bells are the traffic control device. In comparison, 18 percent of all rail crossing intersections in the United States have flashing lights as the traffic control device and 1 percent have highway signals, wigwags, and bells.

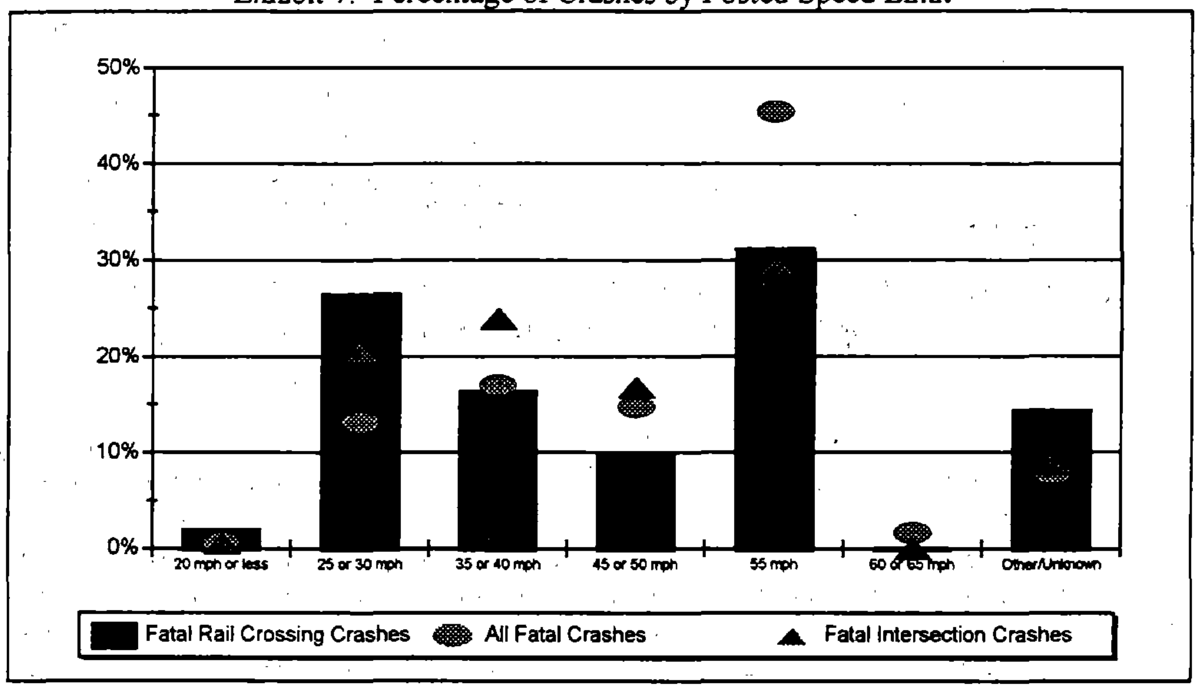
Fifty-one percent of all rail crossings in the United States have crossbucks, while 42 percent of fatal rail crossing crashes occur at such intersections. Exhibit 6c shows that the percentages of fatal crashes that occur at gates, stop signs, and special warning devices are lesser than the percentage representation of such devices at rail crossings. Again, it should be noted that differences in the fatal crash distribution vs. the distribution of rail crossing traffic control devices may also be due to differences in the train-motor vehicle exposure to these crossings.

Roadway Characteristics

The following three variables, posted speed limit, land use (urban or rural), and roadway function class, describe the types of roads where rail crossing crashes occur.

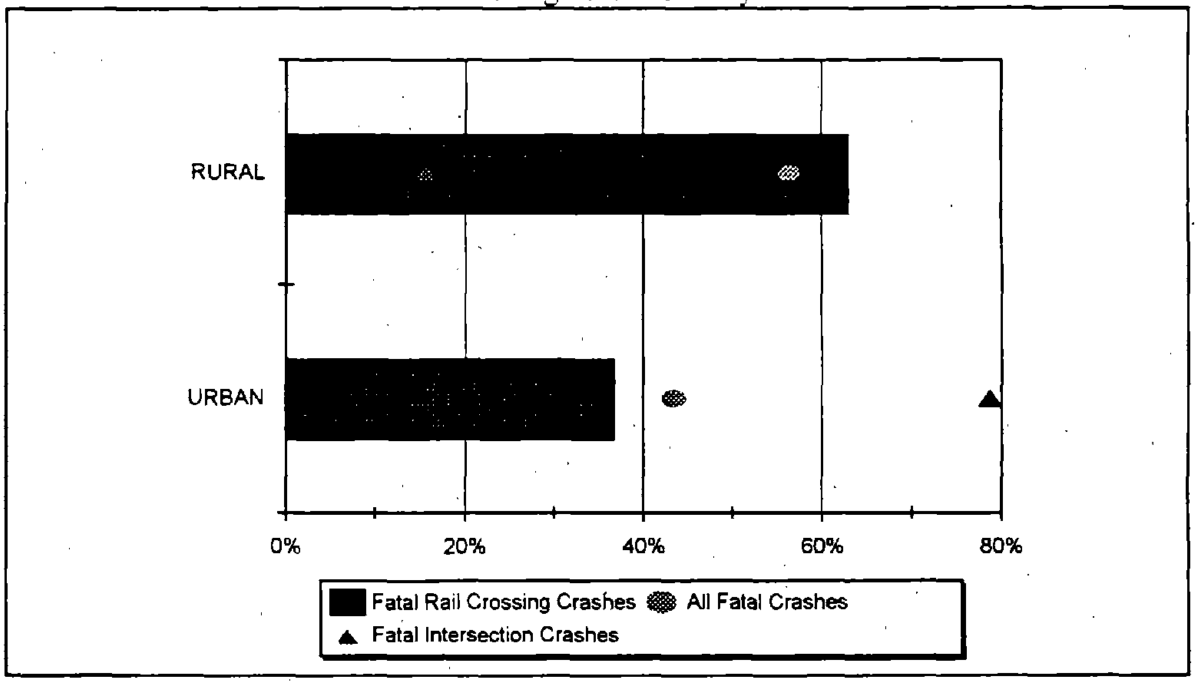
Exhibit 7 displays the percentage of fatal crashes by posted speed limit. The percentages of fatal rail crossing crashes and fatal intersection crashes on 55 mph posted speed limit roads are similar (31 percent and 29 percent, respectively), while 45 percent of all fatal crashes occurred on roads posted at 55 mph. The percentage of fatal rail crossing crashes on 25 mph and 30 mph roads (26 percent) is greater than the percentage of fatal intersection (20 percent) and all fatal crashes (13 percent).

Exhibit 7. Percentage of Crashes by Posted Speed Limit*



*Source: FARS 1975-1992

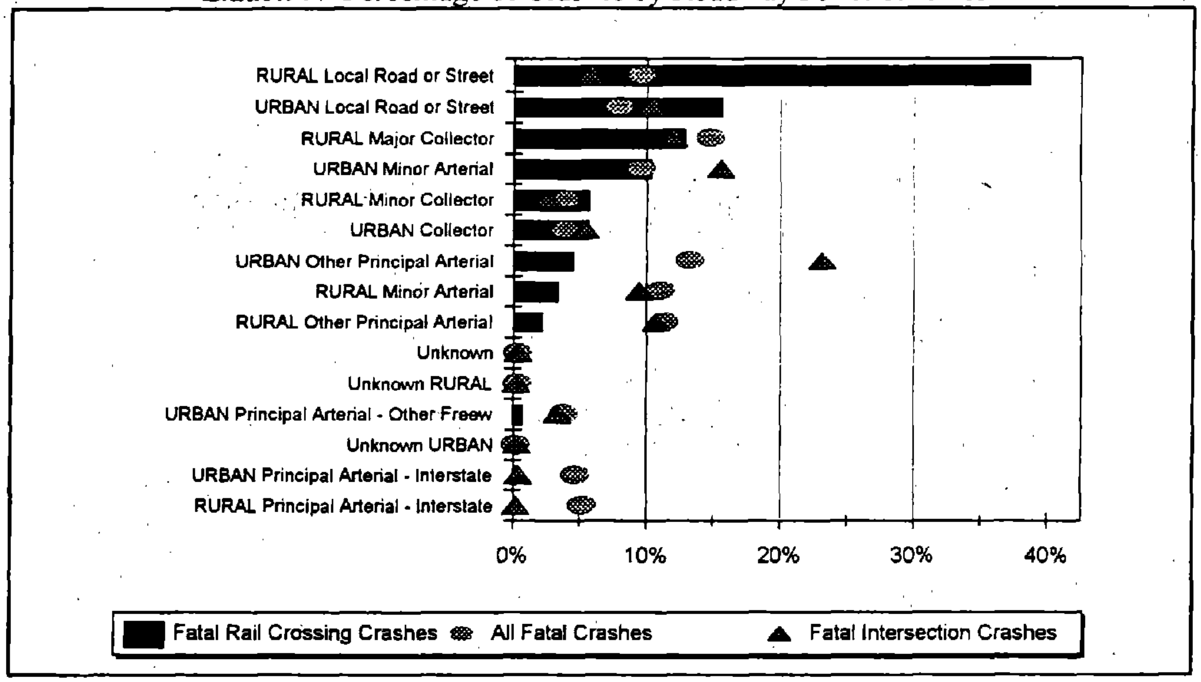
Exhibit 8. Percentage of Crashes by Land Use*



*Source: FARS 1975-1992

The land use (urban or rural) distribution for fatal crashes is displayed in Exhibit 8. Fifty-six percent of all fatal crashes occur in rural areas, and 43 percent in urban areas. Fatal rail crossing crashes also are more prevalent in rural areas than urban, but to an even greater extent than all fatal crashes. Sixty-three percent of fatal rail crossing crashes occur in rural areas and 37 percent in urban areas. This pattern likely parallels the rural-urban distribution of rail crossing locations. Fatal intersection crashes, on the other hand, occur more often in urban areas, which also follows the pattern of intersection location. Seventy-nine percent of fatal intersection crashes occur in urban areas and 16 percent in rural areas.

Exhibit 9. Percentage of Crashes by Roadway Function Class*



*Source: FARS 1975-1992

Exhibit 9 shows the roadway function class for fatal crashes. Fatal rail crossing crashes mostly occur on local roads or streets in rural areas (38 percent). This is substantially different from the two comparison groups, where rural local roads and streets account for only 10 percent of all fatal and 6 percent of fatal intersection crashes. Fifteen percent of fatal rail crossing crashes occur on local roads or streets in urban areas, while urban local roads and streets account for only 8 percent of all fatal and 10 percent of fatal intersection crashes. Taking both rural and urban local roads and streets together accounts for 53 percent of fatal rail crossing crashes, compared to 18 percent of all fatal and 16 percent of fatal intersection crashes. These differences are likely due to the locations of rail crossings, as noted earlier. Rail crossing crashes are less frequent in all other roadway function classes when compared to all fatal and fatal intersection crashes. Rail crossings on the other roadway function classes may be associated with more overpasses or underpasses.

State Statistics

Exhibit 10 presents the number and percentage of fatal rail crossing crashes and rail crossing locations, by state, for calendar year 1992. The table is presented in descending order, by frequency of fatal rail crossing crashes.

Exhibit 10. Number and Percentage of Rail Crossing Crashes and Rail Crossings**

State	FARS 1992 Fatal Rail Crossing Crashes		Federal Rail (FRA) Rail Crossings 1992	
	Number	Percent	Number	Percent
TX	36	9.3%	13,016	7.6%
OH	33	8.5%	6,961	4.1%
IN	27	7.0%	7,055	4.1%
MI	24	6.2%	5,865	3.4%
LA	23	5.9%	3,955	2.3%
IL	23	5.9%	10,364	6.1%
OK	16	4.1%	4,658	2.7%
CA	15	3.9%	8,088	4.7%
KS	14	3.6%	8,100	4.7%
NC	13	3.4%	4,922	2.9%
GA	13	3.4%	6,474	3.8%
MS	13	3.4%	3,033	1.8%
AR	11	2.8%	3,347	2.0%
AL	10	2.6%	4,203	2.5%
FL	9	2.3%	4,102	2.4%
MO	9	2.3%	4,939	2.9%
PA	8	2.1%	5,655	3.3%
NE	8	2.1%	4,159	2.4%
KY	8	2.1%	2,804	1.6%
NY	7	1.8%	3,359	2.0%
MN	7	1.8%	5,432	3.2%
TN	7	1.8%	3,427	2.0%
IA	6	1.5%	5,430	3.2%
ND	6	1.5%	4,802	2.8%
CO	6	1.5%	2,153	1.3%
ID	5	1.3%	1,603	0.9%
WI	5	1.3%	5,123	3.0%
SC	4	1.0%	3,355	2.0%

WA	4	1.0%	3,034	1.8%
VA	3	0.8%	2,355	1.4%
OR	3	0.8%	2,394	1.4%
AZ	2	0.5%	956	0.6%
CT	1	0.3%	506	0.3%
VT	1	0.3%	492	0.3%
MT	1	0.3%	1,550	0.9%
ME	1	0.3%	885	0.5%
DE	1	0.3%	256	0.2%
NM	1	0.3%	825	0.5%
MD	1	0.3%	711	0.4%
WV	1	0.3%	2,228	1.3%
AK	1	0.3%	227	0.1%
SD	1	0.3%	2,194	1.3%
NH	0	0.0%	503	0.3%
NV	0	0.0%	271	0.2%
NJ	0	0.0%	1,910	1.1%
MA	0	0.0%	1,192	0.7%
WY	0	0.0%	533	0.3%
UT	0	0.0%	1,021	0.6%
PR	0	0.0%	24	0.0%
DC	0	0.0%	37	0.0%
RI	0	0.0%	128	0.1%
HI	0	0.0%	6	0.0%

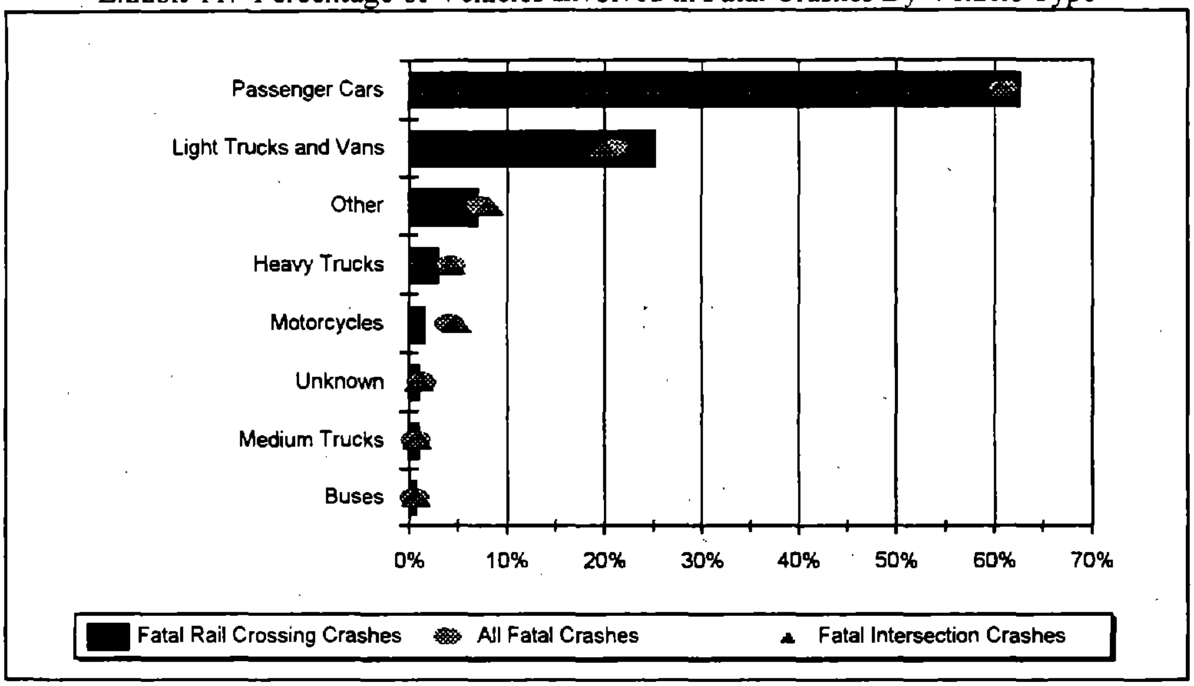
**Source: FARS 1992, Federal Railroad Administration "Highway-Rail Crossing Accident/Incident and Inventory Bulletin" No. 15 Calendar Year 1992

As can be seen in Exhibit 10, the state-level distribution of fatal rail crossing crashes is a continuum, ranging from a high of 36 for Texas to zero for a number of states. In 1992, over 50 percent of the fatal rail crossing crashes occurred in eight states: Texas, Ohio, Indiana, Michigan, Louisiana, Illinois, Oklahoma and California. However, there is no particular reason to cut off this list at California. The next 8 states on the list add an additional 25 percent, yielding an estimate that in 1992, over 75 percent of the fatal rail crossing crashes occurred in 16 states (down to Pennsylvania).

