4.0

Literature Review

4.0 Literature Review

Signal Engineers have always been at the forefront of level crossing engineering, and it is therefore not surprising that most published information originates from that discipline. Similarly, the Railway Inspectorate has published much information, generally as a result of the desire to modernise the railway and in the shape of reports following accidents. No literature within the United Kingdom has been found detailing level crossing costs, presumably as a result of commercial confidence. Volumes of research have been undertaken in the United States, which is hardly surprising given they have the largest number of level crossings in the world, the highest level of fatalities and injuries and are probably the most litigation conscious people in the world.

4.1 Professional Institution Publications

Horler[22] starts by describing the public interest in road rail safety following serious level crossing accidents at Fenny Stratford (1925) and Naworth (1926). He then describes the current state of equipment and mentions experimental measures undertaken in some areas. He recognised two dangers resulting from the possible use of barriers; The danger of a direct hit (barrier lowered onto car) and the danger of trapping motorists. Having discussed these issues he outlines the American practice of automatic crossing equipment, experiments in France and Switzerland with reflectors to highlight gates, signs and etc. Finally he considers that the Acts of Parliament relating to level crossings could be interpreted sufficiently to allow more modern forms of crossing equipment. His paper was essentially a plea for modernisation and advancement.

In his three part paper, Loosemore[23] describes the then current methods of level crossing protection and operation within the United Kingdom; current methods of level crossing protection and operation in a number of overseas countries, concentrating on the automatic systems then in use in the United States, and also including briefer explanations of systems employed in Canada, Holland, France, Australia, Sweden, Belgium, South Africa, Burma, India, New Zealand and South America. In the final part of the paper, Loosemore considers what improvements can be made to UK practice. Of

22 Railway Level Crossings, F. Horler, Institution of Railway Signal Engineers, pages 31-67, Proceedings, 1927.

23 Level Crossing Protection, J. P. Loosemore, Institution of Railway Signal Engineers, pages 41-96 and insert pages 1-8, Proceedings, 1954.

particular note is the statement that Road Signs are of a standard international design throughout the UK. He also mentions that some countries use signals to indicate to motorists that the crossing is clear;

Sweden, white flashing light, 40 times per minute;

Holland, lunar white flashing light, 45 times per minute;

Belgium, green flashing light, 40 times per minute;

Holland also uses a steady orange light to indicate that the crossing has failed and motorists should take the appropriate cautionary action.

Loosemore's paper is somewhat dated, and, as far as UK practice is concerned, relates to crossings utilising gates. At the time of the paper in 1954 only one experimental barrier crossing had been installed at Warthill near York, legalised by Section 72 of the North Eastern Railway Act of 1947[24]. However, Brentall[25] was a member of a joint party of Officers of the Ministry of Transport and British Transport Commission who undertook a study tour of European level crossings with barriers, from which the UK signalling and level crossing principles were developed, and subsequently introduced on the BR network. Brentall describes and outlines the European practice seen and gives a technical description of how such crossings will operate in the UK, with detailed reasoning behind the decisions taken by the working party. It should be noted, however, that his paper preceded the installation of barrier crossings other than the one at Warthill mentioned in Loosemore's paper.

He also describes the Provisional Requirements that were enabled in the British Transport Commission Act of 1957, which legislated for the first time the use of remote and/or automatic operation of public level crossings with barriers. The British Transport Commission Act of 1954 legislated for barriers but with the retention of crossing keepers etc., that is, no automation. The Principles detailed by Brentall are still relevant today but have obviously been modified in the light of experience gained.

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[24] Level Crossing Protection, J. P. Loosemore, Institution of Railway Signal Engineers, page 52 and insert page 3, Proceedings, 1954.

[25] Lifting Barriers at Level Crossings, E.G. Brentall BEM, Institution of Railway Signal Engineers, pages 168-191, Proceedings, 1959.

In the discussion of the paper, Col. McMullen of the Railway Inspectorate and leader of the working party outlines the reasoning behind the strike-in timings and thoughts on zig-zagging motorists if the timing is too long. Jewell's[26] paper follows on from Brentall's paper and gives a good description of the first 5 years or so of experience gained by British Railways. At the time of the paper's presentation, there were some 50 automatic half barrier crossings in use. He describes in detail the design of the BR Mark 1 level crossing barrier machines and also gives a concise outline of the principles employed by BR in circuitry design and the aspects considered in the design of barrier level crossing systems.

Craig[27] discusses the change of circumstances that arose from the accidents at Hixon and Trent Road, Beckingham, level crossings. In particular, the recommendations following the Hixon accident[28] led to major change in the circuitry of crossings and resulted in the introduction of the yellow aspect within the road traffic signal/s. Other changes mentioned include the increase in flash speed of the red road traffic signals from 60±6 f.p.m to 80±10 f.p.m to meet national guidelines relating to flashing rates; the change to train strike-in timing circuits. The Hixon accident stopped, overnight, the rapid progress that BR had achieved in installing modern barrier level crossings.

Craig also puts forward a number of thoughts on possible developments; CCTV supervision; automatic raising of barriers at manually controlled sites to relieve the signalman's workload. Craig was a member of the 1978 DoT/BRB working party[29].

Langley[30], in one of the Institution of Railway Signal Engineers now famous Green technical booklets (No. 25), outlines the basic technical practice applied on the BR system. The booklet covers gate crossings, in the main, although barrier types are

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26 Modern Level Crossing Protection, D.S. Jewell, Institution of Railway Signal Engineers, pages 103-134, Proceedings 1965.

27 Developments in Level Crossing Protection, T.W. Craig,, Institution of Railway Signal Engineers, pages 136-170, Proceedings 1971.

28 Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968, Her Majesty's Stationary Office, Cmnd. 3706. ISBN 10 137060 1.

29 Level Crossing Protection, Report by officers of the Department of Transport and of the British Railways Board, HMSO, 1978, ISBN not known.

30 Level Crossing Protection, P.A. Langley, Institution of Railway Signal Engineers, 'Green' Technical Booklet No. 25, 1961.

mentioned, albeit on a limited scale as at the date of publication barrier crossing were in their infancy.

The Southern Region LC Engineer in more recent years was Cornall[31] who presented a lecture to the IRSE in 1997 in which he outlined the present requirements for level crossings in the UK. His lecture concentrated on current issues rather than reviewing the historical ones.

