IRSE
Institution of Railway Signal Engineers

ADVANCE PAPER ONLY

Paper to be read in London, on 8th November 2000, and not to be published until it has been read

Level Crossings on Rural Railways: Can the Railway Industry Continue to Subsidise Rural Settlements?

*John Tilly**

INTRODUCTION

This paper is a précis of a University dissertation written for the MSc Railway Systems Engineering course at Sheffield University. The views expressed are the author's own and do not represent the views of any organisation.

Level crossings are, perhaps, one of the best examples of railway systems engineering requiring inputs from railway signalling, electrical (traction), permanent way and civil engineers, railway operators, from highway engineers, road and rail legislators and the public. Legislation requires the railway to meet the full initial cost of level crossing installation, including the highway works and road signage, and the cost of the regular railway maintenance.

Rural railways, such as those in Lincolnshire, East Anglia and Northern Ireland are generally loss making and require heavy subsidy. They also have large numbers of level crossings, which represent a considerable financial drain on their limited resources. In many cases these rural level crossings allow access to remote habitations and in some cases several points of access within a short distance. The author believes that, given the vast increases in road traffic and the desire to make the user pay, it is time that legislation is changed in the railways' favour. In the case of rural railways, the railway company is effectively subsidising life in rural areas, be it a small village or an isolated farmhouse.

Historically, the costs of bridging the railway have been claimed to be far higher than a level crossing; the author will show that at current price levels, this is no longer the case and that bridges are, in fact, substantially cheaper in overall terms, although it is accepted that there will always be a need for some level crossings as bridging would be out of the question. The cost of installation, maintenance, failure and delays to the road user are considered.

Extensive research by questionnaire and subsequent analysis has been undertaken into the public's understanding of the road signs and signals associated with level crossings and is presented to support the view that closure of level crossings is a must. In the course of writing this paper a large number of level crossings have been visited and a number of safety issues have been noted.

The only safe and cost effective level crossing is a closed one!

LEVEL CROSSINGS

The title of this paper, "Level Crossings on Rural Railways: Can the railway industry continue to subsidise rural settlements?", may be controversial; However, level crossings serve no useful purpose to the railway or offer any means of improving the railways' operational ability to provide a public service. In reality, level crossings are a liability for any railway company:

- they are expensive to install and maintain;
- they introduce uncontrolled risks onto the railway system in the form of the public;
- introduce risks to the public, largely through their own ignorance of the dangers to themselves;
- cause delay to railway users, impeding the timetabled operation of the railway, particularly where level crossings are manually controlled;
- cause delay to road users and pedestrians;

* HM Railway Inspectorate

- are difficult to close permanently;
- each public level crossing requires a Level Crossing Order;
- they are regularly placed in the 'too difficult' box.

The economic survival of many rural railways is finely balanced. Many such railways rely heavily on public subsidy to enable them to continue to run services that are considered socially necessary. The revenue costs far outweigh the income from customers using the services. Typical 1998 subsidy levels for train operators running rural services are shown in Table 1. Revenue costs are high because such railways have the following characteristics:

- for historical reasons, they are built to heavy rail standards, with the consequent maintenance this entails;
- the services are generally slow and unattractive to the passenger;
- such railways suffer first in renewal and maintenance cutbacks;
- some rural areas have numerous level crossings, bringing with them in some places, unnecessarily low line speeds at ABCL, AOCL and Open crossings and the subsequent loss of headway that results. In some cases level crossings form the major infrastructure component of the line concerned, eg Sleaford to Skegness, Antrim to Londonderry etc.

Table 1: Subsidy Levels 1998/9
Subsidy per passenger mile
(Source: Rail Business Intelligence, 18.02.99)

Train Operator	Subsidy (p per pass mile)
Island Line	63.2
Cardiff	33
North Western	35.5
Northern Spirit	23.7
Central Trains	22.7
Scotrail	21.2
Wales & West	13.4

Level crossings were installed to maintain access to a property that was split in half with the original construction of the railway. Generally, the railway company had purchased their land from such landowners and undoubtedly, in the 1840s it was more economical to put in a level crossing and pay for the staff to operate it than it was to build bridges. The situation was probably exacerbated by the low lying and flatter nature of areas of the country in which some of these rural railways exist. The current infrastructure costs of such rural railways could be reduced significantly if level crossings were abolished wherever possible.