Involvement by Vehicle Type

Exhibit 11 shows the percentage of vehicles by type of vehicle. Passenger cars are the most frequently involved vehicle (about 60 percent) in all fatal crashes, fatal intersection crashes, and fatal rail crossing crashes. Slightly more light trucks and vans were involved in rail crossing crashes than in the two comparison groups. This may be the preferred type of vehicle on rural country roads where rail crossing intersections are more likely to be encountered.

Exhibit 11. Percentage of Vehicles Involved in Fatal Crashes By Vehicle Type



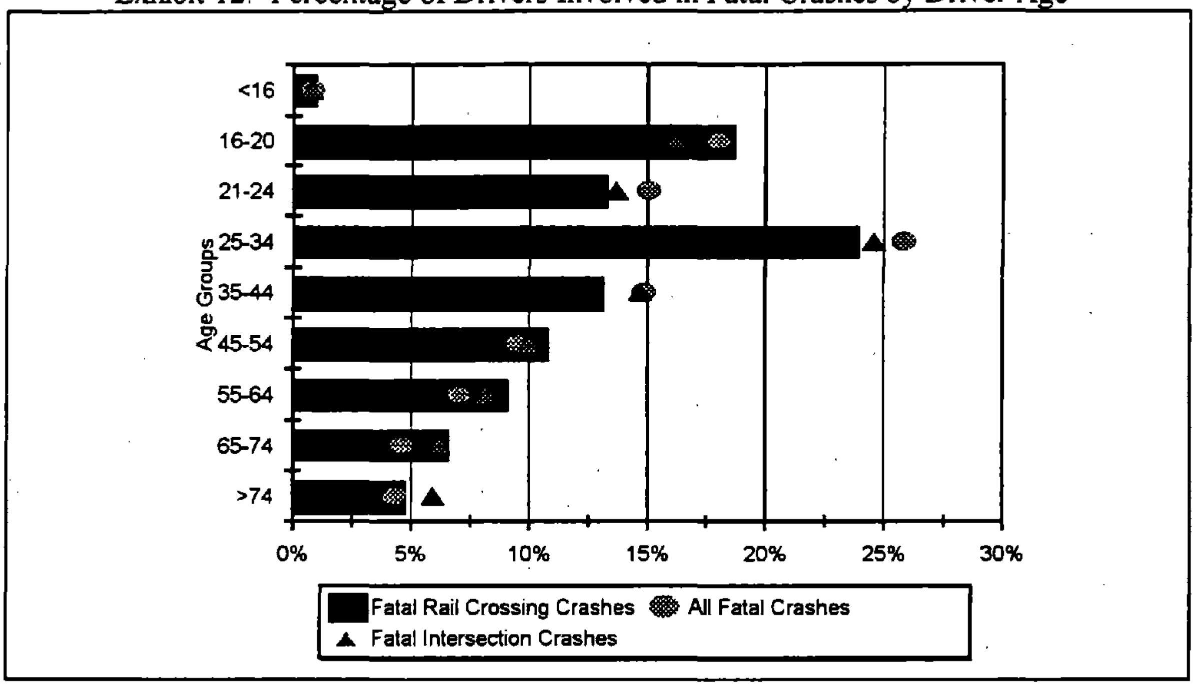
*Source: FARS 1975-1992

As expected, most vehicles involved in fatal rail crossing crashes were severely deformed and were initially impacted in the side. Ninety-two percent of vehicles involved in fatal rail crossing crashes were severely deformed, but only 70 percent of vehicles involved in fatal crashes and 65 percent of vehicles involved in fatal intersection crashers were severely deformed. Eighty percent of rail crossing vehicles were initially impacted in the side and 20 percent impacted in the front.

Drivers Involved

The percentage of drivers involved in fatal crashes by age category is shown in Exhibit 12. Drivers age 25 to 34 are most often involved in fatal rail crossing crashes and drivers age 16-20 are second highest group. The 16-20 year old group is particularly high when considering that this age group includes only five years, while the 25-34 year olds include a ten-year span. These groups also exhibit the first and second highest involvement in fatal crashes and fatal intersection crashes. The percentage of 21 to 44 year old drivers involved in fatal rail crossing crashes is slightly less than the percentage of drivers involved in fatal and fatal intersection crashes. The percentage of 45 to 74 year old drivers involved in fatal rail crossing crashes is slightly more than all drivers involved in fatal crashes.

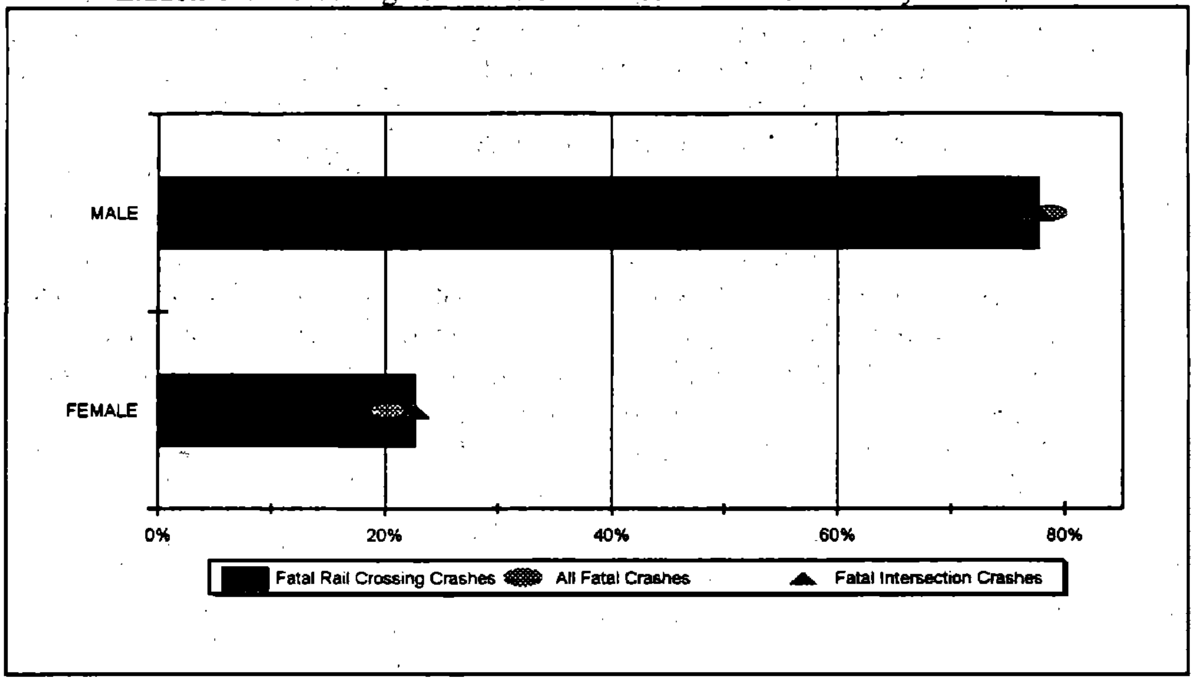
Exhibit 12. Percentage of Drivers Involved in Fatal Crashes by Driver Age*



*Source: FARS 1975-1992

Exhibit 13 shows the percentage of drivers involved in fatal crashes by driver sex. The distribution of female and male drivers involved in fatal rail crossing crashes is similar to drivers involved in both all fatal and fatal intersection crashes.

Exhibit 13. Percentage of Drivers Involved in Fatal Crashes by Driver Sex*



*Source: FARS 1975-1992

Exhibits 14 and 15 show the distribution of alcohol involvement for drivers involved in fatal rail crossing crashes, all fatal crashes and fatal intersection crashes. These distributions represent a combination of known blood alcohol concentration (BAC) test results, and estimated probabilities for drivers with unknown BAC test results using NHTSA's alcohol imputation method.

Exhibit 14. Percentage Drivers Involved in Fatal Crashes by BAC*

	BAC .00	BAC .01-.09	BAC .10+
All	66.1%	7.8%	26.1%
Intersection	80.6%	6.6%	12.8%
Rail Crossing	66.7%	8.9%	24.4%

*Source: FARS BAC Databases 1987-1992

As can be seen, drivers involved in fatal rail crossing crashes exhibit higher rates of alcohol involvement compared to drivers involved in other fatal intersection crashes. The rate of alcohol involvement for drivers in fatal rail crossing crashes is close to that for drivers in all fatal crashes, which is a combination of single-vehicle crashes (in which drivers exhibit much greater levels of alcohol involvement) and multi-vehicle crashes (in which drivers exhibit levels of alcohol involvement similar to those in fatal intersection crashes). Thus, drivers in fatal rail crossing crashes do not appear to exhibit the extremely high levels of alcohol involvement associated with single-vehicle fatal crashes (in which approximately 45 percent of the drivers exhibit BAC's of 0.10 percent or greater).

Exhibit 15 presents driver BAC distributions for various age categories. The same pattern of alcohol involvement as was observed for the aggregate data of Exhibit 14 is found within each individual age categories. That is, drivers in fatal rail crossing crashes exhibit rates of alcohol involvement about equal to the rates observed for drivers in all fatal crashes, and substantially higher than for drivers in other fatal intersection crashes. Drivers 21-24 years old exhibit the highest rates of alcohol involvement for all three crash categories, followed by drivers 25-34 years old.

Exhibit 15. Percentage Drivers Involved in Fatal Crashes by BAC and Age Category*

AGE CATEGORY		BAC .00	BAC .01-.09	BAC .10+
< 16	All	92.0%	3.0%	5.0%
	Intersection	92.7%	3.8%	3.5%
	Rail Crossing	89.4%	4.4%	6.2%
16-20	All	64.5%	11.5%	24.1%
	Intersection	79.3%	8.8%	12.0%
	Rail Crossing	69.2%	12.2%	18.6%
21-24	All	52.6%	10.9%	36.5%
	Intersection	70.5%	10.0%	19.5%
	Rail Crossing	54.5%	12.3%	33.3%
25-34	All	57.4%	8.4%	34.2%
	Intersection	74.5%	7.7%	17.8%
	Rail Crossing	58.3%	10.2%	31.5%
35-44	All	66.3%	6.3%	27.4%
	Intersection	81.4%	5.6%	13.0%
	Rail Crossing	66.4%	7.1%	26.5%
45-54	All	73.3%	5.3%	21.4%
	Intersection	86.0%	4.6%	9.3%
	Rail Crossing	72.7%	7.5%	19.8%
55-64	All	78.5%	5.0%	16.6%
	Intersection	88.8%	4.0%	7.2%
	Rail Crossing	78.5%	5.0%	16.5%
65-74	All	84.7%	4.5%	10.8%
	Intersection	92.2%	3.2%	4.6%
	Rail Crossing	79.0%	4.1%	16.9%
> 74	All	80.2%	5.6%	14.2%
	Intersection	90.4%	3.7%	5.9%
	Rail Crossing	84.3%	3.1%	12.6%

*Source: FARS BAC Databases 1987-1992

Other variables in the FARS database were examined for rail crossing crashes. Ninety-five percent of rail crossing crashes occurred on roads with a straight roadway alignment. Seventy-five percent of rail crossing crashing occurred on a blacktop road surface. For roadway profile, 63 percent of fatal rail crossing crashes occurred on a level profile, and 28 percent on a grade profile. In 94 percent of the fatal rail crossing crashes, the roadway flow was not divided. Road surface conditions were dry in 81 percent and wet in 12 percent of the fatal rail crossing crashes. The driver-related factors most often noted for drivers in fatal rail crossing crashes were failure to yield, failure to obey, or inattentive.

Claritas

NHTSA subscribes to a commercially available market research tool, Claritas, which utilizes geodemographics to characterize different population segments. Geodemographics links demographic and lifestyle data with different geographic units. All population segments are classified by zip code. Claritas a useful tool to gain information about households of drivers involved in certain types of crashes. By using the driver's zip code, Claritas can help determine who the target population(s) are: where they live, what they read, which television programs they watch, and what their consumer habits are like.

A review of the crash data indicated the need to develop additional descriptors of drivers involved in fatal rail crossing crashes. This was accomplished by matching the driver's residential zip code with the data in Claritas to permit program planners to focus educational and informational messages on the subpopulations most at risk of involvement in fatal rail-crossing traffic crashes. Both the content of the messages and the media used to deliver them are important elements in designing effective countermeasures. To this end, Claritas identifies, for each subpopulation, the educational levels, median income, family type, occupation and race/ethnic origin. This information is supplemented by popular media to which these subpopulations subscribe. Taken together, this information should be sufficient to design and implement properly targeted and effective messages.

Claritas classifies each of the more than 3,500 zip codes in the United States into one of 62 cluster groups. Each cluster group represents a unique set of demographic, socio-economic, and lifestyle characteristics. The 62 cluster groups all fall into one of 15 Social Groups with 3-5 clusters each. The 15 Social Groups are organized by urbanization (neighborhood density) and socio-economic status (income, occupation, home value, etc). Each of the 15 Social Groups fall into one of five broad geographic types: Suburban Populations (S), Urban Populations (U), Second City Populations (C), Town Populations (T), Rural Populations (R).

The focus of this data summary will be by Social Groups. Each Social Group is designated by a two character code. The first character, a letter, either S, U, C, T, R is the geographic type. The second character is a number designator 1,2,3,4, or 5. The numbers for each geographic group are in order by socio-economic status. The Social Groups, in affluence order, are defined in Exhibit 16.

Exhibit 16. Claritas Social Group Definitions

	Predominant Social Group Characteristics					
	Education	Median HH Income ($)	Family Type	Occupation	Race/Ethnic Origin	HH Size
US Population Characteristics / **Social Group**	**4+ yrs coll (21%)** **1-3 yrs coll (25%)** **high sch (30%)** **less than HS (25%)**	**31,900**	**Married Cpls (55%)** **Married w/chl(27%)** **Single Parents (9%)** **Sngl Female HH head (12%)**	**Prof/Mgr (26%)** **White-Coll(31%)** **Blue-Collar (27%)** **Service (14%)** **Farm/Ranch/Mine (3%)**	**White (80%)** **Black (11%)** **Asian (2%)** **Hispanic (7%)** **Foreign (8%)**	**1 person (25%)** **4+ per (26%)** **HH w/children (36%)**
S1 Elite Suburbs	4+ yrs coll (41%)	59,000	Married Cpls (69%)	Prof/Mgr (42%)	White (88%)	HH w/ children (39%)
U1 Urban Uptown	4+ yrs coll (40%)	43,100	Married Cpls (43.5%)	Prof/Mgr (42%)	White (78%)/Forgn (17%)	1 person (35%)
C1 2nd City Society	4+ yrs coll (33%)	43,900	Married Cpls (62%)	Prof/Mgr (37%) White-Collar (36%)	White (91%)	HH w/children (32%)
T1 Landed Gentry	4+ yrs coll (29%) 1-3 yrs coll (29%)	47,400	Married Cpls (71%)	Prof/Mgr (34%) White-Collar (33%)	White (94%)	HH w/children (42%)
S2 The Affluentials	1-3 yrs coll (30%) high sch (29%)	38,300	Married Cpls (58%)	White-Collar (36%)	White (85%)	HH w/children (36%)
S3 Inner Suburbs	high sch (32%)	28,100	Married Cpls (49%)	White-Collar (35%)	White (78%)/Black (12%) Hispanic (8%)	HH w/children (34%)
U2 Urban Midscale	less than HS (30%) high sch (29%)	29,900	Married Cpls (46%)	White-Collar (34%)	White (60%)/Forgn (21%) Black (18%)/Hispan (16%) Asian (5%)	HH w/children (35%)
C2 2nd City Centers	1-3 yrs coll (28%) high sch (28%)	27,500	Married Cpls (48%)	White-Collar (34%)	White (85%)	HH w/children (31%)
T2 Exurban Blues	high sch (35%)	30,900	Married Cpls (64%)	White-Collar (31%) Blue-Collar (32%)	White (91%)	HH w/children (41%)
R1 Country Families	high sch (38%)	32,100	Married Cpls (68%)	Blue-Collar (37%)	White (95%)	HH w/children (41%)
U3 Urban Cores	less than HS (45%)	16,300	Married Couples (30%)	Blue-Collar (32%) White-Collar (30%)	Black (42%)/White (33%) Hispan (21%)/Forgn(18%)	HH w/children (37%)
C3 2nd City Blues	less than HS (39%)	17,200	Married Cpls (38%)	Blue-Collar (34%)	White (61%)/Black (27%) Hispano (10%)	HH w/children (35%)
T3 Working Towns	high sch (34%) less than HS (34%)	20,900	Married Cpls (53%)	Blue-Collar (36%)	White (83%) Black (11%)	HH w/children (36%)
R2 Heartlanders	high sch (36%)	22,700	Married Cpls (66%)	Blue-Collar (32%)	White (88%)/Hispan (7%)	HH w/children (39%)
R3 Rustic Living	less than HS (37%)	20,700	Married Cpls (61%)	Blue-Collar (42%)	White (87%)/Black (10%)	HH w/children (38%)

Driver zip code is only available in FARS from 1987 to 1992. These driver zip codes were analyzed with the Claritas database. The drivers involved in fatal rail crossing crashes in 1987 to 1992 are the study population. United States residents age 15 years or greater are the base population. There were 2,678 drivers in our study population and 201,104,559 people in our base population. Comparisons with all drivers involved in fatal crashes, excluding rail crossing crashes, from 1987 to 1992 were computed as well. There were 383,172 drivers in the all FARS population.

