Level Crossing Accidents: A Literature Survey

Covance Pty Ltd

on behalf of the
Australian Transport Safety Bureau

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LEVEL CROSSING ACCIDENTS: A LITERATURE SURVEY

There is increasing interest in level crossing accidents in Australia. As a contribution to research on the subject, the Australian Transport Safety Bureau commissioned Covance Pty Ltd to undertake a literature survey, referencing material published overseas as well as in Australia. The literature survey presented here focuses on published material that explores measures that can be implemented to help prevent level crossing accidents or to improve safety at level crossings.

DATABASES SEARCHED

The bibliography is the result of searches conducted in several databases. The databases utilised are described below.

ROAD

ROAD covers vehicle design and safety and road safety. Coverage also includes vehicle testing. Relevant Australian journal articles, reports, monographs, theses and conference papers are indexed, as well as all ARRB publications. Overseas literature is selectively included. Contains records from 1978 onwards.

TRIS ONLINE

TRIS ONLINE is a collaborative effort between the Transportation Research Board, National Research Council, National Academies, and the Bureau of Transportation Statistics, U.S. Department of Transportation, to provide a public-domain, web-based version of the Transportation Research Information Services (TRIS) bibliographic database as a component of the National Transportation Library, and to enhance transportation research, safety, and operations by sharing knowledge and information. TRIS Online provides:

- over 420,000 bibliographic records covering transportation research published in books, journal articles, technical reports and other media
- coverage of United States -Federal, state, local and association publications and conference proceedings
- coverage of the literature from the 1960s to the present, with some coverage of prior years
- selected links to full text or sources of full text
- searching capability by author, title, subject, corporate author/publisher, journal/conference title

TRANSPORT

TRANSPORT is produced by the OECD in conjunction with the US Transportation Research Board and the European Conference of Transport. It covers journal articles, books, government publications and reports produced in OECD countries.

MEDLINE

Although MEDLINE is essentially a medical database, it was searched as it cites publications related to public health and certain transport related journals such as *Accident Analysis and Prevention*.

KEYWORDS

The keywords used in the searches were appropriate to each database. The thesaurus for each database was utilised to provide relevant keywords. Keywords included but were not limited to:

level crossing
grade crossing
road-rail accidents
warning system
grade-separation
passive railway crossing
active railway crossing
grade crossing protection systems
safety programs
signals
technology assessment

LIMITS

The searches concentrated on level crossing accidents involving motor vehicles; accidents involving pedestrians were excluded. Due to the large number of studies on level crossing accidents, the searches were limited to English language studies from the last ten years (ie 1990-2001). This still resulted in large numbers of publications being found in each search. It was impossible to include every publication found due to resource constraints. For example a search on "level crossing" and "accidents" in ROAD located 490 articles. The article abstracts were reviewed and the articles that matched the primary focus of the search were included. Articles without abstracts were excluded, except for cases where the title was thought to reflect a focus on measures that can be implemented to help prevent level crossing accidents or to improve safety at level crossings.

WEB RESOURCES

An attempt was made to locate other literature, such as government publications and academic research conducted by specialised centres. A search of the web and appropriate transport related sites was conducted. Due to the vast nature of the web, it was impossible to provide an exhaustive bibliography of the available research. However, examples of the available literature are provided in this document. Hyperlinks are provided to link through to the document. At the time of compilation all the links were correct.

CONTENTS OF THIS DOCUMENT

This document contains the full reference and abstract of each article found which was considered relevant. The articles are grouped by country of origin (Australia, United States, Europe, Japan, New Zealand) and sorted in reverse publication year order (ie most recent first). Within publication year they are sorted alphabetically. Web articles form a separate group at the end of this document.

LITERATURE SEARCH RESULTS

Australia

United States

Europe

Japan

New Zealand

Web Resources

Australia

Author	Christiansen L, Douglas J, Viney N
Year	1997
Title	Railway open level crossing safety: a methodology for prioritising the treatment of open level crossings
Publication	International Conference on Accident Investigation, Reconstruction, Interpretation and the Law, 2nd, 1997, Brisbane, Queensland, Australia 1997, pp 307-17, Queensland University of Technology. School of Civil Engineering, Brisbane, Queensland, Australia,
Country	Australia
Abstract	A large number of Queensland's rural open level crossings have no protection from a potential collision between a car and a train other than passive warning signs. Guidelines on the size of 'sight triangles' required to enable drivers to see an approaching train, and stop or proceed safely over the crossing, have long been utilised by Queensland Rail, Main Roads, local governments and cane railway owners. This paper presents an alternative means of classifying crossings with inadequate visibility so that these crossings may be prioritised for remedial work.

Author	Christiansen L, Douglas J, Viney N
Year	1996
Title	Prioritising the treatment of open level crossings in rural areas
Publication	Technology Transfer Forum, 1996, Brisbane, Queensland, Australia 1996, pp 125-32, Queensland Department of Main Roads, Brisbane, Queensland, Australia
Country	Australia
Abstract	A large number of Queensland's rural open level crossings have no protection from a potential collision between a car and a train other than passive warning signs. Guidelines on the size of 'sight triangles' required to enable drivers to see an approaching train, and stop or proceed safely over the crossing have long been utilised by Queensland Rail, Main Roads, local governments and sugar cane railway owners. This paper presents an alternative means of classifying crossings with inadequate visibility so that these crossings may be prioritised for remedial work.

Author	Kidd B Main Roads Western Australia; Road Safety Strategy Branch
Year	1996
Title	Safety at railway crossings : a road safety research project
Publication	Road Safety Research Project, 1996, pp 1v (unpaged), 30cm, MRWA, East Perth
Country	Australia
Abstract	Not available

Author	Standards Australia
Year	1996
Title	Manual of uniform traffic control devices: part 14: traffic signals
Publication	Australian Standard, AS 1742.14-1996, 1996-04-05, pp 48p, Standards Australia, Strathfield, New South Wales, Australia
Country	Australia
Abstract	This standard specifies the type and layout of signals, aspects and displays to be used at locations controlled by traffic signals. Basic requirements for signs and pavement markings to be used in conjunction in accordance with AS 1742.2 are also given. The standard does not cover railway level crossing signals of the type described in AS 1742.7

Author	Viney N, Douglas J, Christiansen L
Year	1996
Title	Open level crossings in rural areas and driver visibility
Publication	Combined 18th ARRB Transport Research Conference and Transit New Zealand Land Transport Symposium, 1996, Christchurch, New Zealand 18, 5, 1996, pp 67-80, ARRB Transport Research Ltd, Vermont South, Victoria, Australia,
Country	Australia
Abstract	The purpose of this paper is to establish a reliable method of identifying the relative degree of hazard at open level crossings where the desirable sight distance is not available. In Australia, a large number of level crossings in rural areas have no protection from a potential collision between a car and a train other than passive warning signs and the available visibility. Warrants have been established to provide guidance on the size of the 'sight triangle' required at these sites to enable drivers to see an approaching train in sufficient time to stop or to proceed safely over the crossing. However the size of the triangle is significant for most typical combinations of car and train approach speeds and in many cases obstructions occur within the sight triangle which limit the effective visibility. This paper proposes a method of classifying crossings with inadequate visibility so that these may be placed in priority order for budgeted improvement works. A system is proposed to quickly identify the relative degree of hazard at any particular crossing. The method was developed following a brief literature search of research into the effects of obstructions in the sight triangle and field surveys of crossing sites to determine the practical application of the proposal. The paper suggests that sight triangle dimensions incorporate several safety factors that allow the triangle to be grade according to rational steps in the safety factors used. This method could be used to grade sites depending on relative visibility hazard and also to highlight sites which are intrinsically hazardous.

Author	Afxentis D
Year	1994
Title	Urban railway level crossings
Publication	Civil Engineering Working Paper, 94/T9, 1994-10, pp 63p, Monash University. Department of Civil Engineering, Clayton, Victoria, Australia, 0156-2126
Country	Australia
Abstract	This report reviews the operating procedures for urban railway level crossings. Safety and performance issues are considered. Of particular interest are crossings located adjacent to suburban railway stations where a distinction must be made between express and stopping trains.

Author	Uber CB
Year	1994
Title	Trial of reflectors on railway wagons
Publication	Australian Road Research Board Ltd (ARRB) Conference, 17th, 1994, Gold Coast, Queensland, Australia 17, 5, 1994, pp 229-43, Australian Road Research Board Ltd (ARRB), Vermont South, Victoria, Australia,
Country	Australia
Abstract	About fifty per cent of the accidents at passive railway crossings during dawn, dusk and darkness involve motor vehicles running into the side of a train. A possible remedial road safety action for this problem is the installation of retroreflective material to the sides of railway freight wagons that, when illuminated by vehicle headlights, may give an indication of the presence of a train already on the crossing. This study presents lab testing of retroreflective sheetings, and of two years of field trials of eight reflectors on railway quarry wagons to measure the loss of reflectivity over time in worst case railway operating conditions of quarry dust and brake dust. In two years without washing, the reflectors lost 85 to 90 per cent of their initial reflectivity. Washing the reflectors after two years recovered from 4 to 29 per cent of the initial reflectivity. Two Class 1A sheetings may be feasible for installation on railway wagons using a 'FIX AND FORGET' policy which could provide a minimum retroreflectivity of 45 cd.lx(super -1)m(super -2) for a period of about 4.4 years without washing. Washing of reflectors might then be considered as a routine part of railroad wagon maintenance.

Author	Vimpani AJ (Royal Automobile Club of Victoria (RACV))
Year	1994
Title	Arterial road redspots: summary
Publication	Report, TS 94/7, 1994-09, pp 26p, Royal Automobile Club of Victoria (RACV), Noble Park, Victoria, Australia
Country	Australia
Abstract	This report presents and discusses data from a survey published in the June 1994 edition of Royalauto. RACV members were asked to identify sites in Victoria where they are often frustrated by delays that appear to be unnecessary. Over 1200 redspots were identified. The top twenty intersections, top twenty sections of road and the top six railway crossings are named in this report. VicRoads' comments on the identified locations are also included, with an emphasis on any proposed actions.

Author	Standards Australia
Year	1993
Title	Manual of uniform traffic control devices, part 7: railway crossings; second edition
Publication	Australian Standard, AS 1742.7-1993, 1993-02-15, pp 36p, Standards Australia, Homebush, New South Wales, Australia 0-7262-7906-4
Country	Australia
Abstract	This Standard specifies traffic control devices to be used to control and warn traffic at and in advance of railway crossings. It specifies the way in which these devices are used to achieve traffic control required for the safety of rail traffic and road users. Requirements and guidance are also given in appendices on the illumination and reflectorization of signs, on their installation and location, and on selection of the appropriate sign size.

Author	Wigglesworth EC
Year	1992
Title	Improving safety at open railway crossings
Publication	Vic Roads
Country	Australia
Abstract	This is a report of a research project where the characteristics of 110 open railway level crossings in Victoria were examined and recorded. At 55 of these crossings there had been one or more fatal motor vehicle-train accidents; the other 55 consisted of accident-free open crossings in close proximity on the same lines for use as controls. The purpose of the study was to identify the human factors considerations that might have influenced driver behaviour at open level crossings. In order to identify the reasons for driver error, a research framework was developed from the standard ergonomics schema and applied to behaviour at open level crossings. In the ergonomics context, error is defined as an inappropriate or missing response to some stimulus. It is a factual description of a particular type of human behaviour with no connotation of blame nor implication of delinquent malpractice. The research therefore was not for the error, but for the stimulus that provoked it. There are two recommendations. They are based on the facts that (a) the risks at open level crossings vary immensely from crossing to crossing and (b) different measures are appropriate to different risks. The first is that a series of regional workshops be held. The objectives are to raise the profile of level crossing accidents in local communities, to inform Shire Engineers of recent research findings and improvements in signing and to involve them in the tasks of evaluating the research proposals and to provide a firm basis for the introduction of specific innovatory treatments at selected crossings. The second is that, after those workshops, a program to introduce and evaluate innovative treatments at identified crossings be developed jointly by Vic Roads and the Injury Research Project.

Author	Allison J
Year	1991
Title	TV campaign tackles rail crossing deaths
Publication	Vic Roads, 1991, Spring, pp 12-3
Country	Australia
Abstract	Not available

Author	Cairney P (Australian Road Research Board (ARRB))
Year	1991
Title	Some possible low-cost treatments for railway level crossings
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 85-92, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	Active protection presently used at railway level crossings appears to offer low safety benefits in comparison to other traffic engineering measures. Cheaper train activated treatments are therefore essential if the benefits of active protection are to be more widely applied. Prospects for some less expensive active treatments are discussed, as are possibilities for improving the visibility of trains and for modifying motorist behaviour through pavement markings and other means.

Author	Henderson M
Year	1991
Title	Improving safety at railway level crossings: some perceptions of the problem
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 51-9, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	The road user wants to be informed about the existence of railway level crossings, about the presence or otherwise of oncoming trains, and about the general level of risk presented by the crossing. Research in Australia and overseas, however, indicates that in general road users have a low level of knowledge about what crossing signs and lights mean, and a confused and sometimes inappropriate response to them. It is suggested in this paper that the special signs used at railway crossings are inconsistent with road-user expectations and normal behavioural responses to signs and light signals used elsewhere throughout the road system, and that efforts should be directed towards reduction of such inconsistencies rather than towards making crossing controls even more unique. Trains themselves should be made as conspicuous as possible.

Author	Hussey F (Australian Federated Union of Locomotive Enginemen)
Year	1991
Title	Level crossings - a train driver's perspective
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 41-6, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	In the long history of level crossings and development of hardware to alleviate their problems the train drivers' perspective has been largely ignored. Indeed level crossings have, until recent years, been separately designed by road and rail authorities with no input from one of their most consistent and regular users. For train drivers, level crossings are stressors. Consequences and trauma from accidents at them have ruined some careers. Trauma associated with them has only recently been addressed. Structures and buildings can be erected ad-hoc which effect the visibility of crossings and add to stress. Whilst appreciating recent trends in protection at frequently used crossings, usually at a high capital cost, much can still be done using low cost solutions for infrequently used ones, such as standard road signals and signed speed humps and rumble strips. Crossing locations should be clearly identified and marked to enable clear information to be given to emergency services.

Author	Tierney A (Roads and Traffic Authority)
Year	1991
Title	Research leading to design changes
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 61-77, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	Whilst it is recognised that the most significant safety improvements at railway level crossings may come from innovative technology which provides active signalling of the presence of a train, there is scope to improve the signposting of crossings controlled solely by signs. This paper discusses the research basis for the review of signs in AS 1742.7-1987, Railway Crossings. Investigations by Wigglesworth for the Victorian Ministry of Transport in the late 1970s identified the desirability of differentiating between active and passive crossings. Subsequent study by Cole and Jacobs confirmed the acceptance of the steam engine symbol as a suitable stereotype. Later a study by Cairney checked the comprehension and visibility of a number of candidate sign displays and a field study by the NSW Roads and Traffic Authority studied driver behaviour. This report deals with the five questions : how to emphasis the presence of a railway level crossing; how to differentiate between active and passive crossings; how to encourage drivers to look for trains; how to indicate the geometry of the crossing; how to enhance the conspicuity of the crossbuck position sign in daylight.