Tinkham[32] includes a paragraph on the common technical practice of grade crossing protection used in the United States whilst Hockings and McGregor[33] describe the Cerberus black box monitoring system applied to level crossings on the State Rail Authority system in New South Wales. The monitor system logs all events at the level crossing, retaining the last 9000 events in non-volatile memory, so that investigation into accidents and more general maintenance information can be recovered. McGregor followed up with a more technical paper on the same subject[34], describing in more detail the current sensor devices and vital indication optoisolator used in the Cerberus level crossing monitoring system.

Thompson and Rutledge[35] describe the technical working of a Harmon PMD2 Motion Detector System fitted to give flashing light protection at the level crossing at Main Road, Clematis on the Puffing Billy tourist railway operated by the Emerald Tourist Railway Board. Three more Australians, Wooderson[36], Perry[37] and M'Cauley[38] describe

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31 Level Crossing Overview, D. Cornall, Lecture notes, Institution of Railway Signal Engineers, Plymouth Section, November 1997.

32 Railway Signalling in the United States, C. P. Tinkham, Proceedings, Institution of Railway Signal Engineers, 1993/1994.

33 'Cerberus' Level Crossing Monitor, G. Hockings & P. McGregor, Institution of Railway Signal Engineers Australasian Section, Proceedings of Technical Meeting, pages 12-18, 15/17th July 1993, Sydney, New South Wales.

34 Interface Sensors for the ('Cerberus') Level Crossing Monitor, P. McGregor, Institution of Railway Signal Engineers Australasian Section, Proceedings of Technical Meeting, pages 18-21, 15/17th July 1993, Sydney, New South Wales.

35 Level Crossing Protection at Main Road, Clematis, M. Thompson & C. Rutledge, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 22 November 1986, Emerald Tourist Railway Victoria.

36 Level Crossing Protection in Queensland Railways, E.C. Wooderson, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1967 Annual Conference, Brisbane, 14th April 1967.

37 Level Crossing Protection in New South Wales Railways, E.C. Perry, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1967 Annual Conference, Brisbane, 14th April 1967.

38 Level Crossing Protection in Victoria, D.E. M'Cauley, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1967 Annual Conference, Brisbane, 14th April 1967.

the history of financial arrangements for installation and maintenance, road signs and signals, and the technical methods employed on their respective railway administrations. The subsequent discussion[39] comprised of a question and answer session between the three administrations seeking guidance and clarification on each other's systems.

Cox[40] outlines many of the human factors that need to be managed carefully in providing level crossing equipment. He discusses Protection Systems; Pre-Crash, Crash and Post-Crash factors; Collision Hazards including accident statistics at unprotected and protected crossings; Human factors such as alcohol related problems, inexperienced drivers; Audible Detection, human reaction to types of sound and sound pressures; Visual Detection, peripheral and foveal vision, colour blindness, visual range of colour; Sighting Distances for road users; Driver Reactions; Driver Error. He concludes that protection levels are proportional to investment and that audible warnings are of somewhat limited use to vehicle drivers as a result of the background noise and soundproofing built into modern vehicles.

McNamara[41] one of Cox's colleagues, outlines the special requirements of the heavily trafficked urban train services and the 169 level crossings in the greater Melbourne area that have to be accommodated. He describes the controls required for train identification e.g. stopping/express; the progression system that allows earlier identification of train type; station controls; approach locking and interlocking of signals; and manual override controls to prevent clearance of automatic signals whilst trains undertake station duties. He also describes in some detail the interlacing of the railway and level crossing signalling systems with the road traffic signalling systems at level crossings in close proximity to road junctions and the road traffic signal phasing necessary to ensure that road vehicles do not block back over crossings.

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39 Level Crossing Protection in Queensland, New South Wales and Victoria, Summary of Discussion, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1967 Annual Conference, Brisbane, 14th April 1967.

40 Melbourne - City of Level Crossings, Human Factors and Road/Rail Protection, J. Cox, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1978 Annual General Meeting, Melbourne Victoria, March 17th, 1978.

41 Melbourne - City of Level Crossings, Special Design Features used in Level Crossing Protection, G. McNamara, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, 1978 Annual General Meeting, Melbourne Victoria, March 17th, 1978.

Deveney[42] gives an account of the installation and technical reasons behind the installation of Harmon level crossing predictors to the new standard gauge line built alongside the existing broad gauge line. It also describes the methods used to interface with the broad gauge equipment were this was necessary. The crossing predictors were installed with switching circuitry to allow use of constant warning time or motion detector modes. Australian railways have tended to follow US practice and Edwards[43] outlines the upgrading of 44 level crossings using Safetran predictor equipment on Tasrail. Advantages claimed are: Consistent warning time; Less maintenance; particularly track circuits; No insulated joints; Simplified equipment housings; Logging facilities; More tolerant of poor ballast condition; Adaptable; Cost c. $(A)42k per crossing!

Lechowicz[44] of Teknis Electronics discusses the Safecross system, a doppler radar based system which measures train speed, operating signals and barriers at pre-determined times. The system uses two outer remote sensors and a master station at the crossing. The outer transmits train speed, direction and estimated time of arrival. The master station uses this information to operate signals etc. The train must pass through the system to complete the cycle or a fault condition will arise. The system can only be used on single lines as trains on double track railways could mask the sensors. The advantages claimed for this system are the total independence of any connections to the track e.g. track circuits, and the cost of $(A)32k excluding signals and barriers. Conventional systems estimated at $(A)40-80k per crossing.

Harrison[45] discusses the prediction of signals passed at danger (SPAD) at signals protecting level crossings. He also describes a possible means of causing the road signals to flash in the event of such an occurrence.

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42 The Application of Level Crossing Processors on the Newport to Ararat standard gauge line, T. Deveney, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, West Lakes, South Australia, July 1996.

43 Introduction and installation of Grade Crossing Predictors in AN (Australian National) Tasrail, C.J. Edwards, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, Launceston, Tasmania, November 1996.

44 Radar Based Level Crossing Control, S. Lechowicz, Institution of Railway Signal Engineers Australasian Section, Paper of Technical Meeting, Launceston, Tasmania, November 1996.

45 SPAD Prediction at Level Crossing Protecting Signals, C. Harrison, 1997, Institution of Railway Signal Engineers Conference Papers, 'Signalling improvements for the new Railway', Birmingham, 20.11.97.