Exhibit 17. Percentage of Claritas Population by Geographic Group

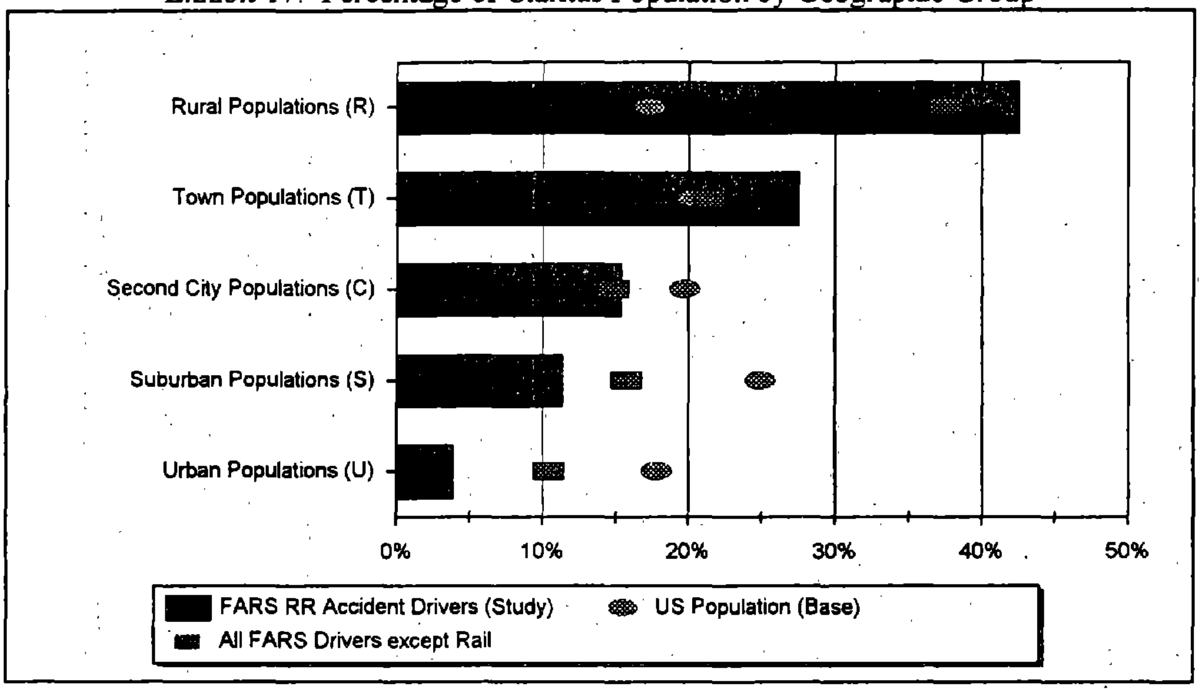


Exhibit 17 displays the study and base populations for each of the five geographic groups. A greater percentage of drivers involved in fatal rail crossing crashes are classified as residing in rural and town populations than would be expected based on their percentage of the U.S. population base or their percentage involvement in other fatal crashes. This "overrepresentation" is likely due, in large part, to their exposure to rail crossing opportunities as a result of geographic locations of these populations. Exhibit 18 further disaggregates these distributions into the 15 major social groups.

Exhibit 18. Percentage of Claritas Population by Social Group

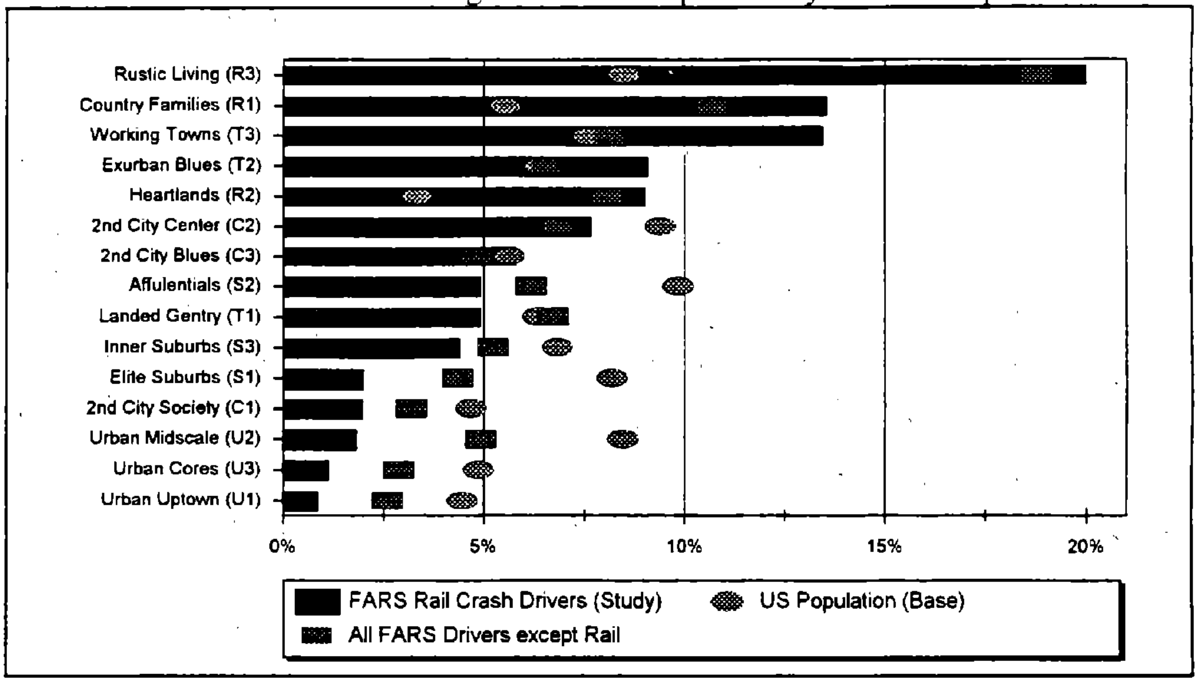


Exhibit 18 presents the percentage distribution of social groups for three populations: drivers involved in fatal rail crossing crashes, drivers involved in all other fatal crashes, and the U.S. population. The graph appears to exhibit three distinct groupings:

(1) The five social groups most involved in fatal rail crossing crashes (rustic living through heartlands) comprise approximately 65 percent of the drivers involved in these fatal crashes. These groups are overrepresented to a relatively high degree compared to either all other drivers in fatal crashes or the U.S. population (31 percent). Three of the five social groups represent rural populations, while the remaining two represent town populations. As noted earlier, the locations of these populations are likely to result in the greatest exposure to rail crossing opportunities, contributing greatly to their population-based overrepresentation.

(2) The five social groups least involved in fatal rail crossing crashes (elite suburbs through urban uptown) comprise approximately 8 percent of the drivers involved in these crashes. These groups are underrepresented to a relatively high degree compared to either all other drivers in fatal crashes or the U.S. population. Three of these social groups represent urban populations, which may have the least exposure to rail crossing opportunities, while the remaining two represent the most affluent city or suburban populations. This lower exposure to rail crossing opportunities is likely a major contributor to their population-based underrepresentation.

(3) The middle five social groups (2nd city center through inner suburbs) comprise approximately 27 percent of the drivers involved in fatal rail crossing crashes. This grouping consists of several populations that are overinvolved relative to other fatal crash-involved drivers or the U.S. population, but their involvement pattern does not fit either the greatest or least involved groups. This group consists of the most affluent town population, and the moderate and less affluent suburban and second city populations..

Claritas contains descriptions for each of the 15 groups on a number of characteristics describing household attributes and media and life style preferences. From the information provided for each of the individual 15 social groups and the percentage distribution in the three populations under study (U.S. population, drivers in fatal rail crossing crashes, and drivers in all other fatal crashes), it was possible to construct a single number for each attribute, that represents the weighted averages of these characteristics within each study population. Exhibit 19 presents demographic statistics for the three populations under study.

Exhibit 19. Characteristics of Drivers Involved in Fatal Crashes

		Percentage of US Population	Percentage of Fatal Rail Collision Driver Population	Percentage All Other Fatal Driver Population
Education	4+ Years College	**20.6%**	15.7%	17.7%
	1-3 Years College	**24.9%**	23.4%	23.9%
	High School Graduate	**29.9%**	33.1%	31.8%
	Less than High School	**24.6%**	27.8%	26.6%
Household Income	Less than $15,000	**24.3%**	27.8%	26.2%
	$15,000 - $34,999	**33.4%**	36.1%	34.9%
	$35,000 - $74,999	**32.8%**	29.9%	31.3%
	$75,000 +	**9.5%**	6.1%	7.7%
	Median HH Income	**$31,900**	$27,667	$29,649
Family Type	Married Couples	**55.2%**	58.6%	57.9%
	Married w/Children	**26.7%**	28.6%	28.2%
	Single Parents	**9.3%**	8.9%	8.9%
	Single Female HH Head	**11.6%**	10.7%	10.8%
Occupation	Professional/ Manager	**25.8%**	21.8%	23.4%
	Other White-Collar	**31.4%**	28.7%	29.6%
	Blue-Collar	**26.6%**	32.8%	31.2%
	Service	**13.7%**	14.0%	13.7%
	Farm/Ranch/Mining	**2.5%**	4.3%	3.9%
Race/Ethnic Origin	White	**80.1%**	85.0%	83.3%
	Black	**10.6%**	8.5%	9.1%
	Asian (API)	**2.1%**	1.0%	1.5%
	Hispanic	**6.5%**	4.5%	5.3%
	Foreign Born	**7.7%**	4.2%	5.6%
Household Size	1 Person	**24.6%**	23.2%	23.4%
	4+ Persons	**26.0%**	26.5%	26.6%
	HH w/ Children	**36.0%**	37.5%	37.1%

A review of Exhibit 19 shows that a larger percentage of drivers involved in fatal rail crossing crashes have no college experience (60.9 percent) compared to both fatal crash-involved drivers (58.5 percent) and the U.S. population as a whole (54.5 percent), with the greatest differences observed for the 4+ years of college category (15.7 percent for fatal rail crossing-involved drivers, 17.7 percent for other fatal crash-involved drivers, and 20.6 percent for the U.S. population).

The median household income for fatal rail crossing-involved drivers also is lower ($27,667) than both other fatal crash-involved drivers ($29,649) and the U.S. population ($31,900), with a greater percentage of households earning under $34,000.

There are only minor differences in the family type (single vs. married, with or without children) among the three populations.

One of the largest differences among the three populations is in the area of occupation, with fatal rail crossing-involved drivers coming from households in which 32.8 percent report blue-collar occupations, close to the 31.2 percent for other fatal crash-involved drivers, and much greater than the 26.6 percent reported for the U.S. population. While the service sector appears equally represented across the three populations, there are fewer professional/manager and other white-collar occupations for both fatal crash-involved groups and more reporting of farm/ranch/miner occupants than in the U.S. population.

In terms of race/ethnic origin, fatal rail crossing-involved drivers come from areas with a greater percentage of white households (85.0 percent), slightly higher than for other fatal crash-involved drivers (83.3 percent), and higher than the U.S. population (80.1 percent). This is also likely a function of geographic location (the higher propensity for involvement by rural and town populations).

There is essentially no differences among the three populations with regard to household size.

Exhibits 20 and 21 show the magazines read and the media use in the fatal rail crossing-involved driver population. These tables were prepared by listing the top ten magazines and media use for each of the 15 social groups and weighting their appearance on the list by the percentage of driver involvements in fatal rail crossing crashes.

Exhibit 20. Top Magazines for Fatal Rail Crossing Driver Social Groups

	Percentage Fatal Rail Crossing Drivers
Field & Stream	65%
Outdoor Life	65%
Sports Afield	64%
Hunting	56%
Country Living	52%
Guns & Ammo	49%

For example, *Field and Stream* and *Outdoor Life* were listed in the top magazines read by households that comprise 65 percent of fatal rail crossing-involved drivers. This was followed by two other outdoor-oriented magazines (*Sports Afield* and *Hunting*). These magazines could be an important delivery mechanism for reaching and educating the population of drivers most likely to encounter and become involved in rail crossing crashes. Informational messages on the potential dangers related to rail crossing maneuvers could be effective if focused on these populations.

Exhibit 21. Top Media Usage for Fatal Rail Crossing Driver Social Groups

	Percentage Fatal Rail Crossing Drivers
Watch The Family Channel	56%
Fish & Hunt Mags	52%
Country Radio	51%
TV Quiz & Aud Participate	39%
TV Wrestling	39%

The prominent representation of fishing-and hunting-related television and radio programs and magazines on the top media use list for fatal rail crossing-involved driver households parallels the top magazines read by this population. Again, this could be an effective medium for information dissemination. The same could be true for country radio stations.

Exhibit 22. Top Lifestyle Activities for Fatal Rail Crossing Driver Social Groups

	Percentage Fatal Rail Crossing Drivers
Use Chewing Tobacco	62%
Go Hunting	52%
Eat at Ice Cream Restaurant	42%
Gospel Music	40%
Eat at Seafood Restaurant	39%

The prominence of hunting on the top lifestyle activities list also parallels this population's media interests. This activity, coupled with the prominent use of chewing tobacco, might suggest the use of certain celebrities for delivering educational and cautionary messages regarding rail crossing-highway interactions.

Appendix A - FARS Data

The tables in this appendix contain the FARS data used to create the figures which fatal crashes, vehicles involved in fatal crashes, and driver involved in fatal crashes. The tables in this appendix are numbered to match their corresponding figures. Exhibit A-1 contains the data used to create Exhibit 1. FARS 1975-1992 data were used in all the tables except Exhibit A-6a and Exhibit A-6b. FARS 1975-1981 data was used in Exhibit A-6a and FARS 1982-1992 was used in Exhibit A-6b.