Author	Turner C
Year	1991
Title	The signal engineer's perception
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 47-9, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	The responsibility and total accountability for the design, installation and maintenance of active level crossing protection devices has always been and still does rest with Rail Authorities. In all States there has been increasing awareness that the decision on which of the current accepted protection levels is most suitable at each location is best handled jointly by Rail and Road Authorities in accordance with some form of defendable warrant. The area of funding responsibility has been the subject of ongoing debate and, although it obviously needs to be resolved, it is not the most critical issue at hand. The areas that are fundamental to progress beyond the current situation in relation to level crossing protection are accountability and liability. Until these issues are addressed it is unlikely that any significant change will be possible.

Author	Uber C (Vic Roads)
Year	1991
Title	The present position
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 17-32, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	This paper first examines the number and types of railway level crossings in Australia. Then it considers the number of road user/ train accidents at each type of railway level crossing and the trends of those accidents, especially in fatalities and injuries.

Author	Viner D
Year	1991
Title	Risk engineering
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 93-102, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	A number of risk engineering models are applied to the estimation of risk at railway level crossings. The use of fault free and event analysis, and outcome analysis provide a means of engineering risk in a predictive and rational manner, seen to be of particular importance in determining priorities for expenditure on risk control projects.

Author	Western Australia Main Roads Department; Western Australia; Railway Crossing Protection Committee
Year	1991
Title	Railway level crossing protection in Western Australia - review of the railway crossing protection criteria - draft
Publication	Western Australia Main Roads Department, Western Australia Railway Crossing Protection Committee 1991, pp 1 v(various pagings), 30cm, MRD, East Perth
Country	Australia
Abstract	Not available

Author	Wigglesworth E (Injury Research Project)
Year	1991
Title	Railway level crossings: what's wrong with the present system?
Publication	Improving Safety at Railway Level Crossings, Conference, 1991, Adelaide, Australia 1991, pp 33-40, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	It is here suggested that four items have contributed to the problem of fatal collisions between motor vehicles and trains at railway level crossings in Australia. The first is the historical pattern of the development of land transport which has resulted in large numbers of level crossings throughout Australia. The development of appropriate protective treatments for these crossings constitutes a major dilemma both in absolute and in cost-benefit terms. The other three items are not specific to accidents at railway level crossings: in varying degree they apply to road traffic accidents more generally. Paramount is the continuing acceptance of the antiquated fault doctrine, which is based on the premise that injuries are caused by faulty human behaviour. This futile conception of the injury process continues to receive wide and unthinking dissemination in the lay media, supported by the enforcement and insurance authorities in our society. The third item is the way in which this conceptual smoke-screen has effectively delayed the introduction of human factors considerations and, hence the introduction of a more advantageous and more scientific approach to injury control. Finally, the absence of an adequate model of the injury process has prevented the creation of an ordered hierarchy of effective countermeasures. Each of these matters is discussed separately and some suggestions are offered in a final section.

Author	Wigglesworth EC, Uber CB
Year	1991
Title	An evaluation of the railway level crossing boom barrier program in Victoria, Australia
Publication	Journal of Safety Research, 22, 3, 1991, pp 133-40
Country	Australia
Abstract	This paper evaluates the effectiveness of a program carried out in Victoria, Australia in which 91 metropolitan and major urban road-rail crossings were upgraded from "flashing light" status to "boom barrier" status during the 19 year period from 1971 to 1989. At these crossings, the number of deaths from motor-vehicle/train collisions was reduced from 61 before boom barrier installation to two thereafter, while the mortality rate (deaths per 100 crossing years) was similarly reduced from 5.71 to 0.33. In a control group, consisting wherever possible of the next "up" crossing on the same line as the upgraded crossing, the mortality rate increased from 1.22 to 1.63 deaths per 100 crossing years. A second comparison was then made between the same 91 crossings and the 82 crossings on the same lines where the flashing light installations had remained unchanged for the whole 19-year period. For this second group, the number of deaths from motor-vehicle/ train collisions increased from 14 to 17 and the mortality rate increased from 1.31 to 2.77. It is concluded that the strategy of installing boom barriers at metropolitan and major urban road- rail crossings protected solely by twin alternating flashing lights is highly effective. This is deemed a significant finding since mortality rates at these crossings have previously been shown to be unusually high.

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Author	Bayley JM, Uber CB
Year	1990
Title	A comprehensive program to improve road safety at railway level crossings
Publication	Australian Road Research Board (ARRB) Conference, 15th, 1990, Darwin, Northern Territory 15, 7, 1990, pp 217-34, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	Earlier programs to install flashing lights or boom barrier protection at crossings in Victoria have been effective in reducing road/rail accidents. However, fewer installations have been provided in the more recent years. It is time for Victoria to consider overseas research and experience and to implement a comprehensive program which would utilise research on road user behaviour to assist in selection of low cost alternative solutions to improve road safety without necessarily upgrading the level of road safety protection. Some portions of the comprehensive program are actions which could aid safety at all crossings, such as placing strobe lights on locomotives, reflectors on freight cars, development of pentagonal reflectors, and developing new standards for traffic control devices for level crossings.

Author	Uber CB
Year	1990
Title	Accidents at railway level crossings in Victoria 1975-1988
Publication	15th ARRB Conference, Darwin, Northern Territory, 26-31 August, 1990; Proceedings, 1990. 15(7):107-22
Country	Australia
Abstract	This paper examines the trends and characteristics of road users involved in accidents at railway level crossings for the period 1975-1988 in Victoria. Total casualty accidents have decreased, however this decrease is entirely in motorised vehicle/train accidents as boom barriers or flashing lights have been installed at crossings with the greatest exposure and accident history. Casualty accidents with trains involving pedestrians, bicycles and horses have increased slightly in this period. Differences in the types of level crossing accidents in Metropolitan Melbourne and the rest of the state are also examined.

Author	Wigglesworth EC
Year	1990
Title	How can safety be improved at 'open' level crossings?
Publication	Australian Road Research, 20, 4, 1990-12, pp 61- 75, Australian Road Research Board (ARRB), Vermont South, Victoria, Australia
Country	Australia
Abstract	This review is concerned only with 'open' railway level crossings, ie, those that have a static array of signs warning of the presence of a crossing, but are not equipped with gates, boom barriers, flashing lights or other device that is activated by an approaching train. It rejects the possibility of using some form of quantitative analysis as a basis for ranking these crossings. It then comments on an earlier series of field studies into human factors at railway crossings, where it was found that many drivers exhibited the same looking behaviour at open and protected crossings. These findings are thought strongly to suggest that advance warning signs at open crossings should differ from crossings with active protection. The paper then emphasises that, as the law now stands, the duty of care requires the provision of some active device that will tell the driver if a train is approaching. In order to improve safety at open crossings, three proposals are offered. First, the most reasonable way to meet the duty of care seems to be to provide a visual warning of an approaching train, probably train-mounted, and probably linked with the train's klaxon. To emphasise the need for a different behavioural response at open crossings, the second proposal is to install different warning signs at open as compared with active crossings. Third, the longer term objective should be to ensure that open crossings do not occur on bitumen roads but are confined to gravel roads. The review concludes with a note on the need to provide dedicated funding for the increased protection of railway level crossings (A).

Author	Ong CK
Year	1989
Title	Signposting trial at uncontrolled railway level crossings
Publication	Australian Road Research 1989/06 19(2):164-72
Country	Australia
Abstract	This paper describes an assessment of trial signposting at uncontrolled railway level crossings in New South Wales. Two experimental signs were selected and compared with the existing standard signs. The analysis was carried out based on the available data of driver head movements, vehicle approach speeds and vehicle registration numbers. The results of trials were eventually found to be inconclusive. However a consideration has been given in this study that the most appropriate signs for uncontrolled railway level crossings should depend upon the level crossing safety and cost effectiveness.

United States of America

Author	American Public Transportation Association
Year	2000
Title	Intelligent grade crossings using its to enhance safety at the highway-rail interface
Publication	Conference Title: Rail Transit Conference Proceedings Sponsored by: American Public Transportation Association Location: St. Louis, Missouri Date Held: 20000610-20000615 Publication Date: 00/00/2000 Pagination: pp 21-27
Country	United States
Abstract	Every year, hundreds of people are killed or injured at grade crossing accidents in the United States. ALSTOM Signalling has been engaged in a research and development project to combine Intelligent Transportation Systems (ITS) technologies with advances in train control technologies such as Positive Train Control (PTC) to make grade crossings safer. The paper explains the reasons and benefits of the functions of the system to the driving public, as well as to the railroad operator. Also addressed are the anticipated safety benefits provided by the system. The system's architecture, its conformance with the national ITS architecture, information of preliminary testing results, and project status are also presented.
Descriptors	Accident causes, Accident prone locations, Advanced vehicle control systems, Grade crossing protection systems, Intelligent transportation systems, Safety programs, Signals, Technology assessment

Author	Carroll AA, Gage S, Gordon J, Reiff R
Year	2000
Title	Evaluation of alternative detection technologies for trains and highway vehicles at highway/rail intersections
Publication	AREMA Proceedings of the 2000 Annual Conference Sponsored by: American Railway Engineering and Maintenance-of-Way Association Location: Dallas, Texas Date Held: 20000910-20000913 Publication Date: 00/00/2000 Pagination: 21p Publisher/Corporate Author(s): American Railway Engineering and Maintenance-of-Way Association
Country	United States
Abstract	The objective of this paper is to evaluate the alternative detection technologies for trains and highway vehicles at highway/rail intersections. Railroad track-based circuitry, which requires the use of railroad rails for signal transmission, is the most common method currently used by North American railroads to detect trains and control warning devices at highway/railroad intersections (HRIs). The introduction of advanced warning systems, such as the four quadrant gates and barriers at HRIs, may require additional information as to train and highway vehicle status to ensure optimal operation and safety. To address these issues, alternative technologies have been proposed for controlling HRI warning devices. These new technologies can be mounted off the railroad property and may not rely on the rails for transmission of detection signals. Some of these technologies offer additional features over conventional track-based circuitry allowing the detection of highway vehicles located within HRI limits, which may further enhance crossing safety.
Descriptors	Approach control, Detection and identification systems, Highway grades, Intersections, Railroad grade crossings, Railroad signals, Railroad tracks, Transmission techniques Colorado

Author	Estes RM, Rilett LR
Year	2000
Title	Advanced prediction of train arrival and crossing times at highway-railroad grade crossings
Publication	Transportation Research Record 1708 pp 68-76
Country	United States
Abstract	There are many issues related to highway-railroad grade crossings. For historic and practical reasons, trains have the right-of-way at grade crossings, which results in delays to motorists. In addition, the differential in size, speed, and stopping ability between motor vehicles and trains raises many serious safety concerns. Historically, the methods used to address these delay and safety problems at grade crossings have been reactive in nature. For example, the "Manual on Uniform Traffic Control Devices" specifies a minimum of 20 s of warning time for active warning devices at grade crossings. Intelligent transportation system (ITS) technology offers potential solutions for increasing the warning time at grade crossings. Advanced on-board devices and off-track detection equipment can allow train position and speed to be monitored. This information can be shared through wireless and wireline telecommunications equipment being deployed for ITS. Transportation management center personnel can then predict the arrival and crossing times of trains at grade crossings. It is hypothesized that if the warning time could reliably be increased, the traffic-operation strategies in the vicinity of grade crossings could be more proactive, reducing delay to motorists and increasing safety for both trains and automobiles. The research focuses on a second-generation technology approach to an advanced prediction of train arrival and crossing (gate-up and gate-down) times at highway-railroad grade crossings, including problems faced at grade crossings, background on detection and prediction technology for grade crossings, the train monitoring system used as the test bed for the research, the development of the methodology, the results of the analysis, and the conclusions of the research and potential applications for the model. Supplemental Information: This paper appears in Transportation Research Record No. 1708, Traffic Control Devices, Visibility, and Rail-Highway Grade Crossings 2000.
Descriptors	Forecasting, Intelligent transportation systems, Position indicators, Railroad grade crossings, Railroad trains, Speed indicators, Telecommunications, Traffic control centers, Traffic delay, Traffic safety, Train arrival time, Train crossing time

Author	Ford GL Jr, Picha DL
Year	2000
Title	Teenage drivers' understanding of traffic control devices
Publication	Transportation Research Board Transportation Research Record Issue 1708 pp 1-11
Country	United States
Abstract	Teenage drivers are involved in traffic crashes more often than any other driver group, and their fundamental knowledge of traffic control devices and rules of the road is extremely important in safe driving. Only limited data exist, however, on teenage drivers' understanding of traffic control devices, and little research has been done on determining their comprehension thereof. Research was performed to document teenage drivers' ability to understand 53 traffic control devices. These traffic control devices included 6 combinations of sign shape and color; 8 regulatory signs; 14 warning signs; 7 school, highway-railroad grade crossing, and construction warning signs; 7 pavement markings; and 11 traffic signals. Research results were then compared with previous comprehension studies to identify specific traffic control devices that the driving public continually misunderstands. In general, the results indicated that surveyed teenage drivers understood the traffic control devices to some degree. Only nine devices were understood by more than 80% of the respondents. The devices found problematic to teenage drivers include combinations of sign shape and color, warning-symbol signs, white pavement markings, flashing intersection beacons, and circular red/green arrow left-turn-signal displays. Recommendations include revising states' drivers handbooks and increasing emphasis in the driver education curriculum to clarify the meaning and intent of problematic traffic control devices. Supplemental Information: This paper appears in Transportation Research Record No. 1708, Traffic Control Devices, Visibility, and Rail-Highway Grade Crossings 2000.

Author	Gilbert DT
Year	2000
Title	Smile! You're on candid camera
Publication	Traffic Safety Volume: 00 Issue: 1 pp 8-9
Country	United States
Abstract	Fort Collins, Boulder, and Denver, Colorado, have been using photo traffic enforcement for the past year with much success. Depending on the application, photo radar can be mounted on a pole, a cabinet, an overhead structure, or a vehicle. The camera is triggered to take a picture if an offender travels through a red light or is speeding. Some devices have the capacity to monitor approaching and departing traffic, which means a photo of the front of the vehicle, with the face of the suspect and the license plate, as well as a photo of the rear license plate. In addition to red-light and speed violations, the Los Angeles Metro Blue Line Grade Crossing Improvement Program uses cameras to photograph drivers who maneuver under or around gates at railroad-highway grade crossings.