THE NEED FOR CHANGE

In the 1840s, the politicians of the day legislated that railways in the UK were to be fenced throughout and subsequently insisted that level crossings required gates that fully closed off the road from the railway and vice versa. They also decreed that the railway should meet the cost of level crossings. In the 1840s however, road traffic consisted of nothing more than a few horses and carts. Other countries did not follow Britain's lead and in many cases did not fence their railways.

Little has changed since the 1840s; the railway is still required to pay[1] for the level crossing installation and maintenance, whilst changes in legislation in the late 1950s allowed automation, and substitution of gates with barriers, half barriers and open crossings. Many wooden gated crossings remain, all the same, however, due to difficulties and cost in substituting modern equipment and issues surrounding the road layouts. Road traffic however, has increased beyond all expectations the politicians could have dreamed off in the 1840s.

The current political view in the UK is that the 'user pays', although in the case of level crossings, generally speaking, the user does not pay and therefore is effectively being subsidised by the railway company, particularly so in rural areas where the majority of level crossings still exist. Whilst the rights of access should not be extinguished lightly, the expansion of the roads network has largely, overcome the need for such access, with many alternatives being possible today that were not there when the railway was originally constructed. Perhaps, closure of a level crossing should be judged on the basis of the 'user' presenting a properly argued case for retention, with the onus being on the user to prove the continuing need for the level crossing, and if successful, meeting the full, whole life, costs.

Prior to the 1968 Transport Act, the railway infrastructure owner was also required to meet the cost of construction, maintenance and improvement of all overbridges, associated approaches and highways crossing the railway. This Act[2] recognised that such costs were an unreasonable burden on the railway infrastructure owner and transferred the responsibility for such costs to the highway authorities, at public expense. This leads to the current practice of bridge costs being met by the 'user' of the bridge span. Thus an overbridge supporting the highway is maintained by the highway authority and, an underbridge carrying the railway over a road, is maintained by the railway infrastructure owner. This is a equitable method of ensuring the 'user pays' and could, justifiably, be used as a precedent to transfer level crossing costs to the user.

Those legislators who prepared the Act, must have recognised that level crossings were a drain on railway resources, as Section 117 gave powers to highway authorities to contribute to the cost of level crossings. It did not, however, enforce contributions, and thus the highway authority can refuse to contribute.

As early as 1929, the Royal Commission on Transport[3] recognised railways' claims that level crossings were a serious problem and suggested a programme to eliminate crossings and replace them by bridges and tunnels. Automation came in the early 1960s but has never been completed, largely because some crossings are deemed to be in the 'too difficult' to deal with category.

This leaves a situation on the UK mainland of a combination of gated crossings that are unmaintainable, and barriered, controlled or automatic crossings many of which date from the modernisation that took place in the 1960s. Automation was seen as the way forward then as reliable staff to operate level crossings were difficult to recruit and the salaries paid to such staff had risen dramatically after the Second World War. Many of these are due for replacement at substantial cost to the railway. The Hixon and Lockington accidents caused major impact to UK level crossing practice as far as automation was concerned and has undoubtedly caused delay to the modernisation process.

Currently, a typical automatic half barrier level crossing is costing Railtrack something in the region of £0.55m at today's prices, excluding their project management costs, with a design life of around 25 years and constant maintenance. Bridges have always been declared as too expensive. However, they have a design life of 125 years or so, and these days are almost maintenance free. No British evidence has been found by the author of any studies comparing level crossings against bridges on a level playing field.

Why should our railways be forced to continue to pay for such level crossings, given that the level crossings only benefit the road user? Perhaps it is time that the legislation was changed in favour of the railway. One of the biggest obstacles is the question of 'right of way', which, to extinguish, requires negotiations with the landowner and subsequently legal sale of the land to the railway company before the level crossing can be abolished. In many cases the railway effectively has a wayleave to cross the land owned by others. If the landowner does not wish to sell, the railway is powerless to act, effectively holding the railway to ransom. Our friends in the road building industry do not suffer the same problems; they compulsory purchase such plots of land without any qualms as to the owner's historical rights of way.