Exhibit A-1. Fatal Crashes and Fatalities by Year

YEAR	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	FATAL RAIL CROSSING CRASHES	ALL FATALITIES	INTER-SECTION FATALITIES	RAIL CROSSING FATALITIES
75	39,161	7,848	690	44,525	8,810	851
76	39,747	7,687	775	45,523	8,745	998
77	42,211	8,007	699	47,878	8,933	859
78	44,433	8,539	754	50,331	9,577	950
79	45,223	8,708	624	51,093	9,788	777
80	45,284	8,579	589	51,091	9,609	724
81	44,000	8,284	519	49,301	9,248	653
82	39,092	7,087	427	43,945	7,978	547
83	37,976	6,565	403	42,589	7,360	507
84	39,631	6,639	478	44,257	7,593	593
85	39,196	6,585	421	43,825	7,420	523
86	41,090	6,803	425	46,087	7,574	543
87	41,438	6,872	437	46,390	7,682	548
88	42,130	6,882	482	47,087	7,709	611
89	40,741	6,788	549	45,582	7,656	688
90	39,836	6,697	462	44,599	7,530	586
91	36,937	6,021	404	41,508	6,724	509
92	34,928	6,065	388	39,235	6,888	489
TOTAL	733,068	130,656	9,526	824,846	146,824	11,956

Exhibit A-2. Fatal Crashes by Month

MONTH	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
JAN	48,794	8,437	943
FEB	46,046	8,190	833
MAR	54,069	9,487	768
APR	56,591	9,947	676
MAY	63,756	11,486	718
JUN	66,173	12,066	677
JUL	70,290	12,282	740
AUG	71,422	12,585	728
SEP	65,883	11,940	739
OCT	66,968	12,407	879
NOV	61,048	10,899	865
DEC	62,024	10,930	960
TOTAL	733,068	130,656	9,526

Exhibit A-3. Fatal Crashes by Day of Week

DAY OF WEEK	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
SUN	118,806	17,954	1,167
MON	83,382	16,254	1,199
TUE	81,860	16,561	1,257
WED	85,747	16,951	1,315
THU	92,957	17,841	1,369
FRI	120,921	22,381	1,603
SAT	149,321	22,714	1,616
UNKNOWN	74	0	0
TOTAL	733,068	130,656	9,526

Exhibit A-4. Fatal Crashes by Time of Day

HOUR	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
12AM -3	122,494	13,843	1,014
3AM-6	54,575	4,834	455
6AM-9	54,944	11,218	1,178
9AM-NOON	58,625	15,329	1,404
NOON-3	79,419	19,755	1,437
3PM-6	113,562	25,173	1,573
6PM-9	121,408	22,081	1,312
9PM-12	124,120	18,227	1,143
UNKNOWN	4,921	196	10
TOTAL	733,068	130,656	9,526

Exhibit A-5. Fatal Crashes by Light Condition

LIGHT CONDITION	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
Dawn/Dusk	29,024	4,974	381
Dark but Lighted	126,237	30,365	1,365
Dark	260,086	21,129	2,162
Daylight	314,199	73,724	5,590
Unknown	3,522	464	28
TOTAL	733,068	130,656	9,526

Exhibit A-6a. Fatal Crashes by Traffic Control Device

TRAFFIC CONTROL DEVICE 1975-1981	RAIL CROSSING FATAL CRASHES
No Controls	375
Yield Sign	1
Man Control RRX	1,377
Stop Sign RRX	888
Other RR Xing	1,898
Not Functioning	37
Unknown	74
TOTAL	4,650

Exhibit A-6b. Fatal Crashes by Traffic Control Device

TRAFFIC CONTROL DEVICE 1982-1992	RAIL CROSSING FATAL CRASHES
No Controls	114
Gates	697
Flashing Lights	1,192
Traffic Control Signal	240
Wigwags	24
Bells	47
Other Train-Activated Device	25
Active Device, Type Unknown	168
Crossbucks	1,480
Stop Sign	346
Other RR Crossing Sign	352
Special Warning Device - watchman, flagman	17
Other Passive Device	20
Passive Device, Type Unknown	51
RR Grade Crossing, type unknown	73
Unknown	28
TOTAL	4,874

Exhibit A-7. Fatal Crashes by Speed Limit

SPEED LIMIT	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
20 mph or less	4,011	728	186
25 or 30 mph	95,743	26,759	2,521
35 or 40 mph	124,142	31,264	1,553
45 or 50 mph	107,504	21,924	925
55 mph	332,702	38,477	2,972
60 or 65 mph	11,610	26	4
Other/Unknown	57,356	11,478	1,365
TOTAL	733,068	130,656	9,526

Exhibit A-8. Fatal Crashes by Land Use

LAND USE	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
URBAN	207,086	63,921	1,970
RURAL	268,398	12,652	3,390
UNKNOWN	1,507	4,704	35
MISSING	256,077	49,379	4,131
TOTAL	733,068	130,656	9,526

Exhibit A-9. Fatal Crashes by Roadway Function Class

ROAD FUNCTION CLASS	ALL FATAL CRASHES	FATAL INTERSECTION CRASHES	RAIL CROSSING FATAL CRASHES
RURAL Principal Arterial - Interstate	24,682	148	3
RURAL Other Principal Arterial	54,038	8,730	111
RURAL Minor Arterial	52,864	7,677	175
RURAL Major Collector	70,769	9,750	691
RURAL Minor Collector	18,577	2,149	301
RURAL Local Road or Street	45,922	4,704	2,076
Unknown RURAL	1,546	210	33
URBAN Principal Arterial - Interstate	22,347	336	4
URBAN Princ Art - Oth Frways/Exp	18,230	2,705	29
URBAN Other Principal Arterial	63,039	18,810	238
URBAN Minor Arterial	46,074	12,681	554
URBAN Collector	18,701	4,408	296
URBAN Local Road or Street	37,744	8,446	834
Unknown URBAN	951	232	15
Unknown	1,507	291	35
Missing	256,077	49,379	4,131
TOTAL	733,068	130,656	9,526

Exhibit A-10. Vehicles In Fatal Crashes by Vehicle Type

BODY TYPE	ALL VEHICLES IN FATAL CRASHES	VEHICLES IN FATAL INTERSECTION CRASHES	VEHICLES IN RAIL CROSSING FATAL CRASHES
Buses	5,653	877	51
Heavy Trucks	45,915	6,001	261
Light Trucks and Vans	223,763	27,923	2,392
Medium Trucks	7,284	1,127	64
Motorcycles	44,510	6,871	118
Passenger Cars	649,519	86,072	6,000
Other	77,630	11,526	660
Unknown	13,269	1,285	78
TOTAL	1,067,543	141,682	9,624

Exhibit A-11. Drivers In Fatal Crashes by Driver Age

DRIVER AGE	ALL DRIVERS IN FATAL CRASHES	DRIVERS IN FATAL INTERSECTION CRASHES	DRIVERS IN RAIL CROSSING FATAL CRASHES
<16	8,440	845	74
16-20	190,686	17,909	1,769
21-24	159,513	15,140	1,258
25-34	273,676	27,239	2,268
35-44	157,485	16,279	1,242
45-54	100,982	11,042	1,019
55-64	74,350	9,035	848
65-74	48,719	6,859	616
>74	45,709	6,562	437
TOTAL	1,059,560	110,910	9,531

Exhibit A-12. Drivers In Fatal Crashes by Driver Sex

DRIVER SEX	ALL DRIVERS IN FATAL CRASHES	DRIVERS IN FATAL INTERSECTION CRASHES	DRIVERS IN RAIL CROSSING FATAL CRASHES
Female	215,307	24,687	7,388
Male	833,983	85,353	2,138
Unknown	10,270	870	5
TOTAL	1,059,560	110,910	9,531

Appendix B - Claritas Social Group Definitions

The following Social Group definitions are published in the Claritas, Inc., 1994 user's manual.

Rustic Living (R3) :

Twenty percent of rail crossing crash drivers reside in the area classified as Rustic Living (R3). This Social Group constitutes only 8 percent of the U.S. population. Claritas describes the households of Social Group R3 as residing in thousands of remote country towns, villages, hamlets, and reservations scattered across the U.S. With two Clusters in the 8th, two in the 9th, and one in the 10th affluence deciles, they are neither affluent nor destitute. In fact, as three R3 Clusters lower-middle incomes, and their cost of living is minimal, they are a promising market. As a Group, they share marriage, plus many elders, mobile homes, kids, carpools, craftsmen and laborers in agriculture, mining, transport, and construction.

Country Families (R1) :

Fourteen percent of drivers involved in fatal rail crossing crashes fall into the Country Families (R1) group. In the U.S., 6 percent of households constitute the R1 group. Claritas describes the households of Social Group R1 as confirming a continuing trend to strong economic growth in rural America. For with two Clusters in the 4th, on in the 6th, and one in the 8th affluence deciles, Group R1 now rival Groups S3, U2, C2 & T2 in midscale affluence and, with far lower living costs, suffer less poverty. Collecting hundreds of small towns and remote exurbs, the Group covers all but a few TV markets. They are largely composed of white, married couples, many with children, in industrial and agrarian occupations, living in owned houses and mobile homes.

Working Towns (T3) :

As Claritas defines, the households of Social Group T3 collect thousands of remote exurbs and satellite towns, lying well outside our major metros and second cities, and in all but four TV Markets. With one Cluster in the 6th, one in the 8th, and two in the 9th affluence deciles, T3 is considerable better off than Groups U3 and C3 in affluence. As a Group, these clusters share lower educations and incomes, with predominant blue-collar occupations, an equal mix of owned and rented single-unit houses, religion, home crafts, and a lot of awesome scenery. Otherwise, they are distinctly different.

Exurban Blues (T2) :

As Claritas defines, the households of Social Group T2 cover the midscale, low-density towns lying at the outskirts of all major metros and second cities alike, thus the Group is represented in all but three small TV markets. With one cluster each in the 4th and 5th, two in the 6th, and one in the 7th affluence deciles, Group T2 is comparable to Groups S3, U2, and C2. Three of these

Clusters are predominantly white, show an even age distribution, own homes, marry and raise kids. The fourth defines lifestyles in military group quarters, and is unique.

Heartlanders (R2) :

As Claritas defines, the households of Social Group R2 describe the nation's agrarian heartland, broadly centered in the Great Plains, South Central, Mountains and Pacific, with a few pockets East. With one Cluster each in the 8th and 10th affluence deciles, the Group is hardly the jet set. But as they are comparatively self-sufficient, with a low cost of living, they are not deprived. As a Group, they share large, multi-generation families, long residential tenure in low density houses and mobile homes, a mix of Hispanics and Native Americans, and a fierce independence.

2nd City Centers (C2):

Claritas defines the five Clusters of Social Group C2 as the midscale, middle-density "edge" cities surrounding major metros as well as the suburbs of most second cities, and cover all but 10 minor agrarian TV markets in the U.S. With one Cluster in the 4th, two in the 5th, and one in the 6th and 7th affluence deciles, and with a lower cost of living, the C2 Clusters are generally better off than their peers in the U Groups Also, with minor exceptions, they are predominantly white. Otherwise, they are fundamentally different in age, marriage, education, occupations, and lifestyle.

2nd City Blues (C3):

Claritas defines the four Clusters of Social Group C3 as covering the downtown neighborhoods of hundreds of second cities and edge cities on the fringes of major metros. With one Cluster in the 8th, one in the 9th, two in the 10th affluence deciles, and with lower costs of living, these Clusters are better off than their big-city cousins in Group U3. Coupled with pockets of unemployment, broken homes, and solo parents, we also see a wide range of occupations, including clerical, retail , labor, transportation, agrarian, public and private services.

The Affluentials (S2):

The five Clusters of Social Group S2 represent the upper-middle income suburbs of major metros. Almost 77 percent of its total households are concentrated in the Top 25 TV Markets, with 90 percent in the Top 50. With one Cluster each in the 2nd and 3rd, two in the 4th, and one in the 5th affluence deciles, S2 is the fifth most affluent Group. As a Group, these Clusters share above average incomes and rentals, and eclectic mix of homes, condos, and apartments, a broad spectrum of business, technical, and public service jobs, daily commuting...and very little else.

Landed Gentry (T1):

The four Clusters of Social Group T1 cover a vast amount of American geography, being found in 180 TV markets covering 86 percent of U.S. Population. With one Cluster in the 1st, one in the 2nd, and two in the 3rd affluence deciles, T1 is the fourth affluent Group. As a Group, they all show large, multi-income families of school-aged kids, headed by well-educated executives, professionals, and techies. Above all, they share serenity, for T1 neighborhoods lie far outside the metro beltways, many in the nation's most spectacular coastal areas and uplands.

Inner Suburbs (S3):

The four Clusters of Social Group S3, comprise the middle income suburbs of major metros, concentrated 59 percent in the Top 25, 84 percent in the Top 50, and 95 percent in the top 75 TV Markets. With two Clusters at the bottom of the 5th and two at the top of the 7th affluence deciles, S3 straddles the U.S. average. Otherwise they are markedly different, two having more college-educated white collars, two with more high-school-educated blue collars, two young, one old, one mixed, and all showing distinct, variant patterns of employment, lifestyle, and regional concentrations.

Elite Suburbs (S1):

The five Clusters of Group S1 all rank in the 1st and 2nd deciles of claritas' education and affluence scale, making this the nations's most affluent Social Group. Group S1 is concentrated in the Top 25 TV Markets. As a Group, S1 Clusters share high income, education, investment, and spending levels. Also, with Group U1 and U2, and despite low incidence levels, they now share high concentrations of wealthy Asian and Arabic immigrants. Beyond these shared patterns, they are very different.

2nd City Society (C1):

The three Clusters of Social Group C1 comprise the upper deck in hundreds of America's "second" and "edge" cities. As a Group, they share high educations and incomes, having one Cluster in the 2nd, and two in the 3rd affluence deciles. They also share high home ownership, employment as executives and professionals in essential local industries, such as business, finance, health, law, communications, and wholesale. They are far more conservative than their upscale peers in the suburbs of major metros.

Urban Midscale (U2):

The five Clusters of Social Group U2 collect the middle income, urban-fringe neighborhoods of America's major metros. As with Group U1, Group U2 is highly concentrated, with 75 percent of total households in the Top 5 TV Markets, and 96 percent in the Top 25. With one cluster in the 4th, two in the 6th, and two in the 7th affluence deciles, Group U2 averages below the mean. As a Group, the U2 Clusters share high population densities, ethnic diversity, public transportation, and all the perks and risks of urban life, yet are otherwise unique.

Urban Cores (U3):

The three Clusters of Social Group U3 are also highly concentrated with over 60 percent of total households in the Top 25 TV Markets, over 99 percent in the Top 50. With one Cluster in the 9th, and two in the 10th affluence deciles, with the nation's lowest incomes, and highest poverty rations, U3 is the least affluent Group. Together, these Clusters share multi-racial, multi-lingual communities of dense, rented row and high-rise apartments, show high indices for singles, solo parents with pre-school children and perennial unemployment.

Urban Uptown (U1):

With three of its five Clusters in the 1st affluence decile plus two in the 3rd decile, Group U1 ranks as the nation's second most affluent Social Group. Major market concentrations are extreme, with over 94 percent of total Group households in the Top 10 TV Markets. Consistent for over two decades, these Clusters show high concentrations of executives and professionals in the fields of business, finance, entertainment, and education. More recently, they have absorbed a wave of upscale immigrants from Eastern Europe, Asia, and the Middle East.

Exhibit B-1. Percentage of Social Group Characteristics

	US	S1	S2	S3	U1	U2	U3	T1	T2	T3	R1	R2	R3	C1	C2	C3
EDUCATION																
4+ Yrs College	20.6	40.6	24.9	16.3	40.4	17.6	10.3	29.4	16.6	11.6	14.1	10.2	9.2	33.0	24.8	9.6
1-3 Yrs College	24.9	28.3	30.0	27.5	25.7	24.3	19.1	29.0	26.8	21.1	24.0	21.1	18.2	29.4	27.6	21.2
HS Graduate	29.9	21.7	29.1	32.1	20.0	28.5	25.8	28.2	34.6	33.8	38.0	36.1	35.4	25.2	28.2	30.7
Less than HS	24.6	9.4	16.1	24.0	13.9	29.6	44.8	13.3	21.9	33.6	23.8	32.7	37.2	12.4	19.4	38.5
HH INCOME																
Less than $15	24.3	6.7	13.0	22.8	14.7	22.8	47.5	10.0	20.0	36.6	19.5	32.8	37.1	12.2	26.1	44.6
$15 - $34,000	33.4	17.6	31.4	40.2	26.9	36.0	33.4	23.9	37.8	38.0	36.2	40.0	38.2	26.8	37.1	36.7
$35 - $74,999	32.8	44.4	44.7	32.4	38.3	34.1	16.8	46.9	36.2	22.5	38.0	23.5	22.0	42.4	31.0	17.0
$75,000 +	9.5	31.3	10.8	4.5	20.1	6.9	2.3	19.3	6.0	2.9	6.4	3.7	2.6	18.7	5.7	1.8
Median HH Inc	$31.9	$59.0	$38.3	$28.1	$43.1	$29.9	$16.3	$47.4	$30.9	$20.9	$32.1	$22.7	$20.7	$43.9	$27.5	$17.2
FAMILY TYPE																
Married Couples	55.2	69.0	57.8	49.1	43.5	45.8	29.8	70.5	64.3	52.9	68.4	65.9	61.3	62.1	47.8	38.4
Marrd w/Chldrn	26.7	34.0	28.1	23.3	18.2	22.6	15.7	36.7	33.3	24.6	34.6	32.3	29.5	26.5	21.8	18.5
Single Parents	9.3	5.1	7.7	10.7	5.5	12.0	21.4	5.7	7.8	10.9	6.6	6.6	8.9	5.2	8.6	16.6
S. Female Head	11.6	7.5	10.2	13.2	8.8	15.7	25.4	7.0	9.1	13.2	7.4	7.3	10.6	7.3	10.8	19.8
OCCUPATION																
Prof/ Manager	25.8	42.0	29.9	22.5	42.0	23.4	16.9	33.8	23.5	19.3	20.4	15.3	16.8	36.8	27.4	16.1
White-Collar	31.4	35.3	36.4	34.8	34.1	34.3	29.9	33.0	31.4	27.9	27.3	21.2	24.1	35.5	33.9	28.6
Blue-Collar	26.6	15.3	23.5	29.3	15.1	28.5	31.9	23.2	31.7	36.0	36.9	31.6	41.6	18.0	24.7	34.0
Service	13.7	8.1	11.1	14.2	9.9	15.1	22.6	9.8	13.2	16.4	12.4	13.0	14.1	10.3	14.4	21.3
Farm/Ranch/Mi	2.5	0.6	0.9	1.1	0.5	0.9	1.2	1.7	1.9	2.2	4.4	19.9	5.0	1.2	1.3	1.9
RACE																
White	80.1	88.3	85.3	78.0	78.0	60.2	33.2	93.9	90.8	83.3	94.8	87.6	86.6	91.4	84.9	60.7
Black	10.6	3.2	6.4	11.9	8.3	18.0	41.7	2.4	4.9	10.7	2.8	3.1	9.5	2.7	7.4	27.2
Asian (API)	2.1	4.6	2.4	1.7	6.0	5.2	3.3	1.2	0.8	0.3	0.2	0.6	0.1	2.1	2.2	1.1
Hispanic	6.5	3.6	5.6	8.0	7.4	16.2	21.2	2.0	2.9	4.6	1.4	7.3	1.9	3.4	4.9	10.3
Foreign Born	7.7	9.6	8.0	7.6	17.1	21.3	17.7	3.8	2.7	2.5	1.6	4.3	1.0	7.7	6.0	6.1
HH TYPE																
1 Person	24.6	16.3	22.9	27.5	35.2	26.9	33.2	15.8	19.8	27.0	17.7	21.1	22.5	23.3	29.0	32.0
4+ Persons	26.0	31.4	26.0	23.2	18.5	26.9	27.2	31.8	28.6	23.6	30.1	29.6	26.5	23.3	20.9	23.6
HH w/Children	36.0	39.1	35.8	34.0	23.7	34.6	37.2	42.4	41.2	35.5	41.2	38.9	38.4	31.7	30.5	35.1