Author	Better Roads
Year	2000
Title	At-grade incidents and fatalities continue to decline
Publication	Better Roads Volume: 70 Issue: 12
Country	United States
Abstract	According to the latest Federal Railroad Administration (FRA) statistics for 1999, both incidents and casualties at highway-rail grade crossings have continued to go down, while grade crossing injuries have shown an increase of a little over 7% from 1998. The FRA has adopted the term highway-rail intersection (HRI) to replace the traditional "at-grade" or "grade crossing" terms. The National Transportation Safety Board has specifically denoted HRIs as a safety challenge that can, and should, be addressed by intelligent transportation systems (ITS). Improvements in safety technology, such as median barriers and barrier gates, have played a part in the declining casualty and fatality statistics. Various ITS projects are also addressing safety problems. Active warning signs in Maryland warn motorists when a second train is approaching while they are stopped at a light-rail grade crossing. In San Antonio, Texas, the Advanced Warning to Avoid Railroad Delays project helps motorists avoid delays from railways that cross freeway frontage roads. In Illinois, the Department of Transportation is studying advisory on-board warning systems that can be placed in school buses, transit vehicles, municipal vehicles, and the like. The receivers in the vehicles are warned of approaching trains by transmitters at railroad crossings. A similar project in Minnesota uses smart license plates as the receivers. A table of the 10 states reporting the most railroad crossing collisions for 1999, supplied by the FRA, is included.

Author	Witte K, Donohue WA
Year	2000
Title	Preventing vehicle crashes with trains at grade crossings: the risk seeker challenge
Publication	Accid Anal Prev 2000 Jan; 32(1):127-39
Country	United States
Abstract	A formative evaluation for a communication campaign to decrease rail-automobile accidents was conducted with a survey of 891 randomly selected residents in Michigan, USA. The formative evaluation was theoretically grounded in the extended parallel process model. The results of the study suggest that the majority of respondents engage in safe driving behaviors around railways. However, 10-20% reported extremely risky behaviors such as trying to 'beat the train' (labeled 'risk seekers'). Further analyses revealed that the risk seekers were disproportionately male with strong sensation seeking tendencies to engage in new and novel experiences and to avoid boredom. The results suggest that high sensation seeking tendencies cause one to experience greater frustration and exhibit greater judgment distortions around rail crossings, which in turn, cause one to try and beat the train. Specific recommendations are given for campaign developers and limitations to the study are addressed.

Author	Carlson PJ, Fitzpatrick K
Year	1999
Title	Violations at gated highway-railroad grade crossings
Publication	Transportation Research Record, 1692, 1999, pp 66-73, Transportation Research Board (TRB), Washington, DC, USA,
Country	United States
Abstract	Not available

Author	Gent SJ, Logan S, Evans D
Year	1999
Title	Evaluation of an automated horn warning system at three highway-railroad grade crossings in Ames, Iowa
Publication	Iowa Department of Transportation
Country	United States
Abstract	In September 1998, the city of Ames, Iowa, began operation of three automated horn warning systems. Traditionally, locomotive engineers begin sounding the train horn approximately 0.25 mi (0.4 km) from the crossing to warn motorists and pedestrians approaching the intersection. This creates a large area adversely impacted by the horn noise, which includes residential areas. The automated horn system provides a similar audible warning to motorists and pedestrians by using two stationary horns mounted at the crossing. Each horn directs its sound toward the approaching roadway. The horn system is activated using the same track signal circuitry as the gate arms and bells located at the crossing. Once the horn is activated, a strobe light begins flashing to inform the locomotive engineer that the horn is working. If the strobe light is not flashing, or the locomotive engineer has a reason for concern, the engineer simply sounds the train horn. This study examined the effectiveness of the automated horn system in reducing the annoyance level for nearby residents and the overall safety at the crossings with the new system. The research included collecting horn volume data to develop noise level contour maps, using before-and-after surveys to document opinions of nearby residents and motorists, and surveying locomotive engineers to document their perception of the new systems. Findings revealed that for nearby residents, the automated horn system greatly reduced the negative impacts resulting from the loud train horns. The automated horns were well accepted by both motorists and locomotive engineers and appeared to provide an equivalent level of safety at the crossings.
Descriptors	Annoyance, at grade intersections, audible warning devices, automation, grade crossing protection systems, horns, locomotive engineers, noise, pedestrian safety, railroad grade crossings, railroad trains, residential areas, safety, surveys, traffic safety, warning signals

Author	George BF
Year	1999
Title	Grade crossings: how to improve safety
Publication	Rail International 199/06 pp 24-27
Country	United States
Abstract	Collisions at road-rail crossings are a leading cause of rail fatalities in the USA. In 1997, the USA had 461 fatalities in 3865 such collisions. Significantly, this was a 5.5% improvement compared to 1996 and a 26% improvement since 1993, which is used as a statistical base for a ten-year goal to reduce collisions and casualties at level crossings by 50%. Preliminary data for 1998 indicate a further decrease of over 5%. These improvements have been achieved despite steady increases in both rail and road mileage since 1993. This article discusses how this safety improvement is occurring and whether it can be sustained. In 1991, a concerted programme began to close and remove redundant crossings by establishing alternative rail and road routes or closing existing routes. Nearly 33,000 of the 293,000 crossings which then existed have been closed, with the help of some Federal financing.

Author	Korve HW
Year	1999
Title	Traffic signal operations near highway-rail grade crossings
Publication	National Cooperative Highway Research Program: Synthesis of Highway Practice, 271, 1999, pp 90p, Transportation Research Board (TRB), Washington, DC, USA
Country	United States
Abstract	Not available

Author	Moon YJ, Coleman F
Year	1999
Title	Driver's speed reduction behavior at highway-rail intersections
Publication	Transportation Research Record 1692 pp 94- 105 Transportation Research Board (TRB), Washington, DC, USA
Country	United States
Abstract	To learn how other countries with high-speed rail operations and large numbers of grade crossings addressed issues of rail crossing safety, the Federal Highway Administration (FHWA) sponsored an international technology reconnaissance tour to Denmark, the Netherlands, Germany, Italy, and Spain. The scan team found several innovative approaches that could provide solutions to highway-rail grade crossing issues in the United States. Spain, Italy, and Germany each have active programs under way to eliminate highway-rail grade crossings. Crossing closure is a national policy, and with the exception of a few grade crossings in Italy, all high-speed rail crossings are grade separated. Grade separation projects are performed by fabricating the tunnel structure outside the railroad in an excavation and then hydraulically inserting it under the tracks. Train detection by magnetic induction wheel sensors in lieu of track circuits was used in a number of the countries visited. Video monitoring of crossings was found to be in use to provide information on crossings being clear of obstructions.
Descriptors	Denmark, Europe, Germany, Grade Crossing Protection Systems, Grade Separations, High Speed Trains, Highway Safety, Italy, Netherlands, Public Policy, Railroad Grade Crossings, Railroad Safety, Spain, Technology Transfer, United States

Author	Osemenam B
Year	1999
Title	In-vehicle signing system for school buses at railroad-highway grade crossings
Publication	International Conference of ITS Australia, 4th, 1999, Adelaide, South Australia 1999, ITS Australia, Canberra, ACT, Australia
Country	United States
Abstract	This paper presents the test objectives and results of a field test to evaluate in-vehicle signing systems installed in 29 school buses in Glencoe, Minnesota. The system provided advanced warning to school bus drivers notifying them of the proximity to and presence of trains at five at-grade signalized railroad intersections. The system was developed by the Minnesota Department of Transportation. 3M and Dynamic Vehicle Safety Systems utilizes the train detection technologies already in place and communicates the information to the approaching buses. This warning system was designed to provide accurate and timely information to drivers, improving safety at grade crossings.

Author	Rapoza AS, Raslear TG, Rickley EJ
Year	1999
Title	Railroad horn systems research
Publication	Department of Transportation Report No: DOT-VNTSC-FRA-98-2, DOT/FRA/ORD-99/10, Final Report
Country	United States
Abstract	The U.S. Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration is conducting a research program with the goal of reducing the number of fatalities and injuries at highway-railroad grade crossings. As part of this program, a study is being conducted to determine the effectiveness of railroad horn systems in reducing accidents at grade crossings. An earlier report in the series, Study of the Acoustic Characteristics of Railroad Horn Systems, presented acoustic characteristics of several types of railroad horn systems. This report addresses the effectiveness of railroad horn systems and their resulting impact on the community noise environment. The insertion loss and interior noise levels of several motor vehicles were measured to determine if the warning signals created by railroad horn systems provide effective warning for the motorist. Acoustic data were also obtained for a horn system through wayside measurements of in-service locomotives to determine the community noise exposure. Also addressed is the distance from the crossing at which the signalling cycle should be actuated to minimize the community noise exposure.
Descriptors	Accident rates, Audible warning devices, Detection and identification, Horns, Noise control, Noise sources, Railroad grade crossings, Warning signals

Author	Schnell T, Zwahlen HT
Year	1998
Title	Accident trends at railroad-highway grade crossings in Ohio
Publication	International Symposium on Railroad-Highway Grade Crossing Research and Safety, 5th, 1998, Knoxville, Tennessee, USA 1999-04, pp 207-20, University of Tennessee. Transportation Center, Knoxville, Tennessee, USA
Country	United States
Abstract	Not available

Author	Texas Transportation Institute
Year	1999
Title	Enhancing the change from passive to active
Publication	Texas Transportation Researcher Volume: 35 Issue: 2
Country	United States
Abstract	Every year, the Texas Department of Transportation spends approximately $22.5 million upgrading 150 grade crossings at highway-railroad intersections (HRIs) from passive to active warning systems. The conversion involves adding a sophisticated system of lights, gates, signals, and circuitry to a crossing where before only the traditional HRI crossing sign -the crossbuck- was posted. The upgrading is based on a priority listing of crossings where passive crossing signage is not enough. However, there is a 24 month gap between identification of a hazardous HRI and the upgrade. One potential solution may be an enhanced sign system. The system, which costs around $4,000, uses a vehicle-activated strobe light to alert drivers to the signs on the signpost. These signs, mounted under the strobe, are the traditional round advanced warning sign as well as a new sign that says, "LOOK FOR TRAIN AT CROSSING." Based on driver reactions, the sign system is an effective traffic-control device and can improve roadway safety at HRIs with passive warnings.
Descriptors	Traffic control devices, Railroad traffic control devices, Strobes, At grade intersections, Grade crossing protection systems, Railroad grade crossings, Railroad signaling, Traffic safety, Traffic signals, Traffic signs, Warning signals, Warning signs

Author	Texas Transportation Researcher
Year	1999
Title	Where the road meets the rail
Publication	Texas Transportation Researcher Volume: 35 Issue: 2 pp 6-7
Country	United States
Abstract	Cars and trains interact daily at almost 260,000 public and private highway-railroad intersections (HRIs). In the past 5 years, crashes at HRIs have decreased by 30% and fatalities by 33% through concerted efforts by federal agencies such as the Federal Highway Administration and the Federal Railroad Administration. In 1998, however, more than 3,500 collisions occurred at HRIs across the United States, resulting in more than 430 deaths and more than 1,300 injuries. Many of the incidents that occur at HRIs relate back to driver behavior or engineering principles. More than 60% of the drivers involved in rail crossing accidents in 1998 never stopped at the intersection. Research personnel are developing a number of technologies, strategies, and principles all being simulated, tested, or monitored from a host of laboratories and test facilities. Current research includes design principles and geometric concerns for new and existing HRIs, signalization and signage around HRIs, automatic enforcement of HRI violations, advanced train detection for quicker emergency response, and new preemption strategies for the movement of vehicles and pedestrians in an HRI.
Descriptors	Accident causes, Accident rates, Accidents, At grade intersections, Automation, Behavior, Fatalities, Grade crossing protection systems, Railroad grade crossings, Research ,Safety, Traffic law enforcement, U.S. Federal Highway Administration, U.S. Federal Railroad Administration

Author	Transportation Research Board (TRB)
Year	1999
Title	Traffic signing, visibility, and rail-highway grade crossings
Publication	Transportation Research Record, 1692, 1999, pp 182p, Washington, DC, USA
Country	United States
Abstract	Not available

Author	Zwahlen HT, Schnell T
Year	1999
Title	Evaluation of two new crossbuck designs for passive highway-railroad grade crossings
Publication	Transportation Research Board Transportation Research Record 1692 pp 82-93
Country	United States
Abstract	Two new crossbuck designs for use at passive highway-railroad grade crossings were evaluated. The standard improved and the buckeye crossbuck were evaluated in Ohio with respect to their potential to alter driver risk-taking behavior (Part I), their accident reduction potential (Part II), user acceptance (Part III), and with respect to their photometric performance at night (Part IV). It was found that the percentage of noncompliant drivers was about the same for both crossbuck designs, with slightly more conservative risk-acceptance times obtained for the Buckeye crossbuck. Based on the past 10 years of Ohio railroad crossing (RRX) accident history, the overall number of accidents at passive RRX has continued to drop. Since the statewide installation of the two new crossbuck designs, no accident reduction pattern could be attributed to one of the two crossbuck designs. A user acceptance survey indicated an overwhelming preference for the Buckeye crossbuck among the user groups surveyed. Photometric crossbuck luminance measurements conducted under automobile low-beam illumination at night indicate that thanks to their increased reflectorization, both new designs provide superior visual stimuli to an approaching driver at night. The Buckeye crossbuck provides by far the strongest visual signal among the measured crossbucks at night. Amendments to the national standard for crossbucks at passive RRX in the "Manual on Uniform Traffic Control Devices" are recommended. Postreflectorization (four-sided) is recommended and the additional use of a striped, angled shield is recommended in situations that require a maximum visual stimulus, ensuring the shortest possible perception reaction times, and in situations that involve visual obstructions, frequent fog, or blinding snow.
Descriptors	Night, Fog, Design, Acceptance, Accident Rates, Photometry, Railroad Grade Crossings, Reaction Time, Reflectorized Materials, Risk Taking, Snow, Standards, Traffic Control Devices, Visual Perception Crossbucks, Visual Obstructions

Author	Abraham J, Datta TK, Datta S
Year	1998
Title	Driver behavior at rail-highway crossings
Publication	Transportation Research Record 1648 Railroad-Highway Grade Crossing Issues pp 28-34. Transportation Research Board (TRB), Washington, DC, USA
Country	United States
Abstract	A study of driver behavior at 37 rail-highway crossings in Michigan revealed the possible association between past crash histories and violations. Data collection included recording license plate numbers for violating vehicles, driver gender, approximate age of the driver, and the vehicle make and model. Driver violations were categorized into five different levels of severity ranging from routine to critical. The 37 study sites were subdivided into four groups based on crossing geometry and traffic control. The number of sites in the groups ranged from 5 to 18. Seven years of crash data on the study sites were considered for significance testing. Observed violation data for the same groups were calculated, and tests for statistical significance were performed on them. The results of this study indicated promise for the use of the violation data in determining the relative hazardousness of rail-highway crossings in combination with crash histories. The violation data may also be used to develop countermeasures that would help alleviate violations and eventually traffic crash problems at rail-highway crossing sites. Targeted enforcement as well should assist in driver behavioral modifications. Additionally, the timely arrival of trains after the warning devices are triggered is an essential element that motorists assess when considering taking risks.
Descriptors	Hazard evaluation, Drivers, Behavior, Behavior modification, Countermeasures, Railroad grade crossings, Traffic accidents, Traffic law enforcement, Traffic violations Railroad/highway grade crossings, Driver behavior, Grade crossing accidents

Author	Coleman F, Moon YJ
Year	1998
Title	Trapped vehicle detection system for four-quadrant gates in high speed rail corridors: design methodology and implementation issues
Publication	Transportation Research Record, 1648, 1998, pp 35-42, Transportation Research Board (TRB), Washington, DC, USA,
Country	United States
Abstract	Not available

Author	Coleman F, Moon YJ
Year	1998
Title	Validation of a four-quadrant gate simulation model: predicted versus actual gate operating values
Publication	Transportation Research Record, 1648, 1998, pp 43-50, Transportation Research Board (TRB), Washington, DC, USA,
Country	United States
Abstract	Not available

Author	National Transportation Safety Board
Year	1998
Title	National Transportation Safety Board. 1998. Safety at passive grade crossings. Volume 1: Analysis
Publication	Safety Study NTSB/SS-98/02. Washington, DC. 124 p
Country	United States
Abstract	More than 4,000 accidents occurred at the Nation's active and passive grade crossings in 1996; 54 percent of the accidents and 60 percent of the fatalities were at passive grade crossings, where drivers are not provided warning from train-activated devices. The Safety Board conducted this study to identify some common causes for accidents at passive crossings and to identify remedies to improve safety at passive crossings that are not scheduled for closure or upgrade. The sample of 60 accidents investigated by the Board as part of the study is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents. The report also relates information obtained at the Board's 1997 public forum on passive crossing safety. The safety issues include (a) the adequacy of existing warning systems to alert the driver to the presence of a passive crossing and an oncoming train; (b) roadway and track conditions that affect a driver's ability to detect the presence of an oncoming train; (c) behavioral factors that affect a driver's ability to detect the presence of an oncoming train; (d) the adequacy of existing driver education material regarding the dangers of passive grade crossings and driver actions required; (e) the need for a systematic and uniform approach to passive grade crossing safety; (f) and the need for improved signage at private passive crossings. Safety recommendations concerning these issues were made to the U.S. Department of Transportation; the Federal Highway Administration; the National Highway Traffic Safety Administration; the Federal Railroad Administration; the States; Operation Lifesaver, Inc.; the American Association of Motor Vehicle Administrators; the American Automobile Association; the American Association of State Highway and Transportation Officials; the Professional Truck Drivers Institute of America; the Advertising Council, Inc.; the Association of American Railroads; the American Short Line and Regional Railroad Association; and the American Public Transit Association.