The aim of this paper (and dissertation in far greater detail) is to compare the typical generic costs of an AHB level crossing versus a bridge meeting similar road profiles over the design life of a bridge, eg 125 years. Evidence has been gathered that shows that the public has a relatively low understanding of the Highway Code in relation to level crossings and the Highway Code in general, and this is discussed in detail.

Bridges remove the public risks from level crossings, remove all of the headway constraints from the railway and reduce deaths and major injuries attributed to the railway. In addition, maintenance is drastically reduced or, in some areas, no longer required at all:

- signalling maintenance for the level crossing is totally eradicated;
- permanent way maintenance, eg tamping machine operation can be carried out without the need to remove the road decking and road closure required to do so;
- the PW alignment can be improved to suit the maximum line speed rather than be constrained to the road profile;
- overhead electrification wiring can be maintained at the optimum height rather than at clearance height thus improving train current collection and reducing 'hard' spots;
- third rail traction no longer needs breaks in the conductor rail, thus improving train current collection and minimising the risk of 'gapping' particularly with locomotives;
- conversely, an underbridge would necessitate railway maintenance expenditure although this would be substantially less onerous than level crossing maintenance;
- if the bridge is built over the railway, the bridge design parameters carrying the road are less onerous than for a bridge that carries a railway and also, the maintenance responsibility and bridge ownership would generally pass to the road infrastructure authorities thus removing all maintenance responsibilities from the railway;
- highway/railway interfaces at road level would be non existent; road signage and signals would be dramatically simplified or removed;
- utility services within the roadway become simpler to maintain as the roadway is now totally removed from the railway environment;
- all of which will allow the railway company to direct financial resources to making the railway more viable.

Whilst this paper is specifically looking at rural railways there is a need for some considerable thought in finding alternatives to level crossings. There appears to be an increasing desire to improve line speeds in the UK for train operators such as Virgin and GNER. Any increase in line speeds above 125mph/200kph requires closure of all level crossings whether public or private, automatic or manually operated.

This will cause some considerable expenditure on lines such as the East Coast Main Line. It is also

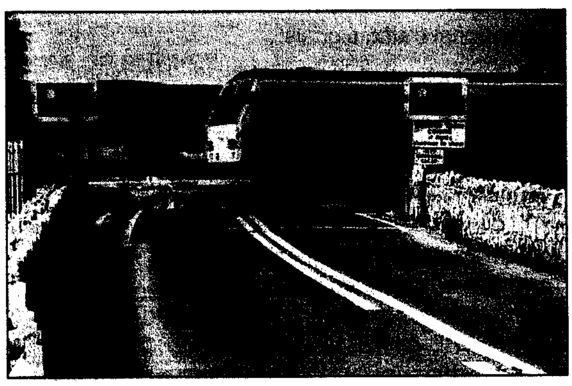

Figure 1: Meigh AHB LC (pronounced 'Mike') Northern Ireland Railways, County Armagh: The mountains of Mourne in the background and a Dublin-bound 'Enterprise' service, just about to cross the border into Eire. Why should the railway pay for the crossing?

likely to lead to some vigorous objections from groups representing footpath and bridleway users who are likely to argue that their rights are more important than the railways and who have substantial political support, and from a few landowners who will not relinquish their rights of access.

THE QUESTIONNAIRE

At the start of this project the author questioned, like many signal engineers before him, why the road traffic signals at level crossings are different from conventional road traffic signals found at thousands of road junctions. The author also felt that as, relatively speaking, level crossings are rare in the context of the overall road infrastructure, particularly with the geographical variation that exists in level crossing location. The author also felt that the level crossing road signals would, or may be, understood to a lesser degree than a conventional set of traffic lights, this would make the road user more vulnerable at level crossings and, more importantly, endangering railway traffic.

Mackie, Higgs and Cooper have 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[4] and was a 'before and after' study carried out 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 second and third 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 Andrew's Cross' (Diagram 774).

The official view is that conventional traffic lights would be displaying a green aspect for most of the time and, consequently, complacency would cause accidents at AOCL and AHB types of crossings where the timing sequence is as short as practical to prevent impatience by the road user. Some other countries do indicate to the road user that the crossing is clear. Canadian research[5] suggests that legal liability would be the deciding factor for not utilising conventional traffic signals.