The Permanent Way Institution textbooks[46] each have a small entry relating to the typical maintenance requirements, from the PW engineer's point of view, whilst White[47] describes in greater detail the Civil Engineer's problems at level crossings and gives details of a scheme completed in the Yorkshire area where concrete slab track and road surface was introduced to save on maintenance costs at eight level crossings. He describes the construction methods and engineering problems and subsequent site problems experienced at some sites. Some ten years later, Dr P. Taylor and M. Rayner[48] in a joint paper, outline the invention of Bomac panels by a Swiss PW engineer in the mid 1960s. The introduction of these panels allowed speedy removal of the road surface to allow PW maintenance to take place. The paper describes the manufacturing processes; the introduction of non-slip surfaces; the introduction of polymer concrete and resin based processes. These panels are now manufactured in the UK by Tarmac. Similar products are also in use manufactured by Omni, Strail, Polysafe and Holdfast.

Coates-Smith[49] describes the Holdfast Combination crossing components in his 1996 paper to the PWI, whilst Bellwood[50] outlines the early legislation in his contribution and concludes that the first public level crossing was probably located on the Surrey Iron Railway opened in 1803. Haynes[51] paper discusses safety improvement on level crossings.

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46 British Railway Track, The Permanent Way Institution; 1st Edition, edited R.A. Hamnett, 1943, page 130; 2nd Edition, edited by R.A. Hamnett, 1956, page 215; 3rd Edition, edited by R.A. Hamnett, 1964, page 263; 4th Edition, edited by D.H. Coombs, 1971, page 352; 5th Edition, edited by C.L. Heeler, 1979, page 317. 6th Edition, edited by G.H. Cope, 1993, page 359, ISBN 0 903489 03 1.

47 Concrete Level Crossings, P. White, Permanent Way Institution, Proceedings, Volume 90, Part 1, pages 38-43, 1972.

48 The Bomac System - History and recent developments, Dr H.P. Taylor & M.S. Rayner, Permanent Way Institution, Proceedings, Volume 107, Part 1, Pages 76-100, 1989.

49 Level Crossings - the Ultimate Solution, P. Coates-Smith, Permanent Way Institution, Proceedings, Volume 114, Part 3, Pages 293-300, 1996.

50 Road Level Crossings - Development of Legislation, A. Bellwood, Permanent Way Institution, Proceedings, Volume 111, Part 3, Pages 234-238, 1993.

51 Road Level Crossings - Operations and Safety, P. Haynes, Permanent Way Institution, Proceedings, Volume 111, Part 3, Pages 239-242, 1989.

4.2 HMRI Publications

Her Majesty's Railway Inspectorate investigate serious accidents, inspect new works and authorise LCs on behalf of the Minister of State. It is not possible to review all level crossing accident reports although a number of interesting ones are discussed.

The Level Crossing Protection[52] report of 1957 profiles the level crossing principles developed by he HMRI and BR Joint Working Party that were subsequently introduced onto the BR network. The Working Party made extensive investigations into overseas level crossing practice utilising automatic mechanisms and barriers instead of gates. (See Brentall, section 4.1).

The Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968[53] describes the circumstances of one of the worst level crossing accidents in the UK when at 12.26 hours on 6th January 1968, a Manchester - Euston inter-city train struck a low loader vehicle carrying a 120 ton transformer on the automatic half barrier crossing at Hixon in Staffordshire. The train was travelling at about 75mph and in the resulting collision, 11 people died and 44 people were injured.

The Public Inquiry was unique in that it was only the second such inquiry ordered under Section 7 of the Regulation of Railways Act, 1871[54]. The Inquiry investigated the accident and made many recommendations that covered both rail and road issues, many of which Craig[55] discussed in his paper to the IRSE.

Perhaps the most significant comment within the Report is that made by Bryan Gibbens Q.C., the Inquiry Chairman, in his covering letter to the Minister of Transport when presenting the Report: ' But " 'tis held with sorrow that makes us wise" and these disasters have produced, I believe, the most profound and intensive examination of the

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52 Report on Level Crossing Protection based on a visit to the Netherlands, Belgian and French Railways by officers of the Ministry of Transport and Civil Aviation and of the British Transport Commission, Ministry of Transport and Civil Aviation, HMSO 1957.

53 Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968, Her Majesty's Stationary Office, Cmnd. 3706. ISBN 10 137060 1.

54 Tay Bridge Disaster; subsequently Clapham Junction Inquiry.

55 Developments in Level Crossing Protection, T.W. Craig,, Institution of Railway Signal Engineers, pages 136-170, Proceedings 1971.

whole problem of the safe operation of such level crossings which has been made in any country in the world' [56].

The following paragraph from the report of The Royal Commission on Transport 1929 was reproduced within the Hixon report[57]:

"In view, however, of the serious accidents which have taken place at railway level crossings and of the obstruction which these crossings constitute, we cannot refrain from expressing our opinion that the time has arrived when these should be abolished altogether...........We consider that the Department should, without delay, formulate and give effect to a programme on a very much wider scale for the speedy elimination of these crossings on all classified roads and the substitution therefore of bridges and tunnels. The only difficulty is that of cost........"

70 years later, we still have considerable numbers of crossings!

The Hixon Accident Inquiry was primarily involved in the accident because it concerned a slow moving vehicle that obstructed the railway. Ten days after Hixon a serious accident involving the loss of five lives occurred at Trent Road[58/59] crossing. The victims were all in a car that was the first in the queue; the barriers raised and the car moved off quite correctly; however a second train had struck in, and as soon as the barrier had fully raised, the bells and lights started again and as a result the driver stalled the vehicle on the crossing, probably as a result of panic. The driver tried to push the vehicle clear to no avail and the train struck the vehicle. The car had a defective starter motor which compounded the situation. This aspect of a second train 'striking in as the first train was striking out was also considered in detail by the Hixon Inquiry.

On the 26th July 1986[60] a driver of a van living almost adjacent to Lockington AOCR level crossing drove onto the crossing as a fast local train reached the crossing. The train

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56 Page 8, paragraph 10, Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968, Her Majesty's Stationary Office, Cmnd. 3706. ISBN 10 137060 1.

57 Royal Commission on Transport 1929; Paragraph quoted from paragraph 232, page 70, Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968, Her Majesty's Stationary Office, Cmnd. 3706. ISBN 10 137060 1.

58 Report on the Accident at Trent Road, Beckingham, Notts. on 16.4.68, HMSO, 1968, ISBN 11 5500049 9.

59 Paragraph 266, page 81, Report of the Public Inquiry into the Accident at Hixon Level Crossing on January 6th, 1968, Her Majesty's Stationary Office, Cmnd. 3706, ISBN 10 137060 1.