Author	National Transportation Safety Board
Year	1998
Title	Safety at passive grade crossings. Volume 2: Case summaries
Publication	Safety Study NTSB/SS-98/03. Washington, DC. 60 p
Country	United States
Abstract	More than 4,000 accidents occurred at the Nation's active and passive grade crossings in 1996; 54 percent of the accidents and 60 percent of the fatalities were at passive grade crossings, where drivers are not provided warning from train-activated devices. The Safety Board conducted this study to identify some common causes for accidents at passive crossings and to identify remedies to improve safety at passive crossings that are not scheduled for closure or upgrade. The sample of 60 accidents investigated by the Board as part of the study is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents. The report also relates information obtained at the Board's 1997 public forum on passive crossing safety. The safety issues include (a) the adequacy of existing warning systems to alert the driver to the presence of a passive crossing and an oncoming train; (b) roadway and track conditions that affect a driver's ability to detect the presence of an oncoming train; (c) behavioral factors that affect a driver's ability to detect the presence of an oncoming train; (d) the adequacy of existing driver education material regarding the dangers of passive grade crossings and driver actions required; (e) the need for a systematic and uniform approach to passive grade crossing safety; (f) and the need for improved signage at private passive crossings. Safety recommendations concerning these issues were made to the U.S. Department of Transportation; the Federal Highway Administration; the National Highway Traffic Safety Administration; the Federal Railroad Administration; the States; Operation Lifesaver, Inc.; the American Association of Motor Vehicle Administrators; the American Automobile Association; the American Association of State Highway and Transportation Officials; the Professional Truck Drivers Institute of America; the Advertising Council, Inc.; the Association of American Railroads; the American Short Line and Regional Railroad Association; and the American Public Transit Association.

Author	Noyce DA, Fambro DB
Year	1998
Title	Enhanced traffic control devices at passive highway-railroad grade crossings
Publication	Transportation Research Board Transportation Research Record No. 1648 pp 19-27
Country	United States
Abstract	More than 2,000 crashes and 239 fatalities were reported at public passive highway-railroad grade crossings in 1994. Driver error, often due to a breakdown in communication between the traffic control devices and the driver, is commonly cited as a factor in passive grade crossing crashes. The objective of this study was to evaluate an improved method for communicating with drivers in an effort to improve safety at passive grade crossings. Specifically, this study evaluated the effectiveness of a vehicle-activated strobe light and supplemental sign as enhancements to the railroad advance (W10-1) warning sign at a passive highway-railroad grade crossing near Temple, Texas. Three study methods were used to evaluate this enhanced sign system including a before and after speed study, a driver survey, and a driver observation study. The results indicated that average speeds on the approaches to the grade crossing were lower after the installation of the enhanced sign system. Drivers responded favorably to the enhanced sign system, and no adverse driver reactions were observed at the onset of the flashing strobe light. The strobe light was effective in directing drivers' attention to the railroad advance warning and supplemental signs. The enhanced sign system appears to increase driver awareness of the passive grade crossing, cause some drivers to approach the grade crossing with additional caution, and reduce the average speed near the nonrecovery zone on both approaches.
Descriptors	Average Speed, Awareness, Before And After Studies, Driver Behavior, Drivers (Vehicle), Effectiveness, Field Observation, Grade Crossing Safety, Railroad/Highway Grade Crossings, Sign Design, Strobe Light, Surveys (Data Collection), Vehicle Speed

Author	Russell ER, Cathcart A, Brunson C
Year	1998
Title	The Kansas grade crossing consolidation program
Publication	International Symposium on Railroad-Highway Grade Crossing Research and Safety, 5th, 1998, Knoxville, Tennessee, USA 1999-04, pp 223-33, University of Tennessee. Transportation Center, Knoxville, Tennessee, USA
Country	United States
Abstract	Not available

Author	Transportation Research Board
Year	1998
Title	Railroad-highway grade crossings issues
Publication	Transportation Research Record, 1648, 1998, pp 50p, Transportation Research Board (TRB), Washington, DC, USA
Country	United States
Abstract	Not available

Author	U.S. Department of Transportation Research and Special Projects Administration & Volpe National Transportation Systems Center
Year	1998
Title	Evaluation of Retroreflective Markings To Increase Rail Car Conspicuity –Safety of Highway-Railroad Grade Crossings
Publication	R9071/RR997
Country	United States
Abstract	The purpose of this study was to develop guidelines and recommendations for the design of retroreflective marking systems to enhance the conspicuity of rail cars at night. Three methods were used to generate and evaluate the marking systems for a standard hopper car. First, a group of human factors and transportation engineers used the Nominal Group Technique to generate candidate retroreflective marking systems. Secondly, two panels, one comprised of individuals with expertise in the area of conspicuity markings and one without this expertise, made subjective judgements as to the effectiveness of the marking systems. Finally, a computer controlled real-time experiment was conducted to establish the relative performance of the systems based on detection and recognition times. The evaluations indicated that any of the retroreflective systems tested improved rail car conspicuity when compared to a nonreflective marking. The data suggest that bright colors distributed to give an indication of the size or shape of the rail car were most effective, and distributions that concentrated the markings along the lower side of the car were less effective, regardless of the color pattern. For detection the fluorescent yellow was the most effective color pattern regardless of the distribution pattern. However, for recognition, fluorescent yellow or red, i.e., single color patterns, were more effective than a color pattern made up of red and white. Additional studies should be performed to determine the dynamic effectiveness of different color and distribution patterns when fitted to different types of rail cars.

Author	Zwahlen HT, Schnell T
Year	1998
Title	Unobtrusive driver behavior measurements at passive railroad-highway grade crossings equipped with new crossbuck designs
Publication	International Symposium on Railroad-Highway Grade Crossing Research and Safety, 5th, 1998, Knoxville, Tennessee, USA SO: 1999-04, pp 113-29, University of Tennessee. Transportation Center, Knoxville, Tennessee, USA
Country	United States
Abstract	Not available

Author	Zwahlen HT, Schnell T
Year	1998
Title	Advances in passive railroad-highway grade crossing protection: the photometric performance of the buckeye crossbuck
Publication	International Symposium on Railroad-Highway Grade Crossing Research and Safety, 5th, 1998, Knoxville, Tennessee, USA 1999-04, pp 131-45, University of Tennessee. Transportation Center, Knoxville, Tennessee, USA
Country	United States
Abstract	Not available

Author	Fambro DB, Noyce DA
Year	1997
Title	Enhanced traffic control devices and railroad operations for highway-railroad grade crossings
Publication	Project Summary Report, 1469-S, 1997-11, pp 26p, Texas Transportation Institute, College Station, Texas, USA; PUB: Texas. Department of Transportation, Austin, Texas, USA; Report, FHWA/TX-98/1469-S, PUB: United States. Federal Highway Administration (FHWA)
Country	United States
Abstract	Not available

Author	Federal Railroad Administration
Year	1997
Title	Grade highway-rail crossing accident/incident and inventory bulletin number 19
Publication	Federal Railroad Administration
Country	United States
Abstract	This eighteenth annual report combines Highway-Rail Crossing Accident/Incident statistics with the National Highway-Rail Crossing Inventory. Accident/Incident data are compiled from monthly reports filed by railroads. The National Highway-Rail Crossing Inventory contains sight-survey data about individual crossings and is provided voluntarily by states and railroads. Information on accidents/incidents and crossings is presented in the following sequence: Historical data on highway-rail crossing accidents/incidents at public crossings; Summary of 1996 accidents/incidents that occurred at public crossings sites; Physical and operational statistics for all public at-grade highway-rail crossings as described in the inventory on July 19, 1997; and Summary of 1996 accidents/incidents occurring at private highway-rail crossings and tabulations of private crossings in the inventory. The majority of the accident tables and charts shown in this bulletin provide information on motor vehicle accidents. Those tables and figures that do not refer to motor vehicle in their title contain data for all accidents/incidents.

Author	Hintersteiner RT
Year	1997
Title	Railroad grade crossing accidents
Publication	Institute of Transportation Engineers 67th Annual Meeting Sponsored by: Institute of Transportation Engineers Location: Boston, MA August 1997
Country	United States
Abstract	This paper will address the traffic signal preemption crisis at railroad-highway grade crossings in the United States. A railroad-highway grade crossing occurs where a public or private roadway crosses railroad tracks. Over the years, there have been many studies and programs to warn the general public of the hazards of crossing railroad tracks. However, the same types of railroad-highway crossing accidents continue to occur, despite attempts to educate the public. This paper also dicusses how communication problems among transportation professionals, and coordination of railroad and highway operations, also contribute to this crisis. The paper is divided into the following categories: roadway design; railroad regulations; vehicle operations; traffic signals at railroad grade crossings; and the preemption problem.

Author	Hakkert AS, Gitelman V
Year	1997
Title	Development of evaluation tools for road-rail crossing consideration for grade separation
Publication	Transportation Research Record 1605 pp 96-105
Country	United States
Abstract	A program for expansion of Israeli railways has resulted in increased train speeds and frequencies on the most heavily used railway lines. These are situated in highly populated regions and are characterized by a significant amount of at-grade road-rail crossings. At-grade crossings present a barrier to road traffic and the danger of train-vehicle collisions. Because the current maximum train speed is about 120 km/hr, there was no clear policy concerning the need and the priority for grade separation at crossings. Simplified tools for rapid crossing evaluation when a crossing potential for grade separation is reviewed were developed. The evaluation tools include a criterion for preliminary crossing qualification and a formula for approximate evaluation of economic losses caused by at-grade crossing functioning. The field measurements and detailed investigation of the 31 most problematic locations provided a basis for building the tools. Two main factors leading to grade separation were considered: safety problems at the crossings and road vehicle delay costs. As demonstrated, the cost of accident risk at Israeli crossings does not significantly affect their ranking for grade separation. In consequence, the crossing parameters influence vehicle delays that constitute the basis for the simplified tools for preliminary crossing evaluation in Israel.
Descriptors	Criteria, Economic Factors, Evaluation (Assessment), Formulas, Grade Separations, Israel, Qualifications, Railroad/Highway Grade Crossings, Safety, Traffic Delay Costs

Author	Jacobson MS
Year	1997
Title	An investigation of traffic signal preemption at railroad-highway grade crossings
Publication	In - Compendium: Graduate Student Papers on Advanced Surface Transportation Systems". Page range: pp Ii-Iiv, I1-I33. Published by Texas Transportation Institute
Country	United States
Abstract	The first step in initiating preemption at a railroad-highway grade crossing is to detect an approaching train. This report provides a detailed investigation of current methods of traffic signal preemption and the problems that are encountered. Those technologies that have been applied in the area of light-rail transit signal priority that have the potential to be adapted to increasing the available warning time at railroad-highway grade crossings are identified. The report concludes by providing a new strategy to improve the safety and efficiency of signal preemption at railroad-highway grade crossings. The issues surrounding signal preemption were obtained through a literature review. Telephone interviews of highway and railroad agencies were conducted to assess the current signal preemption practices. Manufacturers of detection technologies in current use for transit priority systems were interviewed to determine which systems could best be adapted to the railroad-highway grade crossing environment. The literature survey and telephone interviews indicated that a detection device that utilizes a Global Positioning System (GPS) receiver and a two-way radio could best be adapted to provide increased warning time to the traffic signal controllers that a train was approaching the crossing. With the additional warning time that would be provided using the new technology, the traffic signal controller could use the Transitional Preemption Strategy that was developed in this research to help improve the safety and operational efficiency of the crossing environment.
Descriptors	Global Positioning Systems, Interviews, Literature Surveys, Operational Efficiency, Preemption, Railroad/Highway Grade Crossings, Safety, Two Way Communication, Warning Time

Author	Meeker F, Fox D, Weber C
Year	1997
Title	A comparison of driver behavior at railroad grade crossings with two different protection systems
Publication	Accid Anal Prev 1997 Jan; .29(1):11-6
Country	United States
Abstract	An observational study was conducted which compared the behavior of drivers at a railroad-highway grade crossing as trains approached. The effectiveness of a flasher-only protection system was compared with one incorporating flashers and barrier gates for a particular crossing. The addition of the gates significantly reduced the percentage of drivers crossing in front of trains from 67% to 38%. Plots of crossing probabilities showed them reduced as time until train arrival and the distance of the train from the crossing decreased. Train speed did not seem logically related to the probability of crossing perhaps because it is not well perceived. Drivers crossing around barrier gates tended to stop or slow on approach significantly less than those crossing with flashers only. It was suggested that the gates themselves provided an impediment to crossing which forced drivers inclined to cross into making a hurried and sometimes perilous decision. Their behavior was seen as explaining the surprisingly high number of accidents that occur at barrier-gate crossings. Discouraging drivers from driving around barrier gates was seen as essential if safety at these crossings was to be improved. Extending the length of gates and the education of the drivers regarding the law were seen as possible ways of increasing compliance.