Exhibit B-2. Percentage of Top 10 Magazine Usage for Fatal Crash Involved Drivers

	Fatal Rail Crossing Crash Drivers	All Fatal Crash Drivers except Rail Crossing	US Population (greater than 15 years)
Field & Stream	65	53	31
Outdoor Life	65	53	31
Sports Afield	64	53	34
Hunting	56	45	28
Country Living	52	45	23
Guns & Ammo	49	43	26
Organic Gardening	45	34	23
True Story	39	33	22
Hot Rod	38	32	21
National Enquirer	33	27	16
Southern Living	33	27	16
Baby Talk	29	24	18
Car Craft	26	25	14
Yankee	19	18	12
Soap Opera Digest	19	14	14
Family Handyman	14	14	13
Seventeen	13	8	8
Inc:	13	14	15
Self	12	12	16
Sunset	11	13	18
Stereo Review	11	11	8
Audubon	10	13	16
Elle	10	12	17
Cosmopolitan	10	12	17
Ebony	9	14	19
Good Housekeeping	9	8	3
Barron's	9	14	19
Cycle World	9	8	3

Ntl Geographic Trvlr	9	11	17
Golf Magazine	9	7	6
Ladies Home Jrnl	9	7	6
US	9	11	17
Essence	9	14	19
Jet	9	14	19
Esquire	9	14	19
Skiing	8	7	9
Rolling Stone	8	7	9
Ski	8	7	9
Fortune	8	14	18
Omni	8	7	9
Travel & Leisure	7	11	14
Financial World	7	10	11
Consumer Digest	6	8	12
New York	5	12	20
Money	5	7	6
Popular Photography	5	6	10
Sporting News	5	6	10
Sport	5	8	12
Architectural Digest	5	10	17
Colonial Homes	5	7	6
Boating	5	7	6
Working Woman	5	6	10
Working Mother	5	6	10
Smithsonian	5	6	10
Home Mechanix	5	6	10
Inside Sports	5	8	12
Tennis	4	7	13
Mademoiselle	4	11	17
Business Week	4	7	13

American Health	4	5	7
Forbes	4	7	13
Weight Watchers	4	5	7
New Woman	4	5	7
Popular Mechanics	4	5	7
New Yorker	3	7	12
Scientific American	3	7	12
GQ	3	8	13
Vogue	2	5	8
Golf Digest	2	3	5
Food & Wine	1	3	4
Harper's Bazaar	1	3	4
Home	1	3	5
The Star	1	3	5
Shape	1	3	4

Exhibit B-3. Percentage of Top 10 Media Usage for Fatal Crash Involved Drivers

	Fatal Rail Crossing Drivers	All Fatal Crash Drivers except Rail Crossing	US Population (greater than 15 years)
Watch The Family Channel	56	46	25
Fish & Hunt Mags	52	45	23
Country: Radio	51	42	25
TV Quiz& Aud Participate	39	32	22
TV Wrestling	39	32	22
Watch WGN-TV	36	27	17
Watch WPIX-TV	34	40	43
Watch TBS	34	30	14
MOR/Nostalgia: Radio	30	28	24
Bottom 20 percent Nwsppr Reading	29	27	11
Bottom 20 percent For Outdoor	29	26	14
Watch Showtime	22	25	29
Watch ACTS	21	15	17
Radio College Football	20	19	8
Bottom 20 percent Mag Reading	20	19	8
Watch Nickelodeon	20	16	12
Watch Disney Channel	19	17	16
Top 20 percent Daytime TV Viewing	19	13	14
Top 20 percent All Day TV Viewing	19	13	14
Jazz: Radio	18	29	40
Variety: Radio	18	20	25
TV Boxing	17	13	15
Classical: Radio	17	21	28
Watch Comedy Central	17	19	22
TV Auto Racing	15	12	12

Watch The Learning Channel	14	11	6
Watch BET	14	19	29
Spanish/Ethnic: Radio	13	19	20
TV Daytime Drama	13	8	8
Mechanics Mags Net	13	12	13
TV Bowling	13	12	13
Epicurean Mags Net Aud	13	17	26
AQR/Progress Rck: Radio Aud	12	12	16
Men's Magazines Net Aud	12	12	16
Science/Tech Mags Net Aud	11	14	21
Religious Radio	10	10	13
TV Feature Film	9	8	3
Golden Oldies: Radio	9	7	6
Bottom 20 percent for Outdoor	9	8	3
Bottom 20 percent Daytime TV View	9	7	6
Watch Cinemax	9	8	3
TV Horse Racing	9	7	6
Bus & Finance Mags Net	9	14	19
Urban Contemp:Radio	9	13	19
Watch C-Span	8	7	9
News/Talk: Radio	8	13	22
Watch VH-1	8	7	9
All News Radio: Radio	8	18	30
TV Golf	7	10	18
Watch Movie Channel	7	11	18
Watch CNBC	7	10	11
Top 20 percent Newspaper Reading	7	10	11
Read Bus/Finance Nwspr	7	10	18
TV 1am-2am M-F	6	5	6

Top 20 percent Magazine Reading	5	7	6
Easy Listening: Radio	5	7	6
Radio Pro Football	4	7	13
Radio Midnight -6am M-F	4	5	7
Watch WWOR-TV	4	11	17
Sports Magazines Net Aud	4	5	7
Watch HBO	3	8	13
Radio Baseball	2	3	5
TV Tennis	2	3	5
Women Fashion Mags Net Aud	1	3	4
Read TV/Radio Listing Nwspr	1	3	5
Contemp/Soft Rck: Radio	1	3	4

Exhibit B-4. Percentage of Top 10 Lifestyle Activities for Fatal Crash Involved Drivers

	Fatal Rail Crossing Drivers	All Fatal Crash Drivers except Rail Crossing	US Population (greater than 15 years)
Use Chewing Tobacco	62	51	31
Go Hunting	52	45	23
Eat at Ice Cream Rest	42	35	19
Gospel Music	40	35	27
Eat at Seafood Rest	39	32	22
Use Pest Control Svcs	36	33	19
Belong to a Country Club	29	27	11
Snowmobiling	28	26	15
Use Pipe Tobacco	28	21	17
Comedy Records/Tapes	24	21	26
Do Woodworking	23	18	12
Smoke Non-Filter Cigarettes	23	18	21
Go Fresh Water Fishing	23	18	12
Belong to Veterans Club	22	16	11
Sewing Patterns	20	19	8
Country Music	20	19	8
Use Termite Control Svcs	20	19	8
Use Cigars	20	16	19
Ride Motorcycles	20	16	12
Traveled by Rented Car	15	17	20
Stitch Needlework	14	11	6
Cross Country Skiing	14	14	12
Belong to a Union	14	11	6
Belong to a Religious Club	14	14	13
Bowled 20+ Times LstYr	14	11	6
Belong to a Health Club	13	12	13
Karate/Martial Arts	13	13	19
Worked as Political Voluntr	13	8	8

Snorkeling/Skin Diving	10	13	16
Western Europe Lst 3 Yrs	10	17	23
New Wave Rock Music	10	10	14
Go Overnight Camping	9	7	6
Use Trvl Agnt for forgn Trp	9	14	19
Visit Europe Lst 3 Yrs	9	14	19
Rodeo Fans	9	7	6
Belong to a Business Club	9	8	3
Drive Car Leased Employer	9	11	17
Stamp Collecting	9	8	3
Truck Racing/Pulls Fans	9	7	6
Contemporary Christian	9	7	6
Brdway Cast/Soundtrck Music	9	11	17
Soul/R&B/Black Music	9	13	19
Belong to a Fraternal Order	9	7	6
Joggers/Runners	8	7	9
Go Hiking/Backpacking	8	7	9
Attend Rock/Pop Concerts	8	7	9
Aerobics	8	7	9
Water Skiers	8	7	9
Downhill Skiers	8	7	9
Do Weight Training	8	7	9
Eastern Europe Lst 3 Yrs	7	12	19
Mmbr Frequent Flyer Program	7	11	14
Drive Car Leased HH Mmbr	6	10	10
Traveled by Bus	6	9	15
Visit Sea World	6	10	15
Smoke Menthol Cigarettes	6	5	6
Traveled by Boat/Ship	5	6	10
Go Power Boating	5	7	6
1960's Rock Music	5	6	10

Wrote to Elected Official	5	6	10
1st/Bsnss Class Forgn Trip	5	12	20
Dance/Rap Music	5	8	12
3+ Domstc Busnss Trps Lst Yr	5	6	10
Japan,Asia,Other Lst 3 Yrs	5	12	20
Bought Science Fiction	4	5	7
Played Tennis 20+ Times LstYr	4	7	13
Traveled by Car w/Camp Equp	4	5	7
Traveled by Railroad	4	8	13
Trad/Contemp Jazz Music	3	8	12
Have a Passport	3	6	9
Eat at Pancake/Donut Rests	3	8	13
Contrib $50 + to Pub Brdcstn	3	6	9
4+ Movies Last 90 Days	2	6	9
Use Lawn Maintenance	2	4	8
Contrib to Public Brdcstng	2	4	8
Visit Disney Theme Parks	2	5	8
Play Lottery Weekly	2	5	8
$150+ Grocery Shopping Wkly	2	5	8
<$41 Grocery Shopping Wkly	1	3	5
Use Call Forwarding	1	3	5
Took 2+ Foreign trips	1	3	4

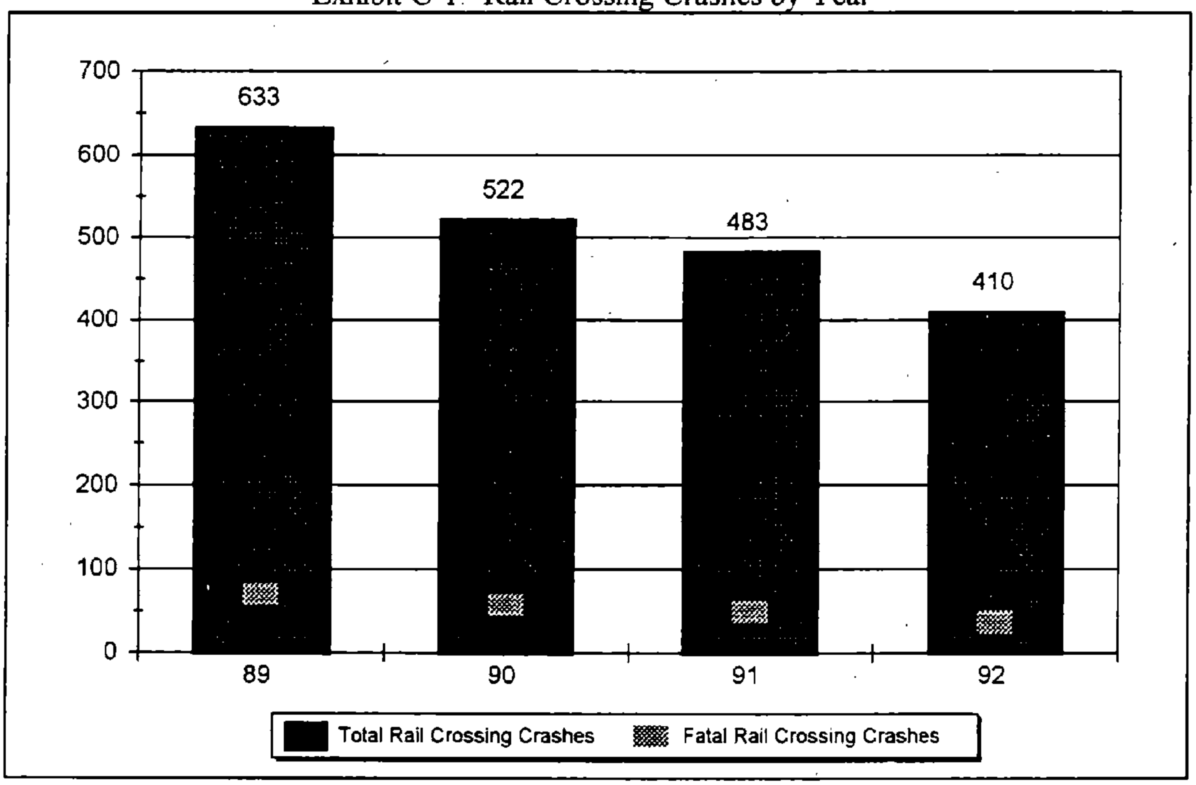
Appendix C - Texas State Data

The Texas state accident data files are a census of all police-reported motor vehicle crashes in the State of Texas. These crashes must occur on a public roadway and result in at least $250 worth of property damage or a personal injury. The data are collected by police on Police Accident Report (PAR) forms and then automated. NHTSA requests these file and creates Statistical Analysis System (SAS) files for analysis.

Texas state data files for calendar years 1989 through 1992 were used to characterize rail crossing crashes in the state. Crashes where the first harmful event was 'Collision of a motor vehicle with a RR Train' were defined as rail crossing crashes in Texas.

Exhibit C-1 shows the number of rail crossing crashes by year. The figure shows a decline in the number of rail crossing crashes and fatal rail crossing crashes over time. This pattern is identical to that observed for the entire country, based on the same time frame in FARS.