60 Railway Accident: Report on the Collision and subsequent Derailment that occurred on 26.7.86 at Lockington Level Crossing, HMSO, 1987, ISBN 0 11 550812 4.

collided with the vehicle and, subsequently, progressively derailed with the leading carriage jack-knifing and eventually coming to rest at the bottom of a shallow embankment facing the rear of its own train. 9 people were killed and 59 injured, 10 seriously. It is believed that the van driver failed to obey the signals, possibly due to distraction[61]. Following this accident Stott was commissioned to report on safety at Automatic Open Crossings[62]. A number of reports surfaced during the Lockington Inquiry that the crossing regularly showed spurious and limited road signal aspects; most of these reports never reached the technical staff of the railway and consequently this threw considerable doubt into the recollections of witnesses to the incident. As a result of both reports, construction of, or conversion to, AOCR level crossings was suspended. Existing AOCR's were converted to other types. By 1997, only one AOCR existed in the UK[63].

A fellow student of the author's investigated the accident at Brunton Lane Level Crossing[64] in his then role as the Tyne & Wear Metro's Signal Engineer, when a bus drove onto the crossing illegally. The driver was prosecuted. In the ensuing investigation the TRRL were called in to judge the actions of road users at this crossing and Fawdon crossing. They found that claims that drivers were acting with disregard to the road signals was false; of 533 vehicles filmed only three crossed after the onset of the red lights and within 2 seconds of the flashing sequence starting. Also observed were eight vehicles who moved off after the train had passed but before the lights had extinguished. Pedestrian action was also examined and found to be in serious contravention of the highway code with 7% of pedestrians crossing on an amber light, and at Fawdon more than one in five pedestrians were observed crossing during the red light sequence. Many were seen to be in close proximity of moving trains.

In another accident, this time at Upper Denton Public Level Crossing between Haltwhistle and Brampton[65] a car skidded on the timber crossing surface and ended up

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[61] Railway Accident: Report on the Collision and subsequent Derailment that occurred on 26.7.86 at Lockington Level Crossing, paragraphs 110-112, page 19, HMSO, 1987, ISBN 0 11 550812 4.

[62] Automatic Open Level Crossings A Review of Safety, Prof. P.F. Stott, HMSO, 1987, ISBN 0 11 550831 7.

[63] Railway Safety, HM Chief Inspecting Officer's Annual Report on the safety record of the railways in Great Britain 1996/97, HSE/HMRI, 1997, ISBN 0 7176 1464 6.

[64] Railway Accident: Report on the Collision that occurred on 22.03.83 at Brunton Lane Level Crossing, Tyneside Metropolitan Railway, HMSO, 1985.

[65] Railway Accident: Report on the Accident that occurred on 24.12.70 at Upper Denton Public Level Crossing between Haltwhistle and Brampton in the Eastern Region of British Railways, HMSO, 1972.

stuck on the cattle grids; a subsequent train hit the car and was derailed, without any injuries. It was concluded that the skid resistance of the timber road surface caused the accident. Investigation also revealed that drivers had regularly been confused by the road markings, particularly in the dark, due to a combination of differing vertical radii of the road surface, causing, in effect, an optical illusion to the vehicle driver. The principal recommendation was to improve the visual presentation of the crossing, by improvements in the vertical profiles of the road surface approaches to the crossing.

The accident at Naas[66] occurred when a refuse lorry was driven onto the crossing which was protected by Miniature Stop Lights. It would appear that the lorry driver had a poor view of the MSL and failed to recheck them having opened the (vehicle) driver operated barriers. The principal recommendation was to convert such crossings to the AOCR type, which subsequently have been withdrawn from use following the Lockington accident[67]. In 1994 at Slaght on NIR[68] an accident occurred with similarities to the accident at Lockington in that the train derailed and the leading carriage ended up facing the opposite direction of travel. Three people were killed and 29 injured, some seriously. The train driver was charged and found guilty of manslaughter having passed the DWL at full line speed rather than at caution as it was not flashing, indicating that the crossing was not functioning properly. The train driver refused to take part in the public inquiry. This incident led to the conversion of all AOCL crossings on the NIR system to AHBs.

Stott[69] was appointed by the Secretary of State for Transport to undertake a review of safety at automatic open level crossings following the Lockington disaster. He concluded that collisions at AOCL crossings were 20 times more likely than at AHB crossings; that AOCR crossings were twice as bad as AOCL crossings based on accident statistics; he accepts that AOCR crossings were possibly as safe as AOCL crossings[70], given that Lockington was a particularly severe accident that raised the death rate

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66 Report on the Accident that occurred on 1.3.79 at Naas Public Level Crossing in the Western Region of British Railways, HMSO, 1981, ISBN 0 11 550551 2.

67 Railway Accident: Report on the Collision and subsequent Derailment that occurred on 26.7.86 at Lockington Level Crossing, HMSO, 1987, ISBN 0 11 550812 4.

68 Railway Accident: A report of the Inquiry into the collision and subsequent derailment that occurred on 1st March 1990 at Slaght Level Crossing on the railway of the Northern Ireland Railways Company Ltd; Department of the Environment for Northern Ireland, HMSO, Belfast, 1994, ISBN 0 337 08332 0.

69 Automatic Open Level Crossings A Review of Safety, Prof. P.F. Stott, HMSO, 1987, ISBN 0 11 550831 7.

70 Automatic Open Level Crossings A Review of Safety, paragraph 9.3, page 8, Prof. P.F. Stott, HMSO, 1987, ISBN 0 11 550831 7.

considerably and that might not have been representative of the normal accident rates, as there had been few accidents at AOCR crossings. But he felt it had to be based on accident statistics. He made a number of recommendations, most of which have been adopted.

Oppenheim[71] chaired a committee that considered and reviewed pedestrian safety at level crossings and reviewed the 1978 DoT/BRB report[72]. Oppenheim concluded that; automatic crossings were no less safe than gated crossings for pedestrians; the Highway Authorities should meet costs associated with highway safety; some public un-easiness exists and is likely to continue to do so as far as automatic equipment is concerned. She also called for improvements in pedestrian access arrangements and these have generally been adopted. Examination of accident statistics showed that most pedestrian injuries were actually caused by road traffic rather than by rail traffic[73].

The Transport Research Laboratory[74] were commissioned by HMRI to investigate driver behaviour at level crossings. The research team identified a number of crossings where red light offences were commonplace; offenders were then filmed by Gatso cameras, and following identification via the DVLA, the drivers were questioned on their actions and understanding of the operation of level crossings, the signs and signals and their reasons for 'jumping' the red lights. Drivers were categorised as unwilling to stop, unable to stop and unaware of signals. The authors made a number of recommendations under the general headings; Engineering, Enforcement and Education.