Author	Russell ER, Rys M, Kovvali V
Year	1997
Title	A new train-illuminated sign for highway-railroad grade crossing
Publication	International Road Federation XIIIth World meeting of the International Road Federation Location: Toronto, Canada Date Held: 19970616-19970620
Country	United States
Abstract	There are approximately 170,000 public highway-railroad crossings at grade in the USA. About 65% of these are on low-volume roads and have no automated warning devices (passive grade crossings). Upgrading these passive crossings to automatic, train activated warning devices (active grade crossings) is not cost-effective because of the low highway traffic volumes involved. The need for effective, low cost device at these crossings has become apparent. The paper describes Passive Warning Sign (PWS) that has no lights or electrical connections, but is designed to light up and have 'an active look' as a train locomotive approaches the grade crossing. The sign was evaluated in many adverse environmental conditions; and it was concluded that the PWS sign is effective under all conditions when illuminated by the train's headlights. The paper details the experimental use of the sign at two grade crossings, and the study design conducted to evaluate its effectiveness.
Descriptors	Cost Effectiveness, Grade Crossing Safety, Grade Crossing Signals, Passive Safety Systems, Warning Signals

Author	Carroll AA, Helser JL
Year	1996
Title	Safety of highway-railroad grade crossings research needs workshop volume 1
Publication	DOT-VNTSC-FRA-95-12.1, DOT/FRA/ORD-95/14.1
Country	United States
Abstract	The Federal Railroad Administration (FRA) recently developed the DOT Action Plan for Rail-Highway Grade Crossing Safety. The objective is to achieve at least a 50% reduction in accidents and fatalities at grade crossings over the next 10 years. The Volpe National Transportation Systems Center hosted and conducted the Highway-Railroad Grade Crossing Safety Research Needs Workshop; 75 delegates participated in the workshop and identified 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.
Descriptors	federal railroad administration, grade crossing accidents, grade crossing safety, high speed ground transportation, intermodal transportation, railroad/highway grade crossings, research needs, workshops (meetings)

Author	Department of Transportation USA
Year	1996
Title	Accidents that shouldn't happen
Publication	Department of Transportation
Country	United States
Abstract	At 7:10 a.m. on October 25, 1995, a school bus transporting 35 high school students stopped at a highway-rail crossing in Fox River Grove, Illinois, and was struck by a commuter train. Seven students died in this tragedy. Following this accident The United States Department of Transportation was ordered to form an internal task force to review the decision making process for designing, constructing, and operating rail crossings. The task force identified 5 problem areas which signified gaps in their knowledge. The five areas include: 1. Interconnected Highway Traffic Signal and Highway-Rail Crossing Warning Devices (Interconnected Signals); 2. Available Storage Space for Motor Vehicles Between Highway-Rail Crossings and Adjacent Highway-Highway Intersections (Storage Space); 3. High-Profile Crossings and Low-Clearance Vehicles (High-Profile Crossings); 4. Light Rail Transit Crossings (Light Rail); 5. Special Vehicle Operating Permits and Information (Special Vehicles). This report looks at what the task force learned about these 5 areas of study, and the recommendations they suggested. Supplemental Information: A Report of the Grade Crossing Safety Task Force to Secretary Frederico Pena.
Descriptors	Intersections, light rail, railroad grade crossing accidents, railroad grade crossings, railroad/highway grade crossings, school bus accidents, school buses, storage, traffic signals, warning devices

Author	Dolan L
Year	1996
Title	Are Minnesotans aware of the dangers of railroad crossings?
Publication	Research Report, MN/RC-96/11, 1996-04, pp 39p, Minnesota. Department of Transportation, St Paul, Minnesota, USA
Country	United States
Abstract	The purpose of this study was to identify the perceptions of Minnesotans regarding the dangers of railroad crossings. This study used market research tools such as focus groups and a 500-person telephone survey to determine this information. Results indicated that most Minnesotans do not perceive railroad crossings as dangerous because they rely on the flashing red warning lights at the railroad crossings to inform them of an approaching train. At the same time, they view railroad crossing crashes as a serious safety issue. Installing street lights at dark crossings and installing a flashing light next to the railroad crossing stop sign and the railroads advance warning sign would help reduce railroad crossing crashes. The survey indicated that most Minnesotans would call a 1-800 number to report a railroad crossing problem. The most frequent problems Minnesotans experience at railroad crossings are being blocked by a train for an unreasonable amount of time, having difficulty judging how soon the train would be at the crossing and being stopped at a railroad crossing when no train was present. Lastly, Minnesotans support increasing railroad crossing safety education in Minnesota.

Author	Klein T, Morgan T, Weiner A
Year	1996
Title	Rail-highway crossing safety: fatal crash and demographic descriptors
Publication	International Technical Conference on the Enhanced Safety of Vehicles, 15th, 1996, Melbourne, Victoria, Australia Report, DOT HS 808 465, 1996-10, pp 1530-7, United States. National Highway Traffic Safety Administration (NHTSA), Washington, DC, USA
Country	United States
Abstract	This report was prepared as part of the June 1994 Departmental Rail-Highway Crossing Safety Action Plan. Initiative VB (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 occurring at intersections and all fatal crashes. Data from the National Highway Traffic Safety Administration's (NHTSA's) Fatal Accident Reporting System, supplemented with information from Claritas, a commercially available geodemographic database, were used to provide the descriptive statistics.

Author	Stackhouse S
Year	1996
Title	Effectiveness of marketing campaigns for grade crossing safety
Publication	Report, MN/RC-1998/02, 1996-09, pp 13p + appendix, Minnesota. Department of Transportation, St Paul, Minnesota, USA
Country	United States
Abstract	Not available

Author	Transportation Research Board (TRB)
Year	1996
Title	Traffic control devices, visibility, and evaluations
Publication	Transportation Research Record, 1553, 1996, pp 140p, Transportation Research Board (TRB), Washington, DC, USA,
Country	United States
Abstract	Not available

Author	Brich SC
Year	1995
Title	Investigation of retroreflective sign materials at passive railroad crossings
Publication	Report, VTRC 95-R22, 1995-06, pp 35p, Virginia Transportation Research Council, Charlottesville, Virginia, USA
Country	United States
Abstract	The goal of this study was to determine the best configuration of retroreflective material on railroad crossing (crossbuck) signs and posts for improving the visibility and safety of passive highway- railroad grade crossings at night. The material costs of upgrading existing crossbucks with the retroreflectorized crossbuck systems were also explored. Five configurations for marking crossbucks and posts were developed and installed at five passive grade crossings on the Virginia Southern Railroad line. At each crossing, photographs of each approach were taken at night using only the low beams and high beams of a vehicle for illumination. To supplement the photographs, researchers videotaped driving through the crossings at night. Each location was driven through twice, once with low beams and once with high beams. Researchers also videotaped a train travelling through each crossing. The photographs and videotape were used as the media for a subjective analysis of which of the five systems was most visible at night. The subjective analysis consisted of one-on-one interviews with 19 individuals watching the videotapes of the systems and answering a questionnaire survey. Although the sample size was limited by the time constraints of the study, results indicated that the double-sided crossbuck with retroreflective material along the full length of both sides of both posts was preferred. If used throughout the Commonwealth, this system will improve: (1) the visibility of the crossing; (2) the uniformity with which passive crossings are marked; (3) the driver's depth perception of the crossing; and (4) the driver's ability to detect a train in the crossing.

Author	Not reported
Year	1995
Title	Kansas, CDC profile grade-crossing deaths, look for solution
Publication	Highway & Vehicle Safety Report, 1995, Vol 22, No 3, pp 5
Country	United States
Abstract	Not available

Author	TranSafety, Incorporated
Year	1995
Title	Motorists killed in railroad crossing accidents: what characteristics do they share?
Publication	TranSafety Reporter Volume: 13 Issue: 4 Pagination: pp 6-8
Country	United States
Abstract	A November 1994 National Highway Traffic Safety Administration Technical Report describes a research study on the demographics of motorists killed in railroad crossing accidents. The aim of the study was to develop a motorist profile to facilitate design and distribution of targeted countermeasures that would reduce railroad crossing fatalities. This article describes the data that was compiled in seven categories: fatal crashes, traffic control devices, roadway characteristics, state statistics, involvement by vehicle type, drivers involved, and Claritas (a commercial data base that divides the United States population into 3,500 groups by zip code). The report was a product of the United States Department of Transportation's Rail-Highway Crossing Safety Action Plan.
Descriptors	countermeasures, demographic studies, driver characteristics, fatal accident reporting system, fatal accidents, highway characteristics, national highway traffic safety administration, population statistics, railroad grade crossing accidents, railroad grade crossings, research report, safety, states, traffic control devices, vehicle type

Author	Transportation Research Board (TRB)
Year	1995
Title	Traffic control devices, visibility, and railroad grade crossings
Publication	Transportation Research Record, 1495, 1995, pp 170p, Transportation Research Board (TRB), Washington, DC, USA, 0361-1981, 0-309-06160-1
Country	United States
Abstract	Not available

Author	US Department of Transportation & Volpe National Transportation Systems Center
Year	1995
Title	Safety of Highway-Railroad Grade Crossings: Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity
Country	United States
Abstract	Historically, highway-railroad grade crossings have represented a major hazard to motor vehicle drivers. The Federal Railroad Administration (FRA), U.S. Department of Transportation (USDOT) has initiated a comprehensive research program to address grade crossing safety issues in order to reduce the number of train-motor vehicle collisions. One area of study investigates measures to improve the ability of motor vehicle drivers to detect the approach of the train at grade crossings by enhancing train conspicuity. The FRA has identified several types of auxiliary external alerting light arrangements as acceptable locomotive conspicuity measures and issued two Interim Rules in 1993 and 1994. This study investigated the performance of currently available external visual alerting devices for installation on locomotives. A variety of passive (paint schemes and reflective materials) and active (lights) systems were reviewed. These devices were evaluated in terms of their ability to assist the motorist to: (1) detect the approaching train, (2) recognize the potential of the hazard, and (3) estimate its approach, and thus avoid a collision with a train at a grade crossing. Controlled field testing was conducted to measure the effect of selected locomotive alerting light systems on observers. In-service railroad test operational experience for locomotives equipped with crossing lights, used in combination with the standard headlight, was also evaluated in terms of capital costs, maintenance, operational concerns, and accident data. The results of the controlled field tests indicate that the use of selected alerting light systems, rather than use of the standard headlight alone, is an effective means of enhancing locomotive visibility. The preliminary in-service accident data provided by participating railroads indicates a potential for significant accident rate reduction with the use of the crossing light system.

Author	Coleman F, Eck RW, Russell ER
Year	Not available
Title	Railroad-Highway Grade Crossings A Look Forward
Country	United States
Abstract	This is a white paper on the state of the art and the state of the practice on railroad-highway grade crossings with a look to the future. In order to look to the future and understand where we are today, it is important to recognize that grade crossing safety is and has been an evolutionary development of operating practices, laws, and institutional responsibilities. Then and now, their purpose is to make the interaction between trains and vehicles at grade crossings as safe as possible while acknowledging and minimizing adverse impacts to other characteristics. Engineering and operating practices from the highway and rail modes alone cannot achieve the level of safety desired. Education of the public and enforcement of laws to encourage desirable driver behavior are also major factors. Therefore, organizations such as Operation Lifesaver and law enforcement agencies have key roles today and in the foreseeable future. Because of length imitations, this white paper will not address pending federal or state legislation as it applies to this discussion. Passive traffic control devices provide static messages of warning, guidance, and in some instances, mandatory action for the driver. Active traffic control devices are those that give warning of the approach or presence of a train. They are activated by the passage of a train over a detection circuit in the track. Active control devices are supplemented with the same signs and pavement markings that are used for passive control.

Author	Bartoskewitz RT, Fambro DB, Richards HA
Year	1994
Title	Texas highway-rail intersection field reference guide
Publication	Research Report, 1273-2F, 1994-05, pp 164p, Texas Transportation Institute, College Station, Texas, USA; PUB: Texas. Department of Transportation, Austin, Texas, USA; Report, FHWA/TX-94/1273-2F, PUB: United States. Federal Highway Administration
Country	United States
Abstract	The design, construction, operation and maintenance of highway-rail intersections present unique challenges to both highway and railroad engineers. The railroad grade crossing represents the physical intersections of two distinctly different modes of transportation, each of which varies considerably in terms of their equipment, travelled ways, and methods of control and operation. Safety at highway-rail intersections has been a national priority for over two decades. Substantial reductions in crashes, injuries, and fatalities have been realised as a result of grade crossing improvement programs. Grade crossing safety has reached a point where further safety improvements will likely require the development of new approaches and innovative technologies. Proper design and construction of new grade crossings ensures safe and efficient operation. Proper maintenance of existing crossings helps to achieve continued safety and efficiency. The field guide has been developed to assist agencies responsible for the design, construction, operation and maintenance of highway-rail intersections in the performance of these responsibilities. It is a reference source for city, country and state personnel who must address these issues as part of their official duties. Railroad personnel will find the reference guide helpful in obtaining a basic understanding of highway and traffic engineering concerns with regard to highway-rail intersections. The guide includes information on problem identification and engineering studies, improvement alternatives, special programs and activities, and key reference documents.

Author	Fambro DB, Beitler MM, Hubbard SM
Year	1994
Title	Enhancements to passive warning devices at railroad-highway grade crossings
Publication	Research Report, 1273-1, 1994-06, pp 240p, Texas Transportation Institute, College Station, Texas, USA; PUB: Texas. Department of Transportation, Austin, Texas, USA; Report, FHWA/TX-94/1273-1, PUB: United States. Federal Highway Administration
Country	United States
Abstract	The current passive signing system for railroad-highway grade crossings is used at both actively and passively controlled crossings. A sign system unique to passively controlled crossings which conveys to the driver his or her responsibility is needed. This research developed two experimental passive signing systems and tested driver comprehension, understanding, and reaction to them under both laboratory and field conditions. The experimental signs were installed at 90 crossings in three Texas counties, with eight crossings identified as test crossings. A before and after study was conducted at each of the eight test crossings. Quantitative measures of driver speeds on the approaches to these crossings, as well as qualitative measures of driver looking behaviour and driver responses to exit surveys, were analysed. The results of these analyses indicate that both sign systems performed well in the field. The results suggest a decrease in driver speed on the approach, an increase in driver looking behaviour, and a positive driver opinion of the sign system. Driver ability to recall signs seen on the approach to the crossing improved from 39 percent for the before condition to 78 percent for the after condition. The survey also indicated that drivers do not know the meaning of the advance warning sign and are unaware of the action required by the advance warning sign. The results of the study indicate promise of increased safety at passive railroad-highway grade crossings. It is recommended that these signs be installed at additional crossings and evaluated over longer periods of time to investigate possible novelty effects that may be occurring.

Author	Klein T, Morgan T, Weiner A
Year	1994
Title	Rail-highway crossing safety: fatal crash and demographic descriptors
Publication	Report, DOT HS 808 196, 1994-11, pp 61p, United States. National Highway Traffic Safety Administration, Washington, DC, USA
Country	United States
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 reports compares fatal motor vehicle rail crossing crashes with fatal crashes occurring 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.