Exhibit C-1. Rail Crossing Crashes by Year*



*Source: Texas State Data 1989-1992

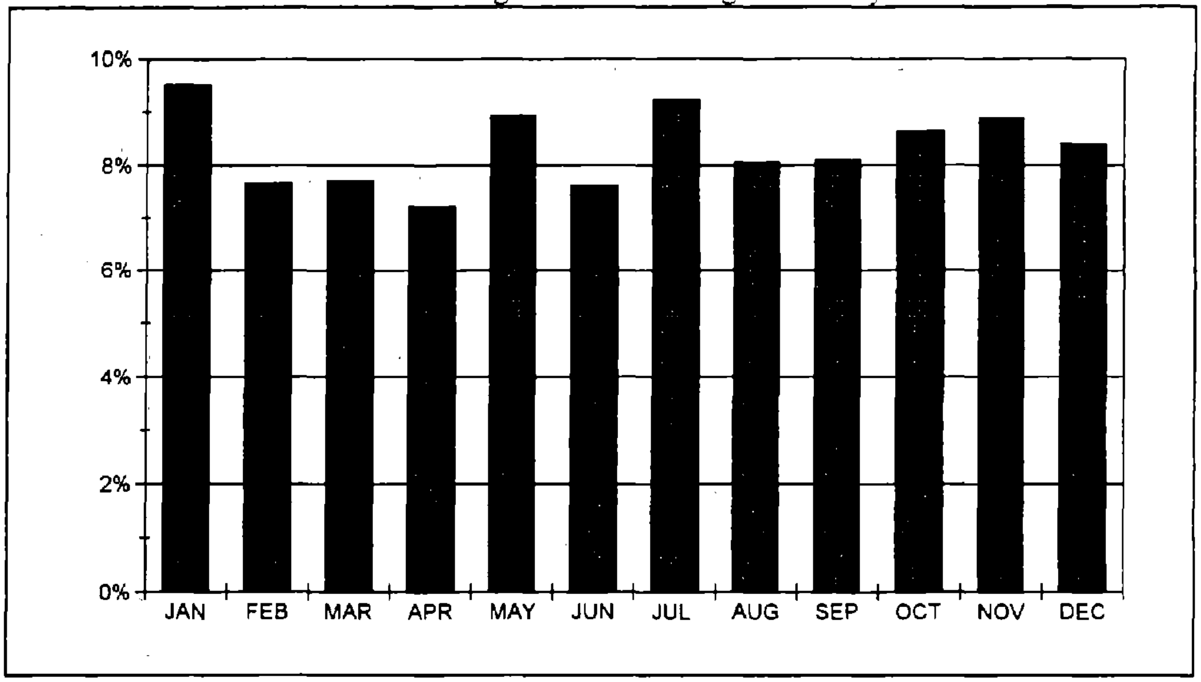
Exhibit C-2. Texas Rail Crossing Crashes by Year

Year	Rail Crossing Crashes	Fatal Rail Crossing Crashes
89	633	69
90	522	57
91	483	49
92	410	36
TOTAL	2,048	211

In 95 percent of these rail crossing crashes, the train was moving forward; in 3 percent, the train was moving backward; and in less than 2 percent of the crashes, the train was standing still.

The following figures show the percentage of rail crossing crashes for various factors.

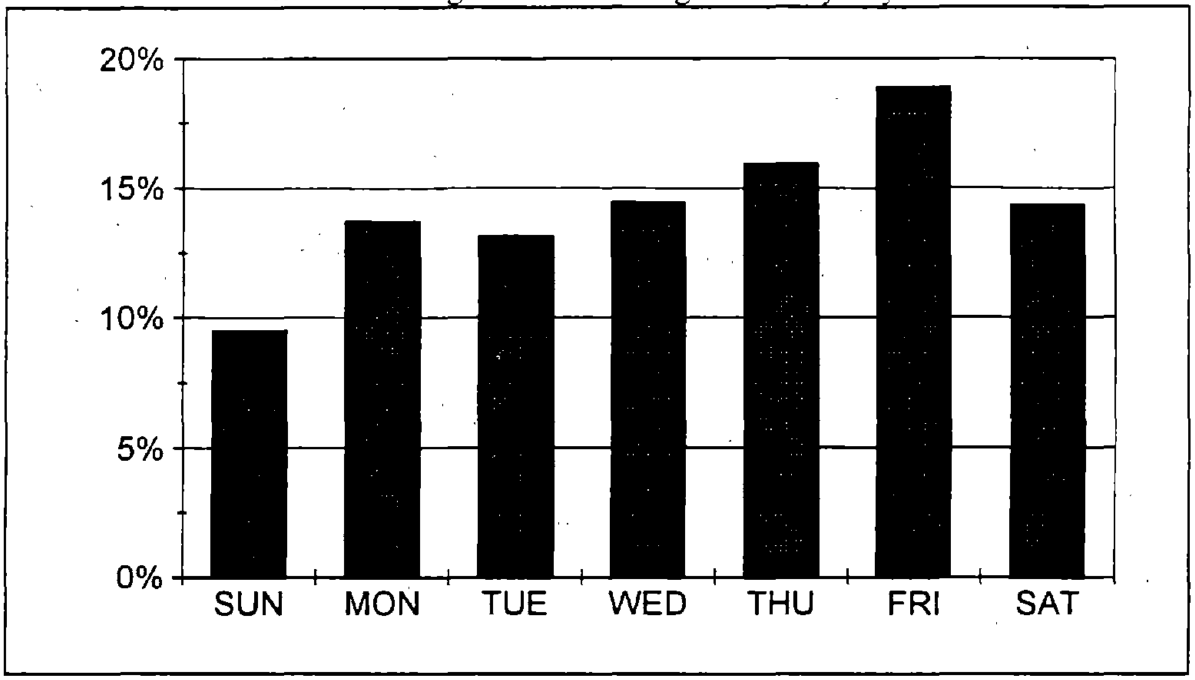
Exhibit C-3. Percentage of Rail Crossing Crashes by Month*



*Source: Texas State Data 1989-1992

Month	Rail Crossing Crashes
JAN	195
FEB	157
MAR	158
APR	148
MAY	183
JUN	156
JUL	189
AUG	165
SEP	166
OCT	177
NOV	182
DEC	172
TOTAL	2,048

Exhibit C-4. Percentage of Rail Crossing Crashes by Day of Week*

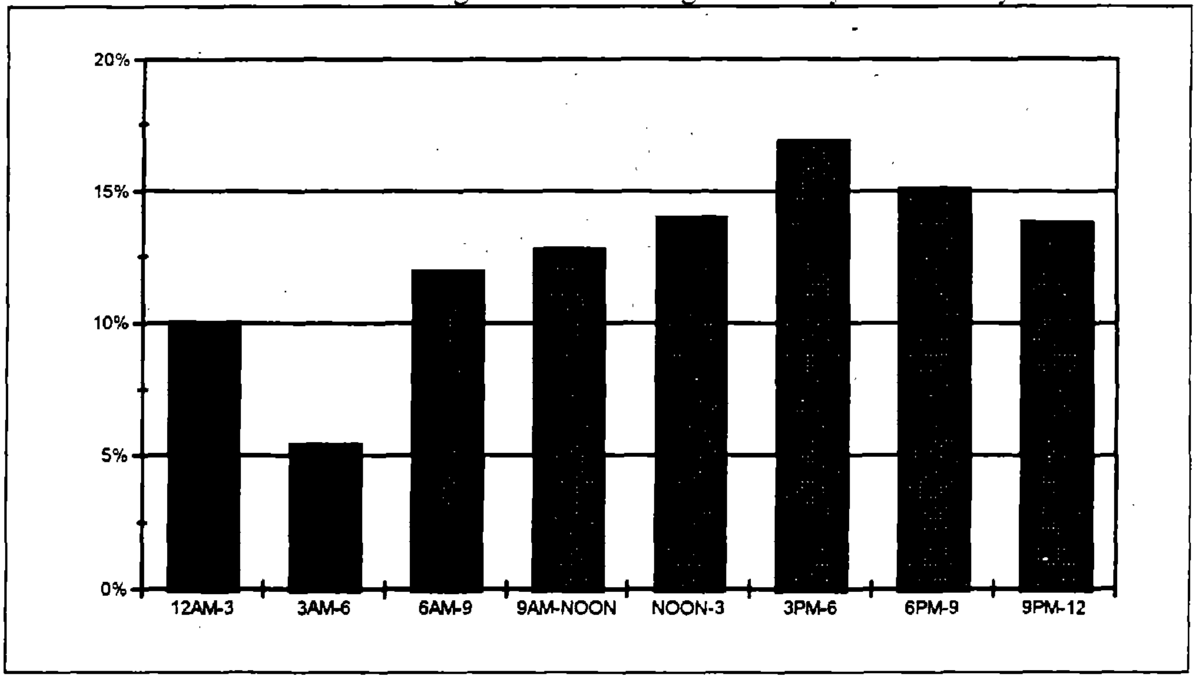


*Source: Texas State Data 1989-1992

Day of Week	Rail Crossing Crashes
SUN	195
MON	281
TUE	269
WED	296
THU	326
FRI	387
SAT	294
TOTAL	2,048

The pattern of daily rail crossing crash involvement in the State of Texas looks much like the national experience. That is, rail crossing crashes are lowest on Sundays, and increase fairly steadily during the week, reaching a peak during Friday and Saturday (although there appear to be fewer such crashes on Saturdays in Texas than the national experience indicates).

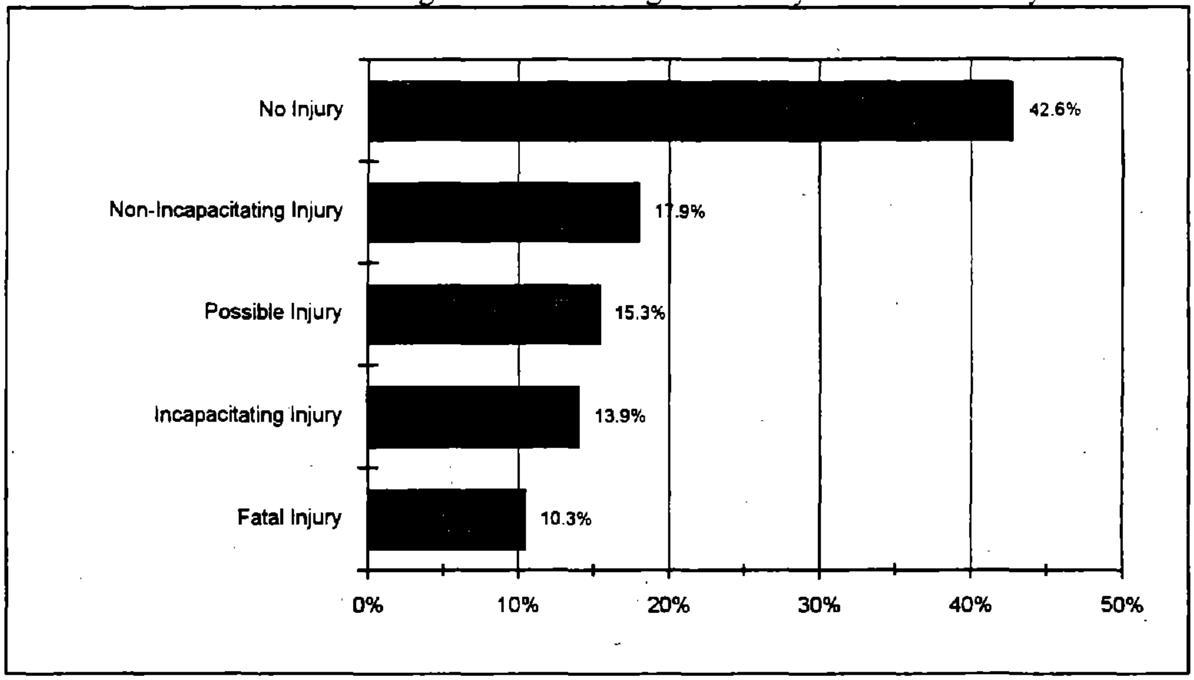
Exhibit C-5. Percentage of Rail Crossing Crashes by Time of Day*



*Source: Texas State Data 1989-1992

Time of Day	Rail Crossing Crashes
12AM-3	205
3AM-6	111
6AM-9	245
9AM-NOON	262
NOON-3	287
3PM-6	346
6PM-9	309
9PM-12	283
TOTAL	2,048

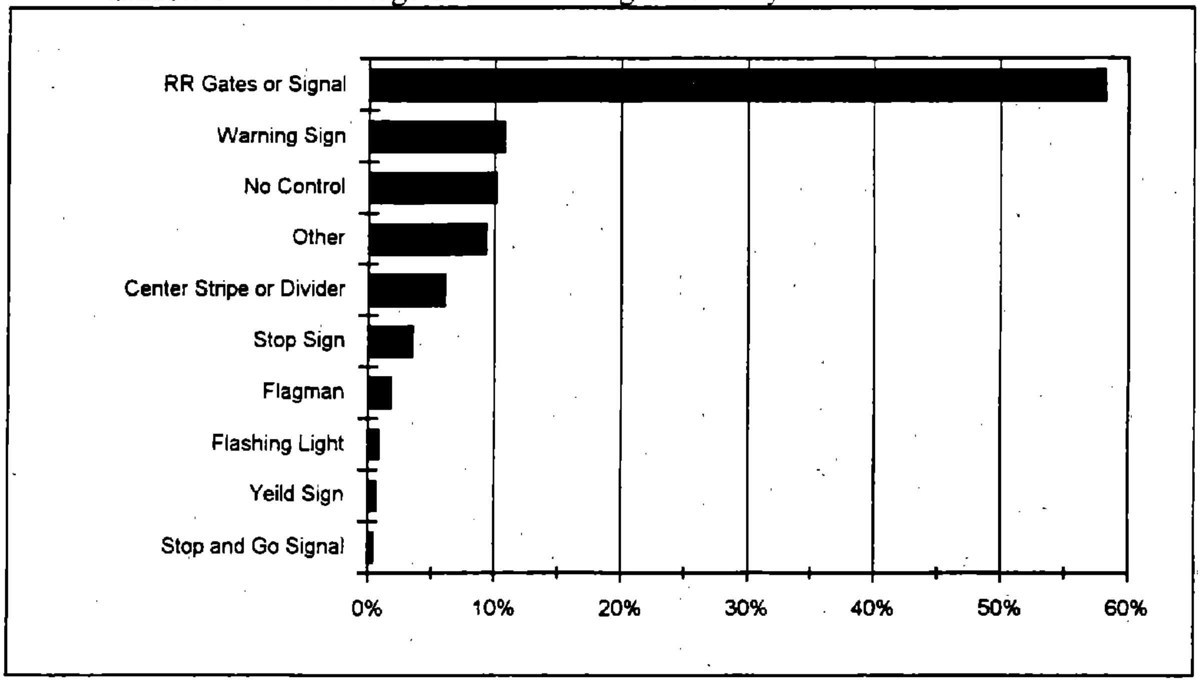
Exhibit C-6. Percentage of Rail Crossing Crashes by Accident Severity*



*Source: Texas State Data 1989-1992

Accident Severity	Rail Crossing Crashes
Fatal Injury	211
Incapacitating Injury	285
Possible Injury	313
Non-Incapacitating Injury	367
No Injury	872
TOTAL	2,048

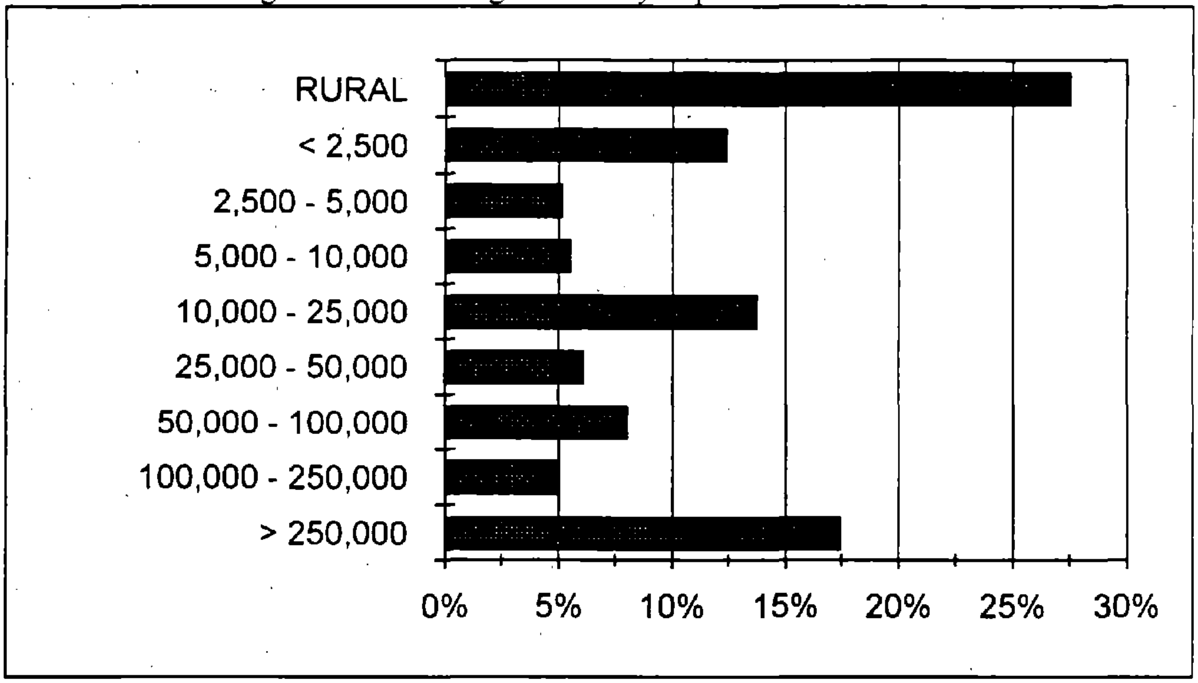
Exhibit C-7. Percentage of Rail Crossing Crashes by Traffic Control Device*