Following the Hixon accident recommendations, level crossing modernisation became far more complex[75] and costly, resulting in progress being very severely limited. A joint BRB, DoT and HMRI working group was set up to investigate the matter by considering all aspects of level crossings, rail, road, signage, vehicle construction et al. In addition,

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71 Pedestrian Safety at Public Road Level Crossings, Report of a Committee chaired by Sally Oppenheim MP, HMSO, 1983, ISBN 0 11 550596 2.

72 Level Crossing Protection, Report by officers of the Department of Transport and of the British Railways Board, HMSO, 1978, ISBN not known.

73 Pedestrian Safety at Public Road Level Crossings, Report of a Committee chaired by Sally Oppenheim MP, pages 13-17, HMSO, 1983, ISBN 0 11 550596 2.

74 Vehicle Driver Behaviour at Level Crossings, M. W. Pickett & G. B. Grayson, HSE Contract Research Report, HSE/HMSO, 1996, ISBN 0 7176 1093 4.

75 Level Crossing Protection, Report by officers of the Department of Transport and of the British Railways Board, HMSO, 1978, ISBN not known.

comparative studies were undertaken in Holland, France, West Germany and Switzerland. The report makes recommendations, many of which were adopted and still form the basis of today's practice in the UK.

Railway Safety Principles and Guidance Part 2, Section E[76], Guidance on Level Crossings, forms one of nine such volumes and lays out the principles of construction, installation and operation of all types of level crossings. It informs the reader of what is required but not how to achieve the installation. The other volumes cover other specific areas of railway engineering, and where appropriate are cross referenced[77/78/79/80/81/82] e.g. Rolling Stock, Signalling, Electrification etc.

A guide to the Level Crossing Regulations 1997[83] is a guide to the regulations which offers an expanded view of what the Regulations mean and follows a similar format to many other HSE Guidance publications.

4.3 Legislative Publications

Statutory Instrument No. 1519[84], The Traffic Signs Regulations and General Directions 1994 outlines the legal requirements for all highway signs, road markings and traffic signals and is used in conjunction with the Railway Safety Principles and Guidance[85] to establish the types of signal, signs and road markings required at the different types of crossing, e.g. Diagram 770 shows the Level Crossing with gates/barriers Sign. The book

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76 Railway Safety Principles and Guidance Part 2, Section E, Guidance on Level Crossings, HMRI/HSE, 1996, ISBN 0 7176 0952 9.

77 Railway Safety Principles and Guidance Part 2, Section D, Guidance on Signalling, HMRI/HSE, 1996, ISBN 0 7176 0953 7.

78 Railway Safety Principles and Guidance Part 2, Section A, Guidance on the Infrastructure, HMRI/HSE, 1996, ISBN 0 7176 0949 9.

79 Railway Safety Principles and Guidance Part 2, Section C, Guidance on electric Traction systems, HMRI/HSE, 1996, ISBN 0 7176 0711 9.

80 Railway Safety Principles and Guidance Part 2, Section B, Guidance on Stations, HMRI/HSE, 1996, ISBN 0 7176 0713 5.

81 Railway Safety Principles and Guidance Part 2, Section E, Guidance on Tramways, HMRI/HSE, 1997, ISBN 0 7176 0951 0.

82 Railway Safety Principles and Guidance Part 1, HMRI/HSE, 1996, ISBN 0 7176 0712 7.

83 A guide to the Level Crossing Regulations 1997, HSE, 1997, ISBN 0 7176 1261 9.

84 Statutory Instrument No. 1519, The Traffic Signs Regulations and General Directions 1994, pages 99-105, 136-179, 257, 260, HMSO, 1994, ISBN 0 11 044519 8.

85 Railway Safety Principles and Guidance Part 2, Section E Guidance on Level Crossings, HMRI/HSE, 1996, ISBN 0 7176 0952 9.

carries illustrations of all current signs etc. and their dimensions, typefaces and similar information as well as the legal citation/s passed into law by Parliament.

The Traffic Signs Manual Chapter 4[86] and *The Traffic Signs Manual Chapter 5*[87] outlines the application of road warning signs and road markings at level crossings and is a pictorial guide aimed principally at those installing the road signs and applying the road markings.

The Highway Code[88] is a self explanatory booklet for road users. Paragraphs 225 - 234 cover level crossings. Additional information on signs and signals appears elsewhere in the booklet whilst *Know your traffic signs*[89] describes the meaning of the vast majority of road signs and signals that the public will come across. The explanations are far more detailed than those in the Highway Code.

The Statutory Instrument No 1421[90] describes 'the power to make a railway' in the Wansbeck and Castle Morpeth area of Northumberland and defines the measures the National Coal Board were required to take at three level crossings located at New Moor, Potland and Linton Lane. It is interesting to note that, should the NCB contravene any provision of this Order, they are liable to a fine not exceeding £50 per offence.

Railway Level Crossings - Signing and Control[91] is best described as the Australian version of the Railway Safety Principles and Guidance Part E, The Traffic Signs Manual and Statutory Instrument 1519. It describes the methods to be used for varying road layouts, how they should be signposted and when booms (barriers) are required.

The Level Crossing Regulations 1997[92] amends and repeals earlier Level Crossings Acts and is the current basis under which a railway administration applies for a level crossing

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86 The Traffic Signs Manual Chapter 4, Warning Signs, pages 21-23, HMSO, ISBN 0 11 550725 6, 2nd Edition, 1986.

87 The Traffic Signs Manual Chapter 5, Road Markings, pages 32/33, HMSO, ISBN 0 11 550708 6, 2nd Edition, 1985.

88 The Highway Code, 1996, HMSO, ISBN 0 11 551843 6.

89 Know your traffic signs, Dept of Transport, HMSO, 1995, ISBN 0 11 551612 3.

90 Statutory Instrument No 1421 The National Coal Board Butterwell Light railway Order 1979 HMSO ref. 150/P25466/7 N 62 K 7.

91 Railway Level Crossings, A guide to the Signing and Control of Railway & Tramway Crossings, published by Main Roads (Assumed to be an official government organisation), 1989.

order. Each order is, effectively, an Act of Parliament specific to the particular level crossing. Similar requirements exist in Northern Ireland although they are known as the Statutory Rules of Northern Ireland. One such order is the Level Crossing (Balnamore) Order (Northern Ireland) 1998[93], a typical Level Crossing Order made under the equivalent Northern Ireland legislation that authorises the railway company, in this case Northern Ireland Railways, to modify and bring up to current standards the level crossing at Balnamore. The Order states what equipment, road signs, signals and road markings will be installed. The railway has a statutory duty to ensure the crossing complies at all times with the Order or until such time it is amended by a new Order. This crossing was visited during this project. The Order is reproduced in full in Appendix B.