Author	Keller AS, Rickley EJ
Year	1993
Title	The safety of highway-railroad grade crossings: study of the acoustic characteristics of railroad horn systems
Publication	DOT/FRA/ORD-93/25, 1993-07, pp 74p, United States. Federal Railroad Administration. Office of Research and Development, Washington, DC, USA; DOT-VNTSC-FRA-93-1, PUB: United States. John A Volpe National Transportation Systems Center, Cambridge, Massachusetts, USA
Country	United States
Abstract	The US Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration, is conducting a research program with the goal of reducing the number of fatalities and injuries at highway-railroad grade crossings. As a part of this program, the Volpe Center's Noise Measurement and Assessment Facility is conducting a study to determine the effectiveness of railroad horn systems. This document is the first publication supporting this study. It presents the results of acoustic measurements performed in Council Bluffs, Iowa; Jacksonville, Florida; Cambridge, Massachusetts; and Omaha, Nebraska, to determine the acoustic characteristics of several types of railroad horn systems. Data obtained includes frequency spectrum, directivity, drop-off rate, maximum A-weighted sound level, and sound exposure level.

Author	Bridwell N, Alicandri E, Fischer D, Kloeppel E
Year	1993
Title	A preliminary laboratory investigation of passive railroad crossing signs
Publication	Report, FHWA/RD-93-153, 1993-12, pp 26p, United States. Federal Highway Administration. Office of Engineering and Highway Operations R&D, McLean, Virginia, USA
Country	United States
Abstract	In 1990, 2,378 accidents, or 47% of all accidents that occurred at grade crossings, occurred at passively signed crossings. This demonstrates the need for an effective passive device at railroad crossings to warn motorists and reduce the number of train-vehicle accidents. The object of this study was to determine the relative effectiveness of seven candidate passive railroad crossing signs, including the current standard crossbuck. Forty-two young/middle aged (25 to 45 years) and forty-two older (65 to 85 years) subjects were tested in the experiment. Data on recognition distance, conspicuity, and comprehension were collected. The results showed no differences between signs for recognition distance. There were statistically significant differences for the conspicuity measure, with the signs falling into three overlapping groups. The Standard-Yield combination, Standard with Barber-Striped pole, and the Canadian-Conrail combination scored in the highest conspicuity group. The Standard-Conrail combination sign was at the midrange of the conspicuity scores. The Manual on Uniform Traffic Control Devices (MUTCD) Standard and the Canadian Crossbuck showed the worst conspicuity scores. Detailed analyses of the comprehension (meaning and action) responses showed that subjects would take the correct action between 33% and 100% of the time as a function of the different signs. The best responses were for the Yield to Trains configuration and the Standard-Yield combination. The worst responses were for the MUTCD Standard and the Canadian Crossbuck. The results of this study suggest that further evaluation is needed. The Standard-Yield combination, the Standard-Conrail combination, and the Yield to Trains combination appear to be good candidates for additional testing.

Author	Meeks KD, Robertson LS
Year	1993
Title	Study of road-rail crashes in Claremore, OK, and allocation of resources for preventive measures
Publication	Public Health Rep 1993 Mar-Apr;108(2):248-51
Country	United States
Abstract	Road-rail crossings where a train and motor vehicle crashed were compared with the next crossing in the direction from which the train travelled at the same time of day and day of week of the crash. The odds of a crash were much lower at crossings with automatically lowered gates (odds ratio = 0.11). Average road traffic was much higher at crash sites; the presence of automatic gates was unrelated to the volume of road traffic. Federally funded modifications of road-rail crossings have substantially reduced deaths at such sites. The program would be more cost effective, however, if criteria for highest risk sites were applied more systematically, and funds were apportioned among the States according to their relative proportions of the problem.

Author	U.S Department of Transportation Research and Special Programs Administrations & Volpe National Transportation Center
Year	1993
Title	The Safety of Highway-Railroad Grade Crossings: Study of the Acoustic Characteristics of Railroad Horn Systems
Country	United States
Abstract	The U.S. Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration is conducting a research program with the goal of reducing the number of fatalities and injuries at highway-railroad grade crossings. As part of this program, the Volpe Center's Noise Measurement and Assessment Facility is conducting a study to determine the effectiveness of railroad horn systems. This document is the first publication supporting this study. It presents the results of acoustic measurements performed in Council Bluffs, Iowa, Jacksonville, Florida, Cambridge, Massachusetts, and Omaha, Nebraska, to determine the acoustic characteristics of several types of railroad horn systems. Data obtained includes frequency spectrum, directivity, drop-off rate, maximum A-weighted sound level, and sound exposure level.

Author	Walters CH, Venglar SP, Fambro DB, Daniel JR
Year	1993
Title	Development of analytical tools for evaluating operations of light-rail at-grade within an urban signal system - interim report
Publication	Research Report, 1278-1, 1993-03, pp 71p, Texas Transportation Institute, College Station, Texas, USA; Texas. Department of Transportation, Austin, Texas, USA; Report, FHWA/TX-93/1278-1, PUB: United States.
Country	United States
Abstract	This document provides a comprehensive, state-of-the-art review of the operation and control strategies of light rail transit systems. It is intended to serve as a basis for further research in the goals of developing an analytical tool for evaluating the operations of light rail at-grade within an urban signal system. The report identifies the various at-grade crossing types that can exist for a light rail transit system, the operating characteristics of light rail vehicles, and the use of control devices at at-grade crossings. The intent of the report is also to summarize both the priority strategies used by transit agencies and the methods of evaluation used to assess the impacts of light rail transit systems. Simulation has been proposed as a method of analysis; therefore, a summary describing the operation of three applicable computer simulation packages is provided. An appendix of this document provides the minutes of both the technical and steering committee meetings for the project. The minutes are an integral part of the project and have had a significant impact on the study focus, especially in avoiding the duplication of research effort.

Author	Brewer KA
Year	1992
Title	Drivers' behavior at railroad grade crossings: before and after safety campaign. Final report
Publication	Iowa Department of Transportation Highway Division Report No: ERI Proj 3440 ,Iowa DOT Proj HR-335 ,ISU-ERI-Ames-92167
Country	United States
Abstract	In April 1991 the Iowa Department of Transportation, the CNW Transportation Company, the SOO Line, and local agencies and business in the Mason City/Clear Lake area initiated an Operation Lifesaver program to attempt to increase public awareness of safety issues and safe behavior at railroad-highway grade crossings. This document reports an initial study of data on traffic characteristics at a selected set of grade crossings in Cerro Gordo County taken before and after the safety program. Twenty-two crossings were studied. The 13 crossings at which collisions were reported for the five years prior to the study were included in the sample of sites. Two field observations were made at each study crossing before the Operation Lifesaver campaign was in full swing, and two observations were made after the conclusion of the main effort of the campaign. The summary of each data set is contained in a companion volume. The research shows that Operation Lifesaver altered drivers' behavior in the following ways: (1) reduced approach speeds and crossing speeds at crossings with low speed limits, (2) reduced the percent of drivers approaching the crossing at speeds in excess of the posted speed limit, and (3) increased alertness of drivers to railroad crossing hazards as evidenced by more drivers looking for a clear track. Thus, Operation Lifesaver enhanced safety in street and highway traffic operations in the vicinity of railroad-highway grade crossings.
Descriptors	alertness, before and after studies, driver behavior, field observation, Iowa, railroad/highway grade crossings, safety programs, speed

Author	Russell ER
Year	1992
Title	Innovative passive device studies and demonstrations currently being conducted in the United States and Canada
Publication	Transportation Research Record Issue: 1368 pp 39-48
Country	United States
Abstract	In the late 1960s a flurry of new warning devices were proposed to improve conspicuity, or driver awareness, or understanding, or all three at railroad-highway crossings. A period of little or no activity in regard to these devices followed, probably because the emphasis in the 1970s and 1980s was on upgrading grade crossings to active warning devices on a priority basis. Most high-volume grade crossings have now been upgraded; however, thousands of passive grade crossings on low-volume roads exist where expensive active devices cannot be justified on a cost-effective basis. Thus, low-cost, innovative devices that are more effective have drawn renewed interest that will likely continue throughout the 1990s. Most of the devices presented are too new to be reported in the published literature. Most are in the early development stage and some have yet to be proven or studied adequately. However, the argument is presented that if a successful effort is to be made in the area of low-cost, innovative devices for low-volume grade crossings, a coordination of effort is needed, starting with an awareness of these as-yet fragmented studies. Brief backgrounds of innovative devices and discussion of recent efforts include the Conrail device (Ohio and Kansas); new retroreflective materials (Arizona, Minnesota, Vermont, and Nebraska); retroreflective trackside objects (Arizona); a proposed 3M/BN passive warning sign; a proposed adaptation of the variable aspect signs to be used at grade crossings; a Texas study to enhance the effectiveness of the current, standard crossbuck; a human factors study being conducted at the FHWA Turner Fairbank research facility; a Canadian study of new sign systems at passive crossings using intermediate signs; and before and after study of the effects of an Operation Lifesaver media blitz on driver behavior at crossings. Supplemental Information: This paper appears in Transportation Research Record No. 1368, Traffic Control Devices and Highway Visibility.
Descriptors	Canada, crossbuck signs, driver behavior, grade crossing protection, human factors, low cost, low volume roads, railroad/highway grade crossings, retroreflective materials, technological innovations, united states, variable-aspect signs, warning signs

Author	Hauer E
Year	1990
Title	Empirical Bayes approach to the estimation of "unsafety": the multivariate method
Publication	Report, FHWA-RD-90-006, 1990-03, pp 62p, United States. Federal Highway Administration. Office of Safety and Traffic Operations R and D, McLean, Virginia, USA; PUB: Transport Canada
Country	United States, Canada
Abstract	There are two kinds of clues to the unsafety of an entity: its traits (such as traffic, geometry, age or gender) and its historical accident record. The essence of the Empirical Bayes (EB) approach to the estimation of unsafety is that it uses both clues. How this is accomplished is described. To estimate the unsafety of an entity using the EB approach, information is needed about the mean and the variance of the unsafety of similar entities which form its reference population. The Method of Sample Moments has been used for this purpose in the past. It suffers from three shortcomings. First, to yield useable estimates a very large reference population is required. Second, the choice of reference population is to some extent arbitrary. Third, entities in the chosen reference population usually cannot match the traits of the entity the unsafety of which is estimated. To alleviate these shortcomings the Multivariate Method for estimating the mean and variance of unsafety in reference populations is offered. Its logical foundations are described and its soundness is demonstrated. The use of the Multivariate Method makes the EB approach to unsafety estimation applicable to a wider range of circumstances, it makes the decision about what entities to include in the reference population less arbitrary and it yields better estimates of unsafety. The applications of the EB and Multivariate Methods to tasks of identifying deviant entities and estimating the effect of interventions on unsafety are discussed and illustrated by numerical examples.

Author	Heathington KW, Richards SH, Fambro DB
Year	1990
Title	Guidelines for the use of selected active traffic control devices at railroad-highway grade crossings
Publication	Transportation Research Record, 1254, 1990, pp 50-9
Country	United States
Abstract	Not available

Author	Richards SH, Heathington KW, Fambro DB
Year	1990
Title	Evaluation of constant warning times using train predictors at a grade crossing with flashing light signals
Publication	Transportation Research Record, 1254, 1990, pp 60-71
Country	United States
Abstract	Not available

Author	Richards SH, Heathington KW
Year	1990
Title	Assessment of warning time needs at railroad-highway grade crossings with active traffic control
Publication	Transportation Research Record, 1254, 1990, pp 72-84
Country	United States
Abstract	Not available

Author	Meeker FL, Barr RA
Year	1989
Title	An observational study of driver behavior at a protected railroad grade crossing as trains approach
Publication	Accid Anal Prev Jun;21(3):255-62
Country	United States
Abstract	Observations were made of 57 drivers who approached a rural rail grade crossing in the presence of activated warning flashers signalling an approaching train. Two thirds of the drivers crossed the tracks in front of the approaching trains. All but four drivers, however, slowed perceptibly or stopped prior to crossing. The probability of crossing was seen to vary reliably with distance of the trains from the crossing and the time available to cross (safety margin). It was concluded that, as a group, the drivers' decision to cross was a considered one that was based on an accurate perception of available evidence.

Europe

Author	Institute of Transportation Engineers
Year	1998
Title	Europe's approach to rail crossing safety
Publication	ITE Journal Volume 68(2):18
Country	Europe
Abstract	To learn how other countries with high-speed rail operations and large numbers of grade crossings addressed issues of rail crossing safety, the Federal Highway Administration (FHWA) sponsored an international technology reconnaissance tour to Denmark, the Netherlands, Germany, Italy, and Spain. The scan team found several innovative approaches that could provide solutions to highway-rail grade crossing issues in the United States. Spain, Italy, and Germany each have active programs under way to eliminate highway-rail grade crossings. Crossing closure is a national policy, and with the exception of a few grade crossings in Italy, all high-speed rail crossings are grade separated. Grade separation projects are performed by fabricating the tunnel structure outside the railroad in an excavation and then hydraulically inserting it under the tracks. Train detection by magnetic induction wheel sensors in lieu of track circuits was used in a number of the countries visited. Video monitoring of crossings was found to be in use to provide information on crossings being clear of obstructions.
Descriptors	Denmark, Europe, Germany, Grade Crossing Protection Systems, Grade Separations, High Speed Trains, Highway Safety, Italy, Netherlands, Public Policy, Railroad Grade Crossings, Railroad Safety, Spain, Technology Transfer, United States

Author	Accident Reconstruction Journal
Year	1997
Title	Europe offers solutions for US rail crossing safety
Publication	Accident Reconstruction Journal 1997; 9(4):5
Country	Europe
Abstract	Not available

Author	Kulmala R
Year	1997
Title	Safety at highway junctions based on predictive accident models
Publication	Third International Symposium on Intersections Without Traffic Signals pp151-157 Sponsored by: Transportation Research Board; Federal Highway Administration; National Center for Advanced Transportation Technology, University of Idaho; Transportation Northwest, University of Washington
Country	Finland
Abstract	The safety of highway junctions in Finland was studied with the help of predictive accident models. The districts of the Finnish Road Administration (FinnRA) undertook an inventory of all at-grade junctions of major roads in the summer of 1988. The inventory, which included a total of 2,700 junctions, provided data for modeling. The data included police reports of accidents and accident victims taken over a 5-year period. The variation in the number of accidents was explained using traffic volumes and the variables collected in the junction inventory. Only junctions that had no major changes during the study period were included in the models. The report describes the method for obtaining a reliable estimate of the expected number of accidents at a single junction based on the accident models and the observed number of accidents in the past. These estimates were used in assessing the effects of a number of frequently used safety measures at junctions. An estimate of the most probable safety effect and the confidence limits of the estimate are given for each of these effects.