*Source: Texas State Data 1989-1992

Traffic Control Device	Rail Crossing Crashes
Stop and Go Signal	8
Yield Sign	9
Flashing Light	13
Flagman	33
Stop Sign	69
Center Stripe or Divider	120
Other	186
No Control	203
Warning Sign	216
RR Gates or Signal	1,187
Unknown	4
TOTAL	2,048

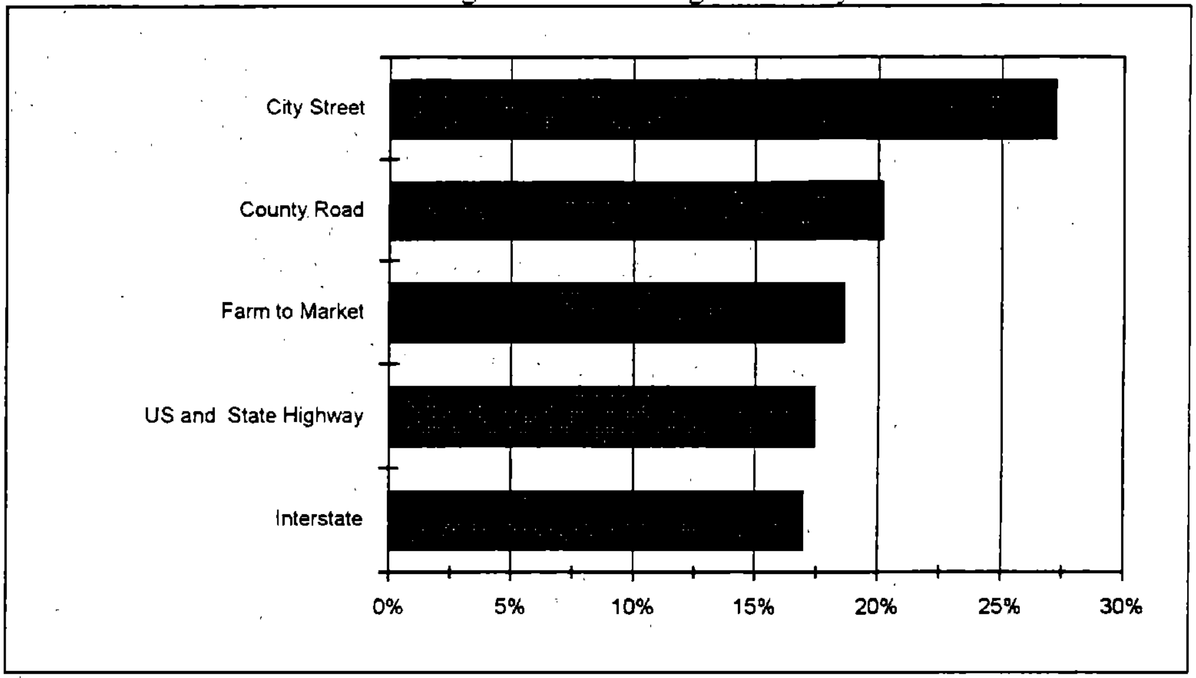
Exhibit C-8 Percentage of Rail Crossing Crashes by Population of Area Where Crash Occurred*



*Source: Texas State Data 1989-1992

Population of Area Where Crash Occurred	Rail Crossing Crashes
> 250,000	355
100,000 - 250,000	101
50,000 - 100,000	163
25,000 - 50,000	121
10,000 - 25,000	279
5,000 - 10,000	111
2,500 - 5,000	104
< 2,500	251
RURAL	563
TOTAL	2,048

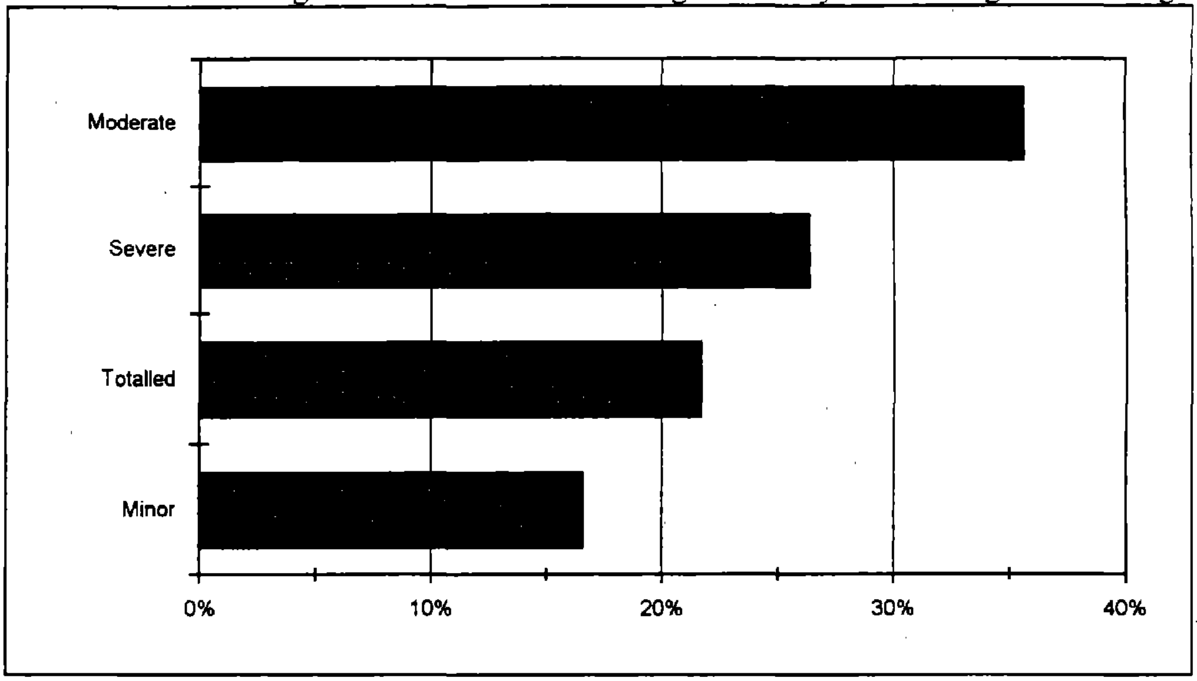
Exhibit C-9. Percentage of Rail Crossing Crashes by Road Class*



*Source: Texas State Data 1989-1992

Road Class	Rail Crossing Crashes
Interstate	101
US and State Highway	104
Farm to Market	111
County Road	121
City Street	163
Unknown	1,448
TOTAL	2,048

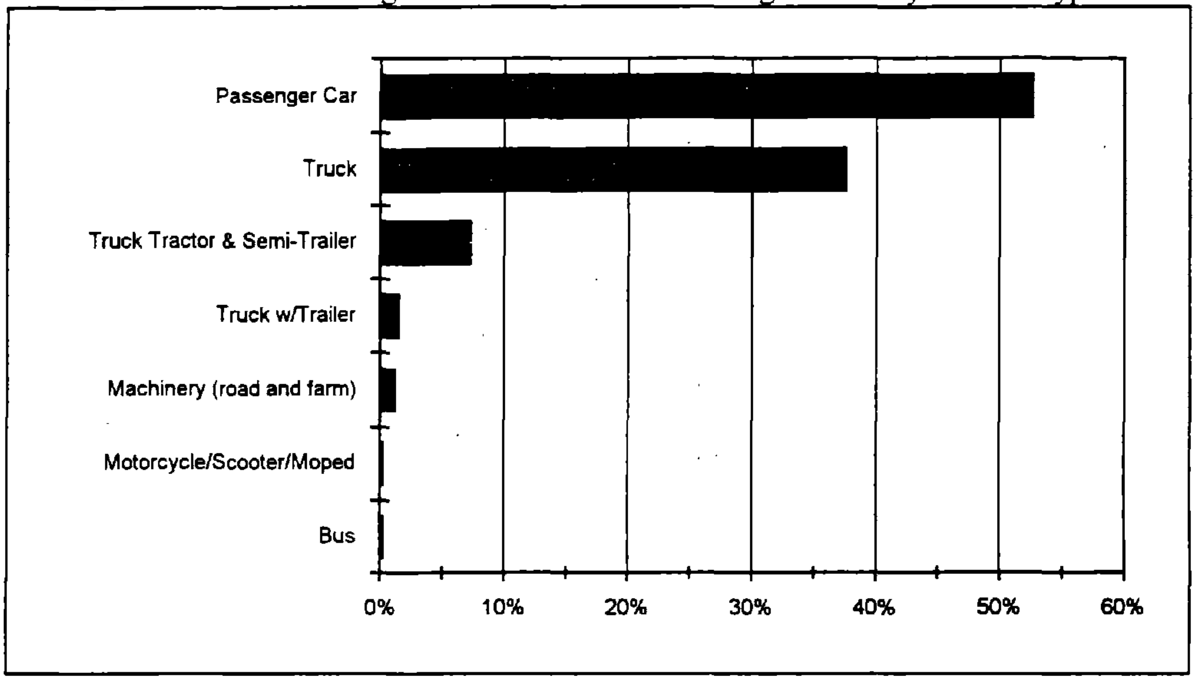
Exhibit C-10. Percentage of Vehicles In Rail Crossing Crashes by Vehicle Degree of Damage*



*Source: Texas State Data 1989-1992

Vehicle Degree of Damage	Rail Crossing Crashes
Minor	330
Totalled	432
Severe	525
Moderate	712
Unknown	4
Missing	74
TOTAL	2,077

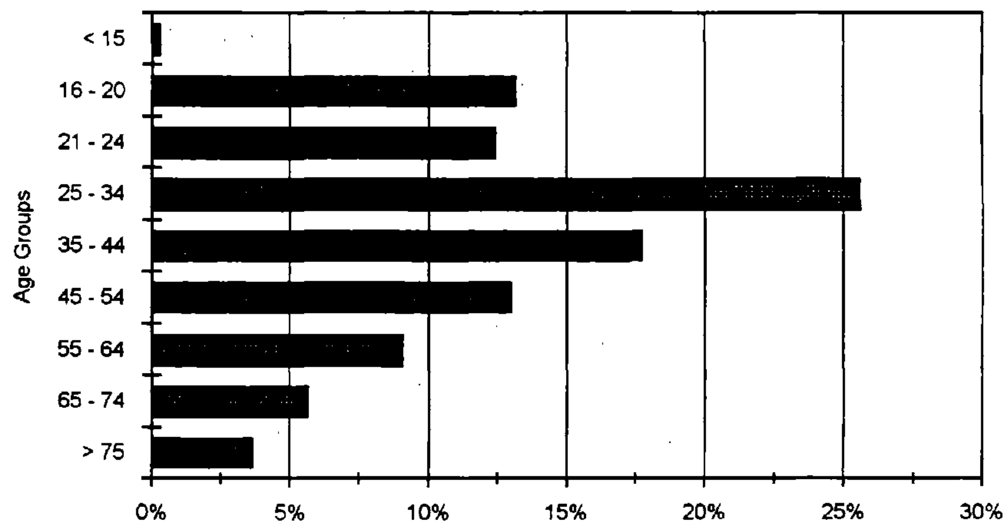
Exhibit C-11. Percentage of Vehicles In Rail Crossing Crashes by Vehicle Type*



*Source: Texas State Data 1989-1992

Vehicle Type	Rail Crossing Crashes
Bus	3
Motorcycle/Scooter/Moped	4
Machinery (road and farm)	19
Truck w/Trailer	30
Truck Tractor & Semi-Trailer	149
Truck	778
Passenger Car	1,090
Unknown	4
TOTAL	2,077

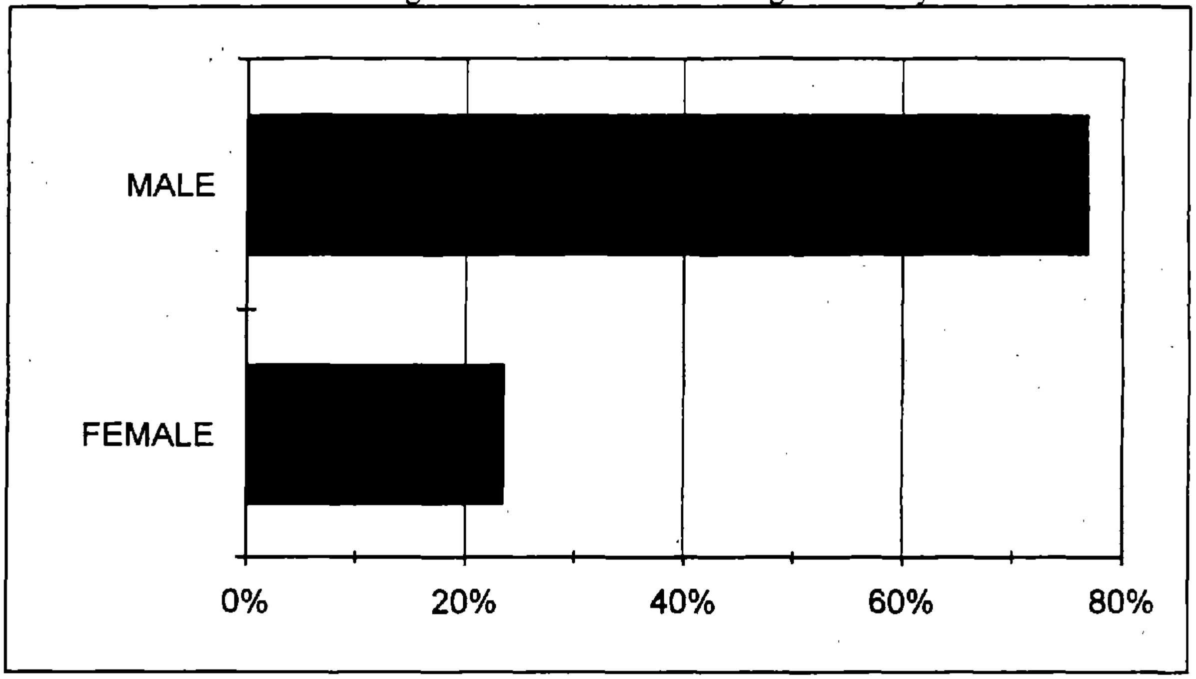
Exhibit C-12. Percentage of Drivers In Rail Crossing Crashes by Driver Age*



*Source: Texas State Data 1989-1992

Driver Age	Rail Crossing Crashes
> 75	69
65 - 74	106
55 - 64	173
45 - 54	247
35 - 44	337
25 - 34	489
21 - 24	237
16 - 20	250
< 15	4
Unknown	165
TOTAL	2,077