The Private Crossings (Signs & Barriers) Regulations 1996[94] prescribes the warning signs that must be used at private level crossings e.g. accommodation and occupation crossings.

Documents studied for this dissertation include a typical letter[95] written by an Inspecting Officer recommending to the Minister of Transport that the level crossing works are acceptable for public use at Teams Level Crossing. Accompanying this letter in the PRO files is a BR check list document and sketches showing the alterations carried out. Also reviewed was a far more detailed HMRI letter[96], outlining the inspection carried out by Col. D. McMullen at the crossing at Warthill, the first in the country to be fitted with barriers, authorised by the London and North Eastern Railway Act of 1947. There was obviously some doubt at the time as to the legality of the barriers as reference is made to Section 72 of the LNER Act and the belief that it is doubtful whether Section 47 of the Railway Clauses Act of 1845 applies to this particular crossing.

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92 The Level Crossing Regulations 1997 Statutory Instrument No 487, 1997, The Stationery Office under the authority of the Controller of Her Majesty's Stationery Office, ISBN 0 11 064020 9.

93 Statutory Rules of Northern Ireland 1998/143, Level Crossing (Balnamore) Order (Northern Ireland 1998, The Stationery Office under the authority of the Controller of Her Majesty's Stationery Office and the Officer appointed to print the Measures of the Northern Ireland Assembly, 1998, ISBN not known.

94 Statutory Instrument SI 1996/1786, The Private Crossings (Signs & Barriers) Regulations 1996, HMSO, 1996, ISBN 0 11 062794 6.

95 Inspection Report, Teams Level Crossing, 1961, Public Record Office, Kew, MT 29/102, P15 1-2. RI 6/3/028.

96 Inspection Report, Warthill Level Crossing, 1953, Public Record Office, Kew, MT 29/99 PUR 1177.

4.4 University & Research Publications

Mackie, Higgs and Cooper[97] carried out four studies within the UK, looking at the understanding of road signs, between 1967 and 1989. Mackie's first study included the 'Level Crossing without gates/barriers to Diagram 771 and was a before and after study carried in north east Hampshire where the new symbolic signs were first tried out. He recorded an average response of 33% correct before and 54% after the introduction of signs. His control group recorded 43% and 34% respectively. Mackie's 2nd and 3rd studies did not include level crossing signs. Cooper's 1989 study included three signs, Level Crossing with gate/barrier (Diagram 770), Level Crossing without gate/barrier (Diagram 771) and St Andrews Cross (Diagram 774). He recorded a success rate of 86%, 87% and 47% respectively for the three signs, although both Mackie and Cooper arrive at these figures including partially correct answers. Compare these figures with the author's study which only recorded correct answers! (see chapter 5).

Figure 4.1
Umbra, AHB LC, NIR, County Londonderry;
An acute skew crossing of the type mentioned by Aberg.

Richards and Heathington's[98] research was based on a survey of 176 drivers and 35 police officers in various areas of Tennessee, in much the same way as the author's Questionnaire mentioned elsewhere in this paper. Richards and Heathington found that the police officers had a better understanding than the general public but still demonstrated a lack of comprehension of some devices. The authors found substantial problems with public knowledge of the devices and recommend various improvements in bringing this information to public attention. One interesting point made relates to American traffic law (at the time of the paper) at crossings with activated flashing lights: a driver is allowed to pass the flashing lights after stopping 'provided it is safe to do so. In the UK, flashing red lights at any level crossing require the driver to stop until they are extinguished or unless authorised by a police officer.

In Grade Crossing Accidents and Human Factors Engineering[99], Leibowitz considers the factors surrounding accidents and why motorists appear to choose to drive under trains in the USA. He suggests that some of the causes are related to human perception of train speed, illusion of size, illusion of velocity and the deceptive geometry of collisions. He repeats a point made by others that, motorists having successfully 'beaten the train' safely on previous occasions, then increase their self-confidence resulting in making the same decision again, perhaps fatally, on following occasions.

The project undertaken by Schultz, Berg and Oppenlander[100]encompassed an analysis of 289 rural grade crossings in Indiana at which accidents had occurred, with a comparison of a further 241 non-accident crossings. The purpose of the research was to develop rural grade crossing protection devices. Analysis considered the environment, geometric

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[97] 1) Motorists Understanding of the meaning of symbolic traffic signs, A.M. Mackie & M.M. Higgs, Proceedings, International Conference on Highway Signs, Symbology, Washington DC, Jun 1972, Federal Highway Administration: 2) National Survey of knowledge of new traffic signs, A.M. Mackie, Road Research Laboratory Report No 51, Ministry of Transport, 1967: 3) Progress in learning the meanings of symbolic traffic signs, A.M. Mackie, Road Research Laboratory Report No LR91, Ministry of Transport, 1967: 4) Comprehension of traffic signs drivers and non-drivers, B.R. Cooper, Transport & Road Research Laboratory, Department of Transport, 1989, ISSN 0266 5247.

[98] Motorist Understanding of Railroad Highway Grade Crossing Traffic Control Devices and Traffic Laws, S.H. Richards & K.W. Heathington, University of Tennessee, Transportation Research Record No 1160, pages 52-59, 1988.

[99] Grade Crossing Accidents and Human Factors Engineering, H.W. Leibowitz, American Scientist, Volume 73, pages 558-562, 1985.

[100] Evaluation of Rail - Highway Grade Crossing Protection in Rural Areas, T.G. Schultz, W.D. Berg & J.C. Oppenlander, Purdue University, Lafayette, Indiana, Record #272, Highway Research Board, Washington DC, 1971.

characteristics, road and rail traffic patterns at each crossing from which a model was developed to predict the relative hazards. They concluded that most accidents occurred in clear weather, involved young male local residents, moderate train speeds and usually, not alcohol related. They developed grade crossing a model that has three hazard indices; < 0.65 require crossbucks, $0.65 > 0.80$ require flashing lights and those higher than 0.80 require barriers. They suggested that these indices could also be used for prioritising improvements.