The second issue is more difficult to quantify. The latest available figures available for the number of protected crossings in the UK indicate that there are 1509. This figure excludes crossings in Northern Ireland which, when included, increase this figure to 1568. It is difficult to confirm that these are all public level crossings; some may be private crossings with additional road signs dictated by circumstances prevalent at the crossing concerned; Du Pont AHB on NIR is one such example; a private crossing with public signposting and signals.

Even if one assumes that all these crossings have a minimum of two sets of road signs, that indicates a total signage of each individual sign of circa 12,000. The figure for road traffic signals is substantially lower with possibly circa 3,200 sets of signals. The excellent booklet, Know your road signs implies there are upwards of 2.5M road signs and signals on the roads of England today (1995). It was therefore concluded that it would be a useful exercise to expand the original view of considering level crossing road traffic signal comprehension and test the public's knowledge of road signals and signs appertaining to level crossings with a suitable questionnaire.

Whilst level crossings are rare, there are areas of the country that have a high density of level crossings, such as Lincolnshire, and other areas where they are few and far between, such as Northamptonshire. The approach taken with the questionnaire was to undertake two separate appraisals concentrating on areas where there is a high incidence of level crossings and a low incidence of level crossings.

DESIGN OF THE QUESTIONNAIRE

Considerable thought and study of The Highway Code, Know Your Traffic Signs, The Traffic Signs Regulations and General Directions 1994, Railway Safety[1] Principles and Guidance, The Traffic Signs Manual and The History of British Traffic Signs was undertaken in order to ensure a thorough and accurate understanding of the signs and signals involved.

This study led the author to believe that a three-part questionnaire was needed. This had to be designed in a way that did not make it obvious test-related to railway level crossing regulations:

- Part 1 – General;
- Part 2 – Road Signs;
- Part 3 – Road Signals.

With the following characteristics:

- multi-choice type;
- anonymous;
- colour coded for high/low incidence of crossings, for ease of data handling;
- based on a spontaneous response;
- use the correct terminology as found in the Highway Code;
- illustrations as similar as possible to those in the Highway Code;
- question with a choice of options, one of which would be the correct one; two of which would be incorrect; one of which would be a Don't Know; one of which would give the respondent the opportunity of his or her own answer; giving five possible answers.

QUESTIONNAIRE PART 1 – PERSONAL

The first section was intended to establish whether the respondent was a motorist or pedestrian and whether they were normally resident in the United Kingdom. This section comprised of questions one to four. The respondent was asked to tick Yes or No as appropriate to their own situation.

QUESTIONNAIRE PART 2 – SIGNS

The second section contained questions five to 19 and each question was illustrated with a specific road sign. Of the 15 different questions, six related to level crossings:

- Level Crossing with Gates or Barrier (Diagram No. 770);
- Level Crossing without Gates or Barrier (Diagram No. 771);
- Overhead Live Wires at Level Crossing or Tramway Crossing (Diagram No. 779);
- Risk of Grounding (Diagram No. 782);
- Level Crossing Count Down Markers (Diagram Nos. 789, 789.1 and 789.2);
- St Andrew's Cross (Diagram No. 774).

All were illustrated with the exception of the question relating to the count-down markers where the respondent was asked to indicate the relevant colour scheme. Given the rarity value of the crossing signs, the remaining signs were chosen from those less common in most cases. The intention of the remaining questions was to disguise the level crossing questions. During a peer review of the paper it was suggested that respondents should also have been asked about the frequency of use of level crossings. The author believes such a question may have amounted to a leading question.

QUESTIONNAIRE PART 3 – SIGNALS

Questions 20 to 34 related to Road Signals. Four of these questions related to level crossings:

- Flashing Red Man (Diagram No. 4006);
- Sequence of operation, Level Crossing Road Signals (Diagram No. 3014);
- Flashing Red Man (Diagram No. 4006);
- Level Crossing Road Signals (Diagram No. 3014).

The question relating to the Flashing Red Man was included twice in different forms as it is an exceptionally rare signal. This acted as a form of control question as the results from both questions should be similar and, the author believes, largely incorrect; conversely a high proportion of correct answers would not suggest a spontaneous response.

It was also concluded that the flashing 'Another Train Coming' signal would be a spurious question as it was felt that the answers received would be almost totally correct. It was therefore decided not to include this signal. On a similar basis the Miniature Stop Lights were not shown. Two questions were illustrated; two were not; one of which required identification of the operational sequence; one was a