Author	Gitelman V, Hakkert AS
Year	1996
Title	The evaluation of road-rail crossing safety with limited accident statistics
Publication	VTI Conferens Proceedings of the Conference: Road Safety in Europe and Strategic Highway Research Program (SHRP) Prague, Czech Republic pp 73-86 Swedish National Road and Transport Research Institute Date Held: 19950920-19950922
Country	Europe, Israel
Abstract	At-grade road-rail crossings are considered to be a significant safety issue as they present a source of permanent danger of train-vehicle collisions. It is especially acute for countries where the basic railway structure was built fifty or more years ago, and as a result, a large amount of at-grade crossings exist. Focus on the problem has intensified lately owing to railway expansion and constant growth of road traffic. This situation is characteristic for Israel, and also for various East European and other developing countries. Ranking must be undertaken to identify those crossings that reasonably require grade-separation. An essential part of this ranking is the evaluation of crossing safety. A model provides for a safety evaluation of 210 crossing variants, both active presently, in the past, or possibly in the future.
Descriptors	Europe Eastern, Grade Crossing Safety, Grade Crossings (Railroads), Israel, Railroad Grade Crossing Accidents

Author	Pickett MW, Grayson GB
Year	1996
Title	Vehicle driver behaviour at level crossings
Publication	HSE contract research report 98/1996
Country	United Kingdom
Abstract	The Health and Safety Executive has been concerned at the behaviour of motor vehicle drivers at road traffic signal controlled level crossings. A particular concern relates to those motorists who drive over a crossing whilst the warning lights are flashing. The Transport Research Laboratory has undertaken a study which has reviewed earlier research, analysed the relevant statistics and interviewed 100 motorists observed driving through a crossing after the lights had commenced flashing. This report details the different elements of the study and discusses possible ways to improve the safety of level crossings

Author	Tenkink E, Van der Horst R
Year	1990
Title	Car driver behavior at flashing light railroad grade crossings
Publication	Accid Anal Prev 1990 Jun;22(3):229-39
Country	Netherlands
Abstract	The behavior of car drivers at two Dutch railroad grade crossings with automatic flashing warning lights was analyzed. Car drivers were videotaped while approaching either the red flashing lights or the white flashing "safe"-signal. Approach speeds, positions, and time intervals were semiautomatically measured from videos of more than 900 drivers: 660 while confronted with the red lights and 272 while passing the white light. Of the latter group, head movements during the approach to the crossing were also registered. Red light compliance was relatively good, as no driver was observed to cross later than 6 seconds after the onset of the red lights, despite train-arrival times of well over 60 seconds. The level of red light compliance was further quantified in terms of both the deceleration and time-to-stopping-line as accepted by drivers. From a comparison with earlier research on red light compliance at signalized road intersections it appeared that red light compliance was better at railroad crossings than at road crossings. It is concluded that faulty red light compliance is not a major cause for car-train accidents and that emphasis should be placed on the ability of the present device to attract attention and to signal unambiguously. The high degree of compliance also causes unexpected driver actions, such as emergency braking and hesitations. A yellow phase may reduce these problems. Some drivers tended to proceed immediately after a train had cleared the road instead of waiting for the end of the red signal (typically some 3 to 5 seconds after the train had passed). This tendency might reveal a major cause of dramatic errors when a second train is approaching. Immediate extinction of the red signal is suggested, or even better, a separate signal to announce the arrival of the second train. Behavior during the white signal phase also showed indications of uncertainty. In some 10% of cases drivers tended to decelerate more strongly than necessary and to make extra head movements. It is recommended that the present white flashing signal be reconsidered.

Author	Aberg L
Year	1988
Title	Driver behavior at flashing-light, rail-highway crossings
Publication	Accid Anal Prev 1988 Feb;20(1):59-65
Country	Sweden
Abstract	The risk of accident at flashing-light, rail-highway crossings has been found to be ten times higher than at crossings equipped with barriers. The purpose of the present investigation was to study driver behavior in rail-highway crossings and to relate measures of driver behavior to variables believed to be associated with increased risks of accident. About 2,000 drivers were observed in 16 different crossings with driver head movements as the major dependent variable. This variable exhibits wide variability among drivers as well as satisfactory interobserver reliability. The results showed that many drivers turned their head to look for trains in rail-highway crossings although the crossings were equipped with flashing warning lights. However, fewer drivers looked when the visibility was restricted, a factor that is associated with increased risk of accident, and in crossings with few trains per day. The conclusion from the present study is that flashing-light crossings should be designed in a way that redundant information about approaching trains should be easily available to the drivers.

Author	Chatfield I
Year	1990
Title	Risky business over the rails
Publication	Surveyor 173(5084):14-15
Country	United Kingdom
Abstract	In July 1986, a passenger train in Lockington was derailed with nine fatalities and 35 injuries. A review was carried out of the safety record of automatic open level crossings. The Stott review concluded that the collisions were almost always due to the failure of vehicle drivers to observe signals and suggested that more should be done to make drivers aware that stopping at crossings when signal lights were in operation was mandatory, to decrease the practice of red light running. Nottinghamshire County Council has carried out an experiment using an automatic camera which photographed red light violation at two signal controlled crossroads in the city centre.

Japan

Author	Fukuda H, Inoue T, Sato Y, Hayashi Y
Year	1999
Title	Study on level crossing design and evaluation method based on cognitive model
Publication	Railway Technical Research Inst, Quarterly Reports Volume: 40 Issue: 1: pp 26-31
Country	Japan
Abstract	This paper proposes crossing designs and an evaluation method bases on psychology, traffic engineering, and graphic design for a global point of view of road traffic flow in order to prevent crossing accidents caused by cars entering crossing immediately before train. The paper describes an information processing model that distinguishes conspicuity of detection/recognition from the concept of visibility, draws up a standardization plan considering a basic crossing design and setting according to crossing features, and develops an evaluation method based on the distance and response time.

Author	Anandarao S, Martland CD
Year	1998
Title	Level crossing safety on East Japan Railway Company: application of probabilistic risk assessment techniques
Publication	Transportation, 25, 3, 1998-08, pp 265-86
Country	Japan
Abstract	Not available

Author	Kusukami K, Inoye T, Fukuda H, Ikeda T, Nagai A, Kon no S
Year	1996
Title	Forming risk assessment models for level crossings and their applications
Publication	Railway Technical Research Inst, Quarterly Reports Volume: 37 Issue: 1 pp 20-25
Country	Japan
Abstract	Risk assessment models are developed for level crossings with automatic barriers in 11 accident types. These are formed by the quantification method of the first type, using 2,614 accident data collected over 5 years from January 1986 to December 1990 and the data representing 30 crossing features in each of 28,059 first grade crossings as of July 1988. Validity of each model is demonstrated by examining the relationship between the risk estimated by the models and the number of accidents which occurred in a period different from the one used in developing the models. So these models can fairly accurately estimate the risk in each one of the first grade crossings.

New Zealand

Author	Land Transport Safety Authority
Year	1994
Title	Road signs and markings for railway level crossings
Publication	New Zealand. Land Transport Safety Authority. Discussion document, 1994, pp 64p. ill. 30cm., Land Transport Safety Authority, Wellington, New Zealand
Country	New Zealand
Abstract	For most drivers, encountering a railway level crossing is a rare event compared with their exposure to most other traffic situations. Further, their encountering a train at a railway level crossing is an even more rare event. Driver expectations of a conflict with a train, and hence their pre-cautionary actions, are conditioned by these low probabilities. On the opposite hand, however, the consequences of a collision with a train are generally more severe than any other road accident type. To counter this, the signs, markings, and other control devices that are used at or in advance of railway crossings must provide positive reinforcement of a risk of collision, in order to prompt an active and appropriate response from approaching drivers. This document makes significant changes to the way existing and new warning signage is used at and in advance of level crossings in New Zealand. This code of practice will bring NZ as close as is considered reasonable into line with overseas practice.

WEB RESOURCES

Author	Cheeks JM US Department of Transportation Highway/Rail Grade Crossing Technical Working Group (TWG)
Year	2000
Title	Highway/Rail Grade Crossing Technical Working Group (TWG) Draft Guidance Document
Web	http://www.ite.org/standards/hrtiwg.pdf
Country	United States
Abstract	Traffic control devices for passive and active crossings are examined, together with grade separation and crossing closure.

Author	Better Roads
Year	2000
Title	Highway-rail intersections: At grade incidents and fatalities continue to decline
Web	http://www.betterroads.com/_vti_bin/shtml.dll/articles/brdec/00a.htm/map2
Country	United States
Abstract	New safety technologies can mean lower accident and fatality rates at railroad crossings.

Author	Land Transport Safety Authority
Year	2000
Title	Road signs and markings for railway level crossings
Web	http://www.ltsa.govt.nz/publications/docs/RSMRLC.pdf
Country	New Zealand
Abstract	This guideline document relates to the provision of new standard road signs and markings on the approaches to and at railway level crossings on New Zealand's roads. It outlines the new standards and provides information on specific treatments for different situations of road/rail interface for those bodies responsible for the provision of appropriate protection at these sites.

Author	Shweieterman JP, Baden B
Year	2000
Title	Alternatives to the Whistle: Economic perspectives on public education and enforcement in promoting highway-rail grade safety in metropolitan Chicago Chaddick Institute Working Paper 09-00
Web	http://www.depaul.edu/~chaddick/Durbin2000.pdf
Country	United States
Abstract	This study offers perspective on the role of public education and enforcement in promoting highway-rail grade-crossing safety and considers their potential relevance to the debate about the Federal Railroad Administration's *Proposed Rule for the Use of Locomotive Horns at Highway-Rail Grade Crossings*. It evaluates: i) the probable social costs of the noise generated by locomotive horns at grade crossings in the Chicago area from the implementation of the rule; ii) the current status of enforcement activity at grade crossings in the region; and iii) the extent to which heightened enforcement and public education can lessen the number of motor-vehicle violations at these crossings, thereby contributing to local efforts to meet the criteria for federally designated "quiet zones". The results show that the region would experience significant losses in property value from the sounding of horns at grade crossings currently subject to whistle bans. If budget constraints prevent the creation of quiet zones in an appreciable number of communities, the losses would likely be in the range of $616 million to $1.0 billion. The study also shows that the existing approach to enforcement and public education has notable flaws. To help resolve this problem, it provides five recommendations built around the principle of intergovernmental cooperation. These suggested actions include a regional program for increased enforcement at grade crossings, modifications to the state's penalty structure for violators, and the development of a regional strategy for the adoption of photo-enforcement technology.

Author	Transport Canada
Year	2000
Title	Proceedings of the second workshop on rail-highway grade crossing research Montreal, Quebec 15 November 2000 (TP 13536)
Web	http://www.tc.gc.ca/tdc/summary/13500/13536%5F2.htm
Country	Canada
Abstract	This report contains the presentations given at the workshop on Rail-Highway Grade Crossing Research. The presentations focused on research and development designed to improve rail-highway grade crossing safety.

Author	US Department of Transportation Federal Railroad Administration
Year	2000
Title	Railroad Safety Statistics Annual Report 1999
Web	http://frarnd.volpe.dot.gov/pubs/reports/acoufils/index.html
Country	United States
Abstract	Not available

Author	Carroll AA, Volpe Center
Year	1999
Title	ITS Technology at Highway-Rail intersections: “putting it to the test”. Proceedings from the ITS Joint Program Office Highway-Rail Intersection Evaluation Workshop May 6 and 7, 1999
Web	http://www.itsdocs.fhwa.dot.gov/jpodocs/proceedn/9jf01!.pdf
Country	United States
Abstract	Not available

Author	Hughes R, Stewart R, Rodgman E Highway Safety Research Center The University of North Carolina
Year	1999
Title	Prior driver performance and expressed attitudes towards risk as factors associated with railroad grade crossing violations
Web	http://www.hsrc.unc.edu/pdf/1999/xrpt.pdf
Country	United States
Abstract	Railroad ‘gate runners’ identified by photo surveillance instrumentation were contrasted with a sample of general ‘users’ of the same grade crossing. The two samples were contrasted in terms of the prior driving histories of the drivers involved. In addition, drivers in the sample of general users were administered a paper and pencil questionnaire developed by HSRC addressing drivers’ perceptions of the risks associated with grade crossing actions and similar actions at signalized intersections. Risk perception attributes of violators were inferred from relationships identified in the general user sample between driver history data and responses to the risk perception questionnaire.

Author	Rapoza AS, Raslear TG, Rickley EJ U.S Department of Transportation
Year	1999
Title	Railroad Horn Systems Research
Web	http://frarnd.volpe.dot.gov/pubs/reports/hsr2fils
Country	United States
Abstract	The U.S. Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration is conducting a research program with the goal of reducing the number of fatalities and injuries at higway-railroad grade crossings. As part of this program, a study is being conducted to determine the effectiveness of railroad horn systems in reducing accidents at highway-railroad grade crossings. An earlier report in the series entitled *Study of the Acoustic Characteristics of Railroad Horn Systems* , presented the acoustic characteristics of several types of railroad horn systems. This report addresses the effectiveness of railroad horn systems and their resulting impact on the community noise environment. The insertion loss and interior noise levels of several motor vehicles were measured to determine if the warning signals created by railroad horn systems provide effective warning for the motorist. Acoustic data were also obtained for a horn system through wayside measurements of in-service locomotives to determine the community noise exposure. Also addressed is the distance from the crossing at which the signaling cycle should be actuated to minimize the community noise exposure.

Author	Transport Canada
Year	1999
Title	Proceedings of the workshop on rail-highway grade crossing research Ottawa, Ontario 18 November 1999 (TP 13536)
Web	http://www.tc.gc.ca/tdc/summary/13500/13536.htm
Country	Canada
Abstract	This report contains the presentations given at the Workshop on Rail-Highway Grade Crossing Research held in Ottawa, Ontario 18 November 1999. The presentations focus on research and development designed to improve rail-highway grade crossing safety.

Author	National Transportation Safety Board
Year	1998
Title	Safety at Passive Grade Crossings Volume 1: Analysis
Web	http://www.ntsb.gov/Publictn/1998/SS9802.pdf
Country	United States
Abstract	More than 4,000 accidents occurred at the Nation's active and passive grade crossings in 1996; 54 percent of the accidents and 60 percent of the fatalities were at passive grade crossings, where drivers are not provided warning from train-activated devices. The Safety Board conducted this study to identify some common causes for accidents at passive crossings and to identify remedies to improve safety at passive crossings that are not scheduled for closure or upgrade. The sample of 60 accidents investigated by the Board as part of the study is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents. The report also relates information obtained at the Board's 1997 public forum on passive crossing safety. The safety issues include (a) the adequacy of existing warning systems to alert the driver to the presence of a passive crossing and an oncoming train; (b) roadway and track conditions that affect a driver's ability to detect the presence of an oncoming train; (c) behavioral factors that affect a driver's ability to detect the presence of an oncoming train; (d) the adequacy of existing driver education material regarding the dangers of passive grade crossings and driver actions required; (e) the need for a systematic and uniform approach to passive grade crossing safety; (f) and the need for improved signage at private passive crossings. Safety recommendations concerning these issues were made to the U.S. Department of Transportation; the Federal Highway Administration; the National Highway Traffic Safety Administration; the Federal Railroad Administration; the States; Operation Lifesaver, Inc.; the American Association of Motor Vehicle Administrators; the American Automobile Association; the American Association of State Highway and Transportation Officials; the Professional Truck Drivers Institute of America; the Advertising Council, Inc.; the Association of American Railroads; the American Short Line and Regional Railroad Association; and the American Public Transit Association.