Russell[101] undertook 'a before and after' study of motorists at Goldsmith grade crossing in Indiana, a high speed, high accident rural crossing. The crossing was originally fitted with 8" flashing lights and, following modernisation, barriers, 12" flashing lights and strobe lights on the barrier arms. Following this change he found that motorists were slowed down by barriers and that the improved warning devices caused motorists to slow down and show a better reaction. One approach to the crossing showed a better reaction than the other. He concludes that most accidents are caused by inattentive drivers. He also reviewed previous accidents and found that the majority of accidents involved old age pensioners.

An extensive piece of research was carried out by Schoppert and Hoyt[102] for the Highway Research Board in the USA. A very thorough analysis of accidents was undertaken and the authors discovered that approximately 66% of accidents did not involve trains directly! Of 3627 accidents in Illinois investigated, 1113 involved trains; 1339 trains were present but not involved; in 1175 no trains were in the vicinity. They also undertook investigation into the road users' sight of the crossing/train; they experimented with a variety of different new signs; produced a quantitative hazard evaluation model and a cost benefit analysis of different methods of crossing protection devices.

A Swedish[103] study by Aberg of driver behaviour at flashing light crossings without barriers concentrated on the head movements of motorists approaching crossings, some

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101 Analysis of driver reaction to warning devices at a high accident rural grade crossing, E.R. Russell, Purdue University, Lafayette, Indiana, 1974.

102 Factors influencing safety at Highway-Rail grade crossings, D.W. Schoppert, D.W. Hoyt, Alan M. Voorhees & Associates, National Highway Research Program Report 50, USA, 1968.

with restricted visibility. The study concluded that drivers require redundant information, and that drivers are safer if they turn their heads to look for trains. Aberg also comments on studies by others that have found that some drivers will drive straight into the train despite the onset of warnings and flashing lights etc. It is suggested that such drivers are being distracted.

Richards, Heathington and Fambro[104] undertook a comparative before and after site study at an urban crossing to determine whether constant warning time devices improved motorist behaviour. They found that CWT devices drastically reduced the overall number of motorists crossing in front of trains by about 69% on average and those crossing in front of trains, having arrived at the crossing within 20 seconds, by 57% average and those crossing with ten seconds, 67% average. They suggest that some 13100 crossings would benefit from CWT predictors thus having a significant effect on highway/railroad safety at such crossings.

Michael[105] reviews research undertaken in the USA. He comments that highway-railway accidents account for only 0.1% of all highway accidents but that the death rate is as high as 2.5% in relation to all highway accidents. The bulk of his paper refers to research undertaken by Schoppert and Hoyt, mentioned elsewhere in this section.
Russell and Konz[106] evaluated the incidence of night time accidents based on US Government statistics between 1967-74 and suggest that a 30% reduction in incidents may be possible if grade crossings were illuminated at night, although they acknowledge that day time accidents are more common. They also detail scale model experiments to determine the optimum positions of lighting masts. They conclude that illumination will offer a reduction in accident levels, but that the illumination has to be directed to the side of the railway vehicle facing the motorist.

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[103] Driver Behaviour at Flashing Light Rail-Highway Crossings L. Aberg, Uppsala University, Sweden, 1988 pages 59-65 Accident Analysis and Prevention 1988 ISBN 0001-4575/88

[104] Evaluation of constant warning times using train predictors at a grade crossing with flashing light signals, S.H. Richards, K.W. Heathington & D.B. Fambro, Transportation Research Record No 1254, pages 60-71, 1990.

[105] Factors influencing safety at Highway-Railway grade crossings - a summary of recent research, Prof. H.L. Michael, American Railway Engineers Association, No 69, pages 790-796, 1968.

[106] Night Visibility of Trains at Railroad Highway Grade Crossings, E.R. Russell & S. Konz , Transportation Research Record No 773, pages 7-11, 1980.

Ward and Wilde[107] undertook a field study in Canada to evaluate motorist reaction during day and night-time conditions at the same level crossing. They discovered that motorists approach more slowly and brake less in the dark. Various safety issues are discussed and commented on. In a further Canadian field study[108], the same authors looked at motorists reaction to new signage advising a complete stop at the crossing at a rural level crossing with limited visibility. They found that motorists slowed down more but still failed to stop completely. Discussion focuses on the lack of motorist compliance with the signage.

In a short Israeli paper, Hakkert and Stephensky[109] consider the principal differences between the traditional automatic level crossing systems, e.g., British, which operate on the basis of the maximum permitted train speed and the American constant warning time systems that utilise time as the basis of operation. They conclude that CWT systems offer a better solution where level crossings have an absence of trains with high dynamic performance, and where the majority of trains have a low maximum speed, e.g., industrial freight lines. Hakkert and Gitelman[110] describe a mathematic method of ranking level crossings in a country such as Israel that has very limited data with which to work with. The model proposed presents a sufficient base from which a safety evaluation can be made of 168 crossing installations.

In an American University paper[111], by Meeker, Fox and Weber, reports on an observational study of driver behaviour at a particular crossing, originally fitted with warning lights and subsequently with lights and half barriers. They noted that drivers crossing in front of trains were reduced from 67% to 38%, a considerable safety improvement. They also concluded that barriers forced some drivers into making

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107 A comparison of vehicular approach speed and braking between day and night-time periods at an automated level crossing, N.J. Ward & G.J.S. Wilde, Loughborough University HUSAT Institute & Dept of Psychology, Queen's University, Kingston, Ontario, Canada, Safety Science, 19 (1995) 31-44.

108 Field Observation of advance warning/advisory signage for passive railway crossings with restricted lateral sightline visibility: an experimental investigation, N.J. Ward & G.J.S. Wilde, Loughborough University HUSAT Institute & Dept of Psychology, Queen's University, Kingston, Ontario, Canada, Accident Analysis & Prevention, Vol. 27, No 2, pages 185-197, 1995.

109 Choosing a system to control level crossing signalling, A. Hakkert & B. Stephensky, Transportation Research Institute, Israel, 1996, ISSN 1104-7267.

110 The Evaluation of road-rail crossing safety with limited accident statistics, V. Gitelman & A. Hakkert, Transportation Research Institute, Israel, 1997, ISSN 0001-4575, 1997.

111 A comparison of driver behaviour at railroad grade crossings with two different protection systems, F. Meeker, D. Fox & C. Weber, Ball State University, Muncie USA, 1997, Accident Analysis & Prevention Volume 29 pages 11-16, ISSN 0001-4575/97.

perilous decisions to cross in front of trains and that discouraging drivers from driving around barriers was essential to improve safety further. Meeker and Barr[112] carried out another field based piece of research looking at motorist behaviour; In this case two thirds of the motorists observed crossed in front of approaching trains. They concur with Leibowitz in believing that drivers are encouraged to relay on their own judgement.