Exhibit C-13. Percentage of Drivers In Rail Crossing Crashes by Driver Sex*



*Source: Texas State Data 1989-1992

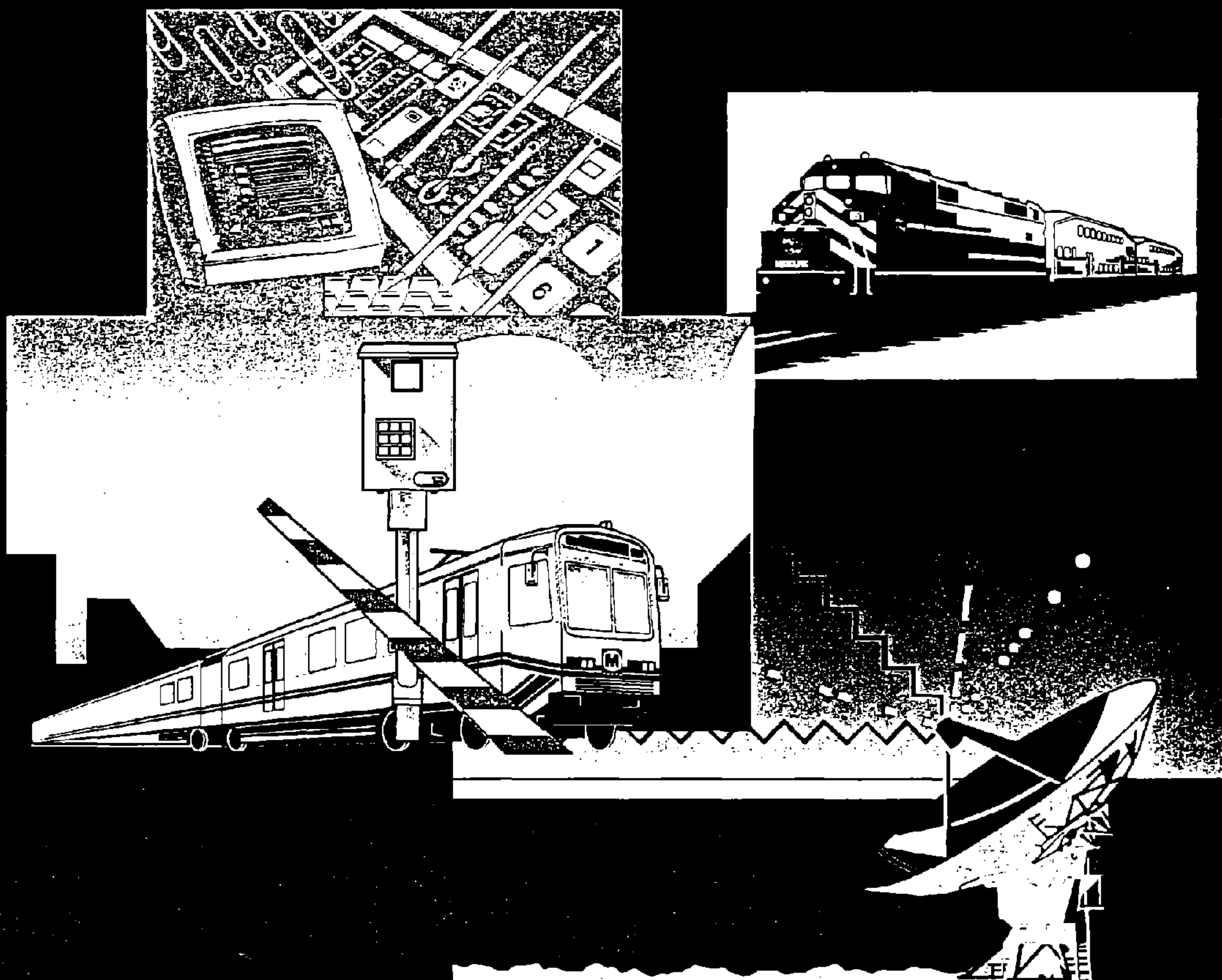
Driver Sex	Rail Crossing Crashes
Female	446
Male	1,474
Unknown	154
TOTAL	2,077

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

Highway - Railroad Grade Crossing Safety
Innovative Data Needs



Prepared by:
Linda Meadow
Systems Safety Manager
Metropolitan Transportation Authority
(213)-244-6419

METRO

HIGHWAY-RAILROAD GRADE CROSSING SAFETY INNOVATIVE DATA NEEDS

Introduction

The highway-railroad intersection has three primary users: trains, drivers of passenger/commercial vehicles and pedestrians/bicyclists. Understanding the behavior of each of the users of the intersection requires specific types of information.

Traditionally, transportation data has been collected by modes, in accordance with the organization of the U.S. Department of Transportation (DOT). For example, Federal Highway Administration (FHA) collects data on highway accidents; National Highway Traffic Safety Administration (NHTSA) analyzes driver and pedestrian behavior at highway intersections; Federal Railroad Administration (FRA) collects accident and inventory data concerning railroads and highway-railroad grade crossings; and the Federal Transit Administration (FTA) collects data concerning transit accidents.

However, DOT has recognized that the highway-railroad grade crossing is an intermodal issue. Therefore, existing modal data is not adequate to address the needs of this type of intersection.

This paper will address requirements for intermodal data and will also explore the use of innovative technologies to be used for data collection. Innovative data collection methods include the use of digitized video, radar, Global Positioning Satellites (GPS), high resolution cameras and cellular communications. The goal of data collection is ultimately to reduce accidents at highway-railroad grade crossings by providing traffic control devices and enforcement technologies that prevent collisions between trains, vehicles and pedestrians.

Required Types of Intermodal Highway-Railroad Grade Crossing Data

To get a complete understanding of the characteristics of the highway-railroad intersection, many different types of data are required including but not limited to the following:

- Inventory of all crossings
- Exposure data on vehicles, pedestrians, bicyclists
- Collision and incident data
- Law enforcement reports
- Risky behavior (near miss) data
- Train information (location, speed, direction of travel)

- Status of traffic control devices
- In-vehicle data
- Intrusion-detection of objects in the crossing.

Inventory of All Crossings

The FRA maintains a data base containing inventory information on all freight railroad and commuter railroad grade crossings. In addition, certain states, such as California, are requested to submit rail transit grade crossing inventory data to a regulatory agency such as the California Public Utilities Commission (CPUC)). However, there is no comprehensive rail transit grade crossing inventory data base.

To facilitate analysis of rail grade crossing incidents, one source of nationwide rail grade crossing inventory data is required. Geographical Information Systems (GIS) could be used to collect and display inventory data. GIS capabilities are widely available in today's marketplace. Use of GIS combines inventory data with demographic information.

Exposure

Exposure data includes daily traffic counts of all traffic within the highway-railroad intersection including number of trains, number of vehicles traveling on parallel roadways and cross streets, number of pedestrians and bicyclists who use the intersection. This data needs to be stratified by time of day, day of the week, vehicle type, direction of travel, traffic lane and any turning movements.

Many methods are available to obtain exposure data. Traffic engineers use manual traffic counters and/or inductive loops in the street to count vehicles. Some devices count numbers of vehicles performing certain types of movements, such as high resolution cameras used for photo enforcement. Traffic counts are also being made by devices (such as AUTOSCOPE) that digitize intersections through the use of video technology and interactive graphics software.

Capturing vehicle type is more difficult. One cumbersome way would be to access Department of Motor Vehicle records through matching license plate numbers. This information would determine whether the vehicles were private automobiles, trucks, buses, etc.

Collisions

The DOT currently collects many different types of accident data for differing modes of transportation. For example, the NHTSA's Fatal Accident Reporting System (FARS), collects data on fatal train vs. motor vehicle collisions. The FRA collects rail collision data through the Rail Accident Incident Reporting System (RAIRS). The FTA, as part of the SAMIS data base, collects data on rail transit collisions that involve a transit vehicle which results in death, injury or property damage in excess of $1,000. The SAMIS data reporting requirements have been modified for 1995 to include more specific information on grade crossing collisions (with other vehicles, with objects, with people (accidental and suicides).

Also, individual state regulatory agencies, such as the CPUC, require that rail transit properties submit collision reports. Data are filed by type of incident, including a sketch of the specific geometric factors involved in grade crossing collisions.

More specific information is needed on grade crossing collisions to identify causal factors. The Transit Cooperative Research Program (TCRP)'s Project A-5 "Integration of Light Rail Transit Into City Streets" identified the need to know whether the collision was caused by left or right turns in front of trains, going around gates, auto encroachment, etc.

One important aspect of understanding grade crossing collisions for light rail is knowing the type of right-of-way. For example, light rail collisions that occur on street median running right-of-way typically fall into one of the following categories:

- Same direction left turn collisions between the train and a left turning motor vehicle
- Right angle collisions between the train and motor vehicle as the vehicle turns left
- Opposite direction, left turn collisions between the train and motor vehicles as the vehicle turns left
- Pedestrian walks into the path of the train

Data collection for light rail needs to be by alignment type as well as casual factors.

Train Information

A key problem at the highway-rail intersection is warning motorists and pedestrians of the approach or presence of a train at the grade crossing and of providing railroad operators with information on traffic in the intersection. Train position, location, speed and direction can be determined through location systems such as Global Positioning Satellites to obtain real-time train positional information. Radar detection systems can also be used to precisely locate trains and detect train speed.

This train information can then be communicated to motorists using in-vehicle alert devices. Pedestrians and/or vehicles can be advised of an approaching train through active warning signs indicating train direction, arrival time and speed.

Status Monitoring

Many grade crossing collisions occur because motorists and/or pedestrians have a lack of confidence in warning devices, such as automatic gates. In many instances, gate failures result in long down times. Motorists assume the gate is broken and tend to drive around the closed gate into the path of an oncoming train.

Remote monitoring of warning devices can be accomplished using cellular communications to create a grade crossing health monitoring system. If a malfunction occurs, the cellular system dials phone numbers of key officials including dispatchers, maintainers and law enforcement personnel. Such devices can call pager numbers, generate phone calls, and issue faxes to appropriate locations. In this manner, signal problems can be corrected more quickly.

Many railroad systems have centralized dispatching systems which use Supervisory and Control Data Acquisition Systems (SCADA) to remotely monitor status of the rail system. When an automatic warning gate fails, the failure appears on the computer consoles at the central facility. The dispatchers then send a maintainer out to the site to correct the problem.

Driver Behavior

One of the most difficult types of data to obtain at highway-railroad intersections is driver and pedestrian behavior in response to warning devices and signs. Evaluating human reactions to warning devices and signs is necessary to gauge their effectiveness in preventing collisions.

For example, many grade crossing collisions are caused by motorists "beating the train" and going around down warning gates, but forgetting that the second train is coming in the other direction. TCRP Project A-5 is proposing the use of a "Second Train" illuminated active warning sign to warn motorists and pedestrians of the presence of a second train. As part of demonstration tests, driver reaction to these signs needs to be evaluated.

There are several methods to test human reactions to traffic control devices. Focus groups of representative individuals have been used on many different types of projects to determine human reactions to various types of devices. These groups can be held in a laboratory environment or, better yet, at the actual location of the device. For example, in Los Angeles on the Metro Blue Line a series of focus groups of community residents were used to evaluate reactions to the use of a horn being blown at the wayside.

Another method to evaluate behavior is through the use of a driver simulator. The University of Loughborough is developing a driver simulator that can be used to test new technologies, before they are actually installed in vehicles or in the field environment. Real driving scenes are presented to the driver on a large video screen. Reactions can be monitored and recorded by interactive computer links to the driver and the video system.

Risky Behavior

The commonly accepted measure of rail safety is the number of collisions that occur in the rail system. However, there is a relatively small number of specific types of highway-railroad grade crossing collisions at any given location. The safety analysts might need to wait for several years to achieve the required sample size for statistical inferences. There is often little difference between the occurrence of rail collisions, near-misses and serious conflicts between the train and the road user.

Korve Engineering, in TCRP Project A-5, developed a technique to measure traffic conflicts and evasive actions between railroads and road users that indicates a safety problem at the intersection. These near-misses, conflicts and evasive actions are represented in the pyramid shown in Figure 1. Risky behavior is defined as those movements by the road user that present a real threat of collisions with rail vehicles. The most serious risky movements occur when the road user or both must take evasive actions to avoid impending collisions.

Examples of risky behavior for light rail systems include motorist risky behavior leading to left-turn collisions, motorists risky behavior leading to right-angle collisions, motorists risky behavior leading to mid-block collisions, and pedestrian risky behavior.

Risky behavior can be measured by video taping the intersection over a fixed time frame. This data can then be analyzed for significant instances of risky movements on the part of motorists and pedestrians. Project A-5 used this method to evaluate such behaviors. The Los Angeles Metro Blue Line has also used video analysis to identify areas where risky motorist and pedestrian behavior occurs. For example, at one intermodal light rail station (for two light rail lines and a freight line) pedestrians were rushing for trains across a pedestrian crossing, ignoring red flashing warning lights. Behavior was video taped prior to installation of swing gates at this location. Swing gates were installed to make pedestrians stop and look, prior to running across the tracks. Video is being used to evaluate the effectiveness of such gates. Preliminary results suggest that the gates are preventing pedestrians from running in front of the trains.

Intrusion Detection

Several demonstration projects are on-going or proposed to collect information in detecting objects on the highway-railroad intersection. For example, AUTOSCOPE combined with wireless transmission technologies is being used on a New York state rail corridor to transmit video of the objects at specific rail crossings to the video monitor in the cab of the locomotive.

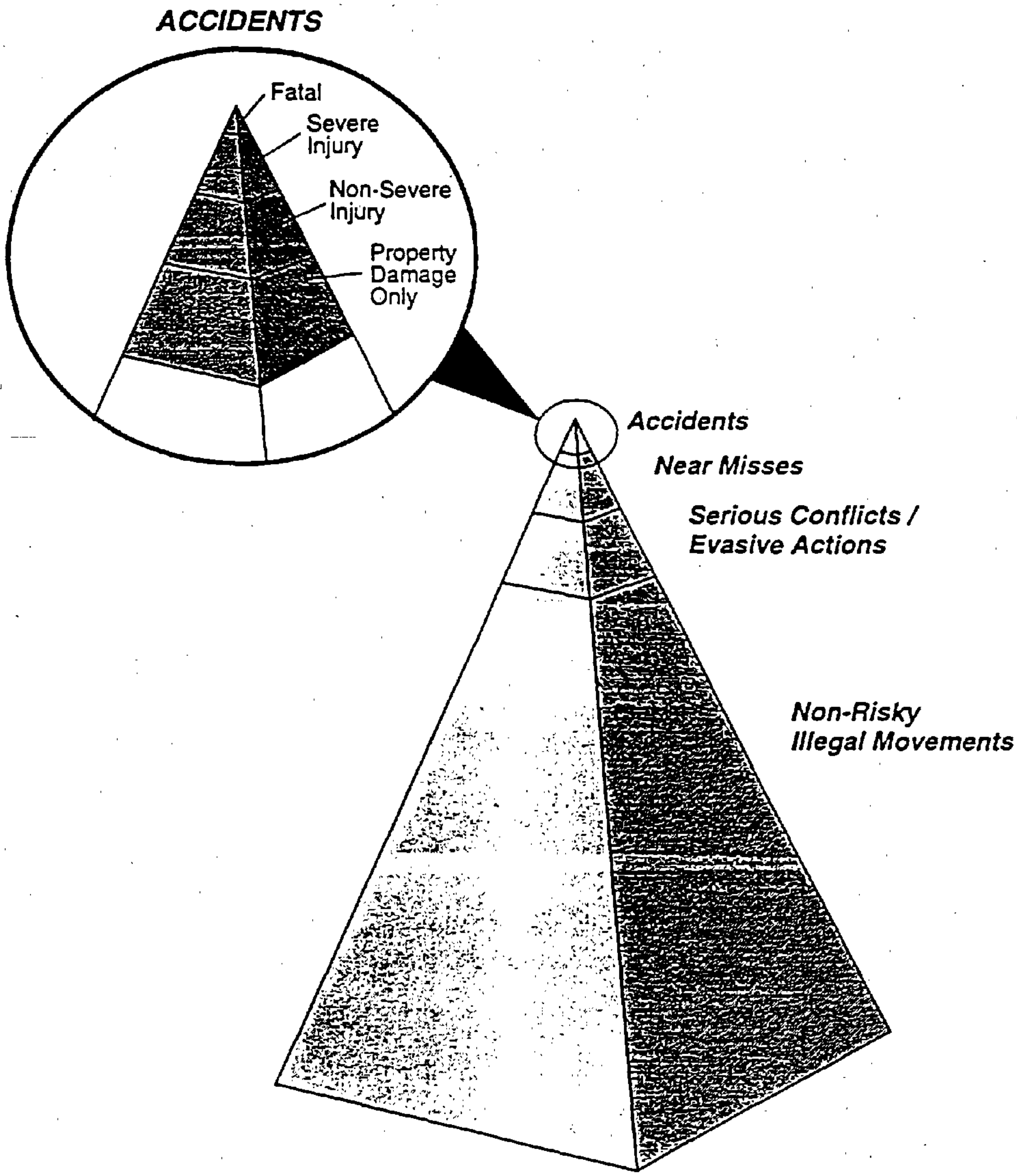
Photo enforcement high resolution cameras along with digital loop detection are utilized to record grade crossing violations. The Los Angeles Metro Blue Line has had a 92% reduction in violations over a seven month period. U.S. Public Technologies has been awarded a contract to install, operate and maintain a comprehensive photo enforcement system at seventeen gate crossings on the Metro Blue Line.

CONCLUSIONS

Many types of rail grade crossing data are currently being collected by federal and state agencies by specific mode of transportation (freight railroad, commuter railroad, rail transit, bus, highway).

These data bases cannot easily be related to each other due to differences in reporting requirements, data elements, software systems, etc. Understanding how to improve safety at the highway-railroad intersection requires detailed information concerning highway and railroad collisions and near misses. This information must be easily accessible to the safety analyst who is trying to determine appropriate safety solutions. The use of innovative technologies to collect data is one way to capture intermodal behavior.

FIGURE 1



TCRP Project A-5 Phase I Interim Report - January 1995

 *U.S. GOVERNMENT PRINTING OFFICE: 1996-700-778/20027