Author	National Transportation Safety Board
Year	1998
Title	Safety at Passive Grade Crossings Volume 2: Case summaries
Web	http://www.ntsb.gov/Publictn/1998/SS9803.pdf
Country	United States
Abstract	More than 4,000 accidents occurred at the Nation's active and passive grade crossings in 1996; 54 percent of the accidents and 60 percent of the fatalities were at passive grade crossings, where drivers are not provided warning from train-activated devices. The Safety Board conducted this study to identify some common causes for accidents at passive crossings and to identify remedies to improve safety at passive crossings that are not scheduled for closure or upgrade. The sample of 60 accidents investigated by the Board as part of the study is not intended to be statistically representative of the entire population of accidents at passive grade crossings during the study period, but rather to illustrate a range of passive grade crossing accidents. The report also relates information obtained at the Board's 1997 public forum on passive crossing safety. The safety issues include (a) the adequacy of existing warning systems to alert the driver to the presence of a passive crossing and an oncoming train; (b) roadway and track conditions that affect a driver's ability to detect the presence of an oncoming train; (c) behavioral factors that affect a driver's ability to detect the presence of an oncoming train; (d) the adequacy of existing driver education material regarding the dangers of passive grade crossings and driver actions required; (e) the need for a systematic and uniform approach to passive grade crossing safety; (f) and the need for improved signage at private passive crossings. Safety recommendations concerning these issues were made to the U.S. Department of Transportation; the Federal Highway Administration; the National Highway Traffic Safety Administration; the Federal Railroad Administration; the States; Operation Lifesaver, Inc.; the American Association of Motor Vehicle Administrators; the American Automobile Association; the American Association of State Highway and Transportation Officials; the Professional Truck Drivers Institute of America; the Advertising Council, Inc.; the Association of American Railroads; the American Short Line and Regional Railroad Association; and the American Public Transit Association.

Author	Transport Canada
Year	1998
Title	Study of adding reflective materials to crossing signs and posts (TP 13128E)
Web	http://www.tc.gc.ca/tdc/summary/13128e.htm
Country	Canada
Abstract	More than half of all accidents in Canada occur at non-automated crossings. There is an urgent need for low cost and effective warning devices at these crossings.

Author	US Department of Transport & John A Volpe National Transportation Systems Center
Year	1998
Title	Evaluation of retroflective markings to increase rail car conspicuity
Web	http://frarnd.volpe.dot.gov/pubs/reports/tenrrpt/tenrtotl.pdf
Country	United States
Abstract	The purpose of this study was to develop guidelines and recommendations for the design of retroreflective marking systems to enhance the conspicuity of rail cars at night. Three methods were used to generate and evaluate the marking systems for a standard hopper car. First, a group of human factors and transportation engineers used the Nominal Group Technique to generate candidate retroreflective marking systems. Secondly, two panels, one comprised of individuals with expertise in the area of conspicuity markings and one without this expertise, made subjective judgements as to the effectiveness of the marking systems. Finally, a computer controlled real-time experiment was conducted to establish the relative performance of the systems based on detection and recognition times. The evaluations indicated that any of the retroreflective systems tested improved rail car conspicuity when compared to a nonreflective marking. The data suggest that bright colors distributed to give an indication of the size or shape of the rail car were most effective, and distributions that concentrated the markings along the lower side of the car were less effective, regardless of the color pattern. For detection the fluorescent yellow was the most effective color pattern regardless of the distribution pattern. However, for recognition, fluorescent yellow or red, i.e., single color patterns, were more effective than a color pattern made up of red and white. Additional studies should be performed to determine the dynamic effectiveness of different color and distribution patterns when fitted to different types of rail cars.

Author	Legislative Assembly of Queensland Parliamentary Travelsafe Commitee
Year	1997
Title	Parliamentary Travelsafe Committee Report No. 23 Brisbane's Citytrain network – part one – safety of the rail system and infrastructure
Web	http://www.parliament.qld.gov.au/comdocs/travelsafe/Tsafe23.pdf
Country	Australia
Abstract	Not available

Author	US Roads Auto and Road User Journal
Year	1997
Title	Motorists killed in railroad crossing crashes: what characteristics do they share?
Web	http://www.usr777.com/journals/aruj/9703/ru970304.htm
Country	United States
Abstract	Not available

Author	Erickson JK
Year	1996
Title	Vehicle Detection at Highway-rail intersections 1996 Undergraduate Transportation Engineering Fellows
Web	http://rce.tamu.edu/docs/RCE_PDF_Vol_I/Tamu/Erickson.TM02.UF.pdf
Country	United States
Abstract	Vehicle detection is defined as a system for indicating the presence or passage of a vehicle. It has been the weakest link in traffic applications throughout the years. Vehicle detection is imperative at highway-rail intersections due to the numerous collisions that occur every year by stopped or stalled vehicles remaining on the railroad tracks. Most of the collisions occurring at highway-rail intersections are due to drivers not seeing a train coming or believing that they can beat the train. With increased protection of the four quadrant gates and increased reliability of vehicle detection this number can be decreased.

Author	United States General Accounting Office
Year	1996
Title	Railroad Safety DOT Faces Challenges in Improving Grade Crossing Safety, Track Inspection Standards, and Passenger Car Safety Statement for the Record by Phyllis F. Scheinberg, Associate Director, Transportation and Telecommunications Issues, Resources, Community, and Economic Development Division
Web	http://www.ntl.bts.gov/ntl/data/rc96115t.pdf
Country	United States
Abstract	Not available

Author	United States General Accounting Office
Year	1996
Title	Railroad Safety DOT Faces Challenges in Improving Grade Crossing Safety, Track Inspection Standards, and Passenger Car Safety Statement for the Record by Phyllis F. Scheinberg, Associate Director, Transportation and Telecommunications Issues, Resources, Community, and Economic Development Division
Web	http://ntl.bts.gov/data/rc96114t.pdf
Country	United States
Abstract	Not available

Author	US Department of Transportation
Year	1996
Title	Accidents that shouldn't happen. A report of the Grade Crossing Safety Task Force to Secretary Federico Pena
Web	http://safety.fhwa.dot.gov/fourthlevel/pdf/TaskForceReport.pdf
Country	United States
Abstract	This report explains how a lack of information and/or guidelines in the design, construction, operation, maintenance, and inspection of grade crossings led the Task Force to identify five safety problem areas for detailed examination-interconnected Signals; Vehicle Storage Space; High-Profile Crossings; Light Rail Transit Crossings; and Special Vehicle Operations. The five problem areas are described in the context of current practices using information drawn from technical studies, public outreach, and professional sources. As in the Action Plan, the crosscutting issues of funding, enforcement, coordination, information, standards, and education permeate the discussion.

Author	CDC – Morbidity and Mortality Weekly Report (September 22, 1995)
Year	1995
Title	Fatalities From Motor-Vehicle Collisions With Trains - Kansas, 1990-1994
Web	http://www.cdc.gov/mmwr/PDF/wk/mm4437.txt
Country	United States
Abstract	During 1983-1992, a total of 5831 deaths in the United States were attributed to motor-vehicle collisions with trains. During that same period, Kansas had the third highest death rate in the United States from motor-vehicle collisions with trains, and the annual rate for the state (0.8 per 100,000 persons) was approximately four times the national rate (0.2 deaths per 100,000 persons). To identify approaches for preventing such collisions, the Kansas Department of Health and Environment (KDHE) characterized all fatal motor-vehicle collisions with trains at highway-rail grade crossings in the state from 1990 through 1994. This report summarizes the results of that study.

Author	U.S. Department of Transportation Research and Special Programs Administration & John A. Volpe National Transportation Systems Center
Year	1995
Title	Safety of Highway-Railroad Grade Crossings: Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity
Web	http://frarnd.volpe.dot.gov/pubs/reports/lcnsrpt/lcnstotl.pdf
Country	United States
Abstract	Historically, highway-railroad grade crossings have represented a major hazard to motor vehicle drivers. The Federal Railroad Administration (FRA), U.S. Department of Transportation (USDOT) has initiated a comprehensive research program to address grade crossing safety issues in order to reduce the number of train-motor vehicle collisions. One area of study investigates measures to improve the ability of motor vehicle drivers to detect the approach of the train at grade crossings by enhancing train conspicuity. The FRA has identified several types of auxiliary external alerting light arrangements as acceptable locomotive conspicuity measures and issued two Interim Rules in 1993 and 1994. This study investigated the performance of currently available external visual alerting devices for installation on locomotives. A variety of passive (paint schemes and reflective materials) and active (lights) systems were reviewed. These devices were evaluated in terms of their ability to assist the motorist to: (1) detect the approaching train, (2) recognize the potential of the hazard, and (3) estimate its approach, and thus avoid a collision with a train at a grade crossing. Controlled field testing was conducted to measure the effect of selected locomotive alerting light systems on observers. In-service railroad test operational experience for locomotives equipped with crossing lights, used in combination with the standard headlight, was also evaluated in terms of capital costs, maintenance, operational concerns, and accident data. The results of the controlled field tests indicate that the use of selected alerting light systems, rather than use of the standard headlight alone, is an effective means of enhancing locomotive visibility. The preliminary in-service accident data provided by participating railroads indicates a potential for significant accident rate reduction with the use of the crossing light system.

Author	Keller AS, Rickley EJ
Year	1993
Title	The Safety of Highway-Railroad Grade Crossings: Study of the Acoustic Characteristics of Railroad Horn Systems
Web	http://frarnd.volpe.dot.gov/pubs/reports/acoufils/index.html
Country	United States
Abstract	The U.S. Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration is conducting a research program with the goal of reducing the number of fatalities and injuries at higway-railroad grade crossings. As part of this program, the Volpe Center's Noise Measurement and Assessment Facility is conducting a study to determine the effectiveness of railroad horn systems. This document is the first publication supporting this study. It presents the results of acoustic measurements performed in Council Bluffs, Iowa, Jacksonville, Florida, Cambridge, Massachusetts, and Omaha, Nebraska, to determine the acoustic characteristics of several types of railroad horn systems. Data obtained includes frequency spectrum, directivity, drop-off rate, maximum A-weighted sound level, and sound exposure level. The U.S. Department of Transportation, Research and Special Programs Administration, Volpe National Transportation Systems Center, in support of the Federal Railroad Administration is conducting a research program with the goal of reducing the number of fatalities and injuries at higway-railroad grade crossings. As part of this program, the Volpe Center's Noise Measurement and Assessment Facility is conducting a study to determine the effectiveness of railroad horn systems. This document is the first publication supporting this study. It presents the results of acoustic measurements performed in Council Bluffs, Iowa, Jacksonville, Florida, Cambridge, Massachusetts, and Omaha, Nebraska, to determine the acoustic characteristics of several types of railroad horn systems. Data obtained includes frequency spectrum, directivity, drop-off rate, maximum A-weighted sound level, and sound exposure level.

Author	Triggs TJ, Harris WG
Year	1982
Title	Reaction time of drivers to road stimuli Human Factors Report No. HFR-12 Monash University
Web	http://www.general.monash.edu.au/muarc/rptsum/hfr12.pdf
Country	Australia
Abstract	The assumption of a reaction time value for drivers responding to road situations is fundamental for the design requirements involving sight distance, in particular for vertical and horizontal curves. This response time is frequently referred to as the "perception-reaction time" in traffic engineering literature. Previous attempts to estimate an appropriate value for this time are discussed, along with other relevant laboratory and field reaction time literature. It is suggested that the procedures used have generally been deficient on one of several grounds. The majority of studies have used briefed subjects in an experimental situation. The duration of various processing stages have generally been arrived at by a subtractive technique. Responses have usually been assumed to be the result of speeded processes. Within single studies, the stimulus situations examined have typically been limited. The requirement for unobtrusive observational techniques is stressed so that reaction time estimates can be obtained that are representative of real world performance. This approach was used in the study reported here to obtain data for a range of eliciting stimuli . The salience of the stimulus type was estimated by the driver response rate and form of response distribution. Vehicle speed was observed for some situations, so as to allow an assessment to be made of whether driver response times depend on vehicle speed. The data showed generally that faster drivers had lower reaction times under otherwise similar conditions. The road situations that yielded the highest responding rates were railway level crossing signals, and the amphometer (pairs of cables across the road surface used by Victoria police to detect speeding drivers). The estimates obtained are discussed in terms of the commonly assigned design value of 2.5 s. Values of the 85th percentile reaction time were found that were both above and below this design value. However, the pattern of results overall suggests that the current standard may be inadequate in some circumstances, and a review of this standard is strongly recommended.

Author	Coleman F, Eck RW, Russell ER
Year	Not available
Title	Railroad-Highway grade crossings a look forward
Web	http://www.nas.edu/trb/publications/millennium/00096.pdf
Country	United States
Abstract	This is a white paper on the state of the art and the state of the practice on railroad-highway grade crossings with a look to the future.

Author	Russell ER, Rys M
Year	Not available
Title	An innovative, train-illuminated passive warning sign for highway-railroad grade crossings
Web	http://www.ctre.iastate.edu/pubs/semisesq/session2/russell/
Country	United States
Abstract	In the United States, there are approximately 170,000 public highway-railroad crossings at grade. About 65 percent of these are on low-volume roads and have no automated warning devices (passive grade crossings). Upgrading these passive crossings to automatic, train activated warning devices (active grade crossings) is not cost effective because of the low highway traffic volumes involved. These passive grade crossings on low-volume rural roads account for about one-half of the 600 annual fatalities from vehicle-train collisions at grade crossings in the U.S. (A high percentage of these occur at night.) There is need for effective, low-cost devices at these grade crossings. One such device that was evaluated by the authors was developed by the Burlington Northern Railroad Company (BN) and 3M Company (3M). This Passive Warning Sign (PWS) has no lights or electrical connections, but is designed to light up and have an "active look" as a train locomotive approaches the grade crossing. The sign is a rectangular "box" with clear side panels and a translucent front panel which can contain any message or symbol. Light from the train locomotive's headlamps strikes the side panel of the sign and is redirected and spread through the front panel by a special 3M, proprietary thin-film material. Thus, the sign appears to have internal lighting. Whatever message or symbol on the front panel is lit up and can be seen by an approaching motorist from several hundred meters. The sign takes very little light and a train's headlamps illuminate the sign from distances in excess of 650 meters. For a train traveling at 105 kph, an approaching driver has approximately 23 seconds of warning, about the same as most train activated warning systems. The sign was evaluated in many adverse environmental conditions—rain, ice, snow, blizzard, dusk, etc. It was concluded from the study that the PWS sign is effective under all these conditions when illuminated by a train's headlamps. The paper details the experimental use of the sign at two grade crossings and the study design conducted to evaluate its effectiveness. It is concluded that the PWS is effective and should be promoted for use at specific grade crossings, as recommended in the paper. Key words: highway-railroad grade crossings, passive warning sign, train-illuminated warning sign, low-cost grade crossing warning devices.