Wilde, Hay and Brites[113] carried out video studies of driver approach behaviour at seven Canadian level crossings and found that critical incidents were commonplace with about 66% of the drivers violating the onset of warning signals. Another Canadian[114] study looked at the recognised deficiencies in flashing light protection which are stated to be sudden onset, poor conspicuicity and inobservance. Hauer also states that conventional traffic lights are unacceptable for liability reasons even though an offence is being committed if passed at red (Hauer implies that passing a LC flasher at red is not an offence). Technological advancement is limited by liability issues and there is little evidence of progress in Canada. Costs of flashing lights on Canadian National Railways are quoted at $60k of which CNR pays 7.5%, Highway Authority 12.5% and Canadian Transport Commission 80%. Hauer concludes that no one knows how effective flashers are at reducing accidents and that greater co-operation is needed between railways, manufacturers and government to solve the problems.

Improving safety at level crossings was the subject of a multi disciplinary conference organised by the Australian Road Research Board[115]. Topics included an international overview, train driver's and signal engineer's perception, improving safety, design changes and research, low cost schemes, changes to the road signage, the legal position, reliability, and etc. The Australians would appear to legislate and act on a state by state basis. The conference recognised the need for a national approach.

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[112] An Observational Study of Driver Behaviour at a Protected Railroad Grade Crossing as Trains Approach, F.L. Meeker & R.A. Barr, Ball State University, Muncie, USA, Accident Analysis & Prevention, Volume 21, pages 255-262, 1989.

[113] Video recorded driver behaviour at railway crossings: Approach speeds and critical incidents, G.J.S. Wilde, M.C. Hay & J.N. Brites, Report No. TP 9014E, Canadian Institute of Guided Ground Transport, Queens University, Kingston, Ontario, 1987.

[114] Flashing lights and bells at level crossings; Present problems and directions for the future, E. Hauer, Dept of Civil Engineering, University of Toronto, Ontario, 1984.

[115] Improving safety at level crossings, edited P. Cairney, Conference Proceedings 26/27 September 1991, Australian Road Research Board.

4.5 Official Railway Publications and Railtrack Standards

Safety First[116], 1961, was produced for the original leaflet drop for the first automatic level crossing in the UK at Spath, Staffordshire.

Leaflets, such as 'New automatic half barrier level crossings'[117] and 'An Automatic Open Level Crossing will be introduced at Holywell'[118] are leaflets issued by RT and BR respectively to the local population and they describe the conversion of level crossings to automatic operation. It is the usual practice to do a leaflet drop in the vicinity of the crossing concerned, local schools, police stations and etc. These are two such leaflets.

Figure 4.2 Scorborough AHB LC, East Yorkshire; When the LC controls are altered the infrastructure owner has to notify the local people, usually with a leaflet 'drop'. A typical leaflet, in this case plasticised and pinned up at the LC.

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[116] Safety First, 1961, British Railways London Midland Region 1961.

[117] New automatic half barrier level crossings, Hagg Lane, Woodhall Lane and Rowland Hall, Leaflet, Railtrack plc, 1997.

Croesi'r Rheilffordd? Crossing the Railway ?[119] is a similar dual language English/Welsh leaflet issued to the local population on the Cambrian Coast line explaining how to use self operated crossings.

Details of further Railtrack Standards referring to level crossings may be found in Appendix C along with commercial publications and magazine articles.

4.6 Miscellaneous Publications

Esveld[120] describes three types of road surfaces for level crossings; light and heavy universal plates for light and moderately heavy road traffic respectively, that appear to be of a similar form to Omni, Strail or Bomac panels and a system known as the Harmelen crossing for heavy road traffic which is effectively slab track with an appropriate road surface.

Hall[121] was BRB's Signalling and Safety Officer and participated in many formal inquiries into railway accidents. In chapter 12 of 'Danger Signals' he considers level crossings and in particular the accidents at Hixon and Lockington, both of which had a significant impact on level crossing development. In Railway Detectives[122], Hall describes the history of Her Majesty's Railway Inspectorate. Hall mentions a number of incidents involving level crossings; Naworth, Cumberland, 1926 which resulted in the recommendation to interlock signals with gates; Hixon as already mentioned; Lockington which led to a further detailed review of AOCR crossings and the Stott report[123]. Hall has published a further two handbooks[124/125] intended more for the enthusiast; both give excellent layman's explanations of the various types of level crossings, along with illustrations of signs and similar, both rail and road.

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118 An Automatic Open Level Crossing will be introduced at Holywell, British Rail (ER), 1985.
119 Croesi'r Rheilffordd ? Crossing the Railway ?, leaflet, Railtrack plc, date unknown.
120 Modern Railway Track, Coenraad Esveld, pages 116/8, MRT Productions, 1989, ISBN 90 800324 1 7.
121 Danger Signals, S. Hall, Chapter 12, Ian Allan, 1987, ISBN 0 7110 1704 2.
122 Railway Detectives; the 150 year saga of the Railway Inspectorate, S. Hall, Pages 21, 63, 84, 120/1, 135/6, Ian Allan Ltd, 1990, ISBN 0 7110 1929 0.
123 Automatic Open Level Crossings A Review of Safety, Prof. P.F. Stott, HMSO, 1987, ISBN 0 11 550831 7.
124 BR Signalling Handbook, S. Hall, Ian Allan Ltd., 1992, ISBN 0 7110 2052 3.
125 Modern Signalling Handbook, S. Hall, Ian Allan Ltd., 1996, ISBN 0 7110 2471 5.

4.7 Summary

There has been extensive research into level crossings carried out primarily in the United States which has the largest number of level crossings and the highest number of casualties annually. Much of the American research seems to address local problems rather than the overall national problem. Interestingly, Schoppert and Hoyt's paper[126], found that one third of US fatalities at grade crossings did not involve any railway vehicles, and in a further third railway vehicles were in the vicinity but were not involved in the accident that followed. British publications tend to be confined to Professional Institutions and the HMRI, whose principal publications on level crossings have followed accidents.

The public attitude to level crossings seems to be similar and insouciant in all parts of the world and that is another good reason to abolish as many level crossings as possible.

[126] Factors influencing safety at Highway-Rail grade crossings, D.W. Schoppert, D.W. Hoyt, Alan M. Voorhees & Associates, National Highway Research Program Report 50, USA, 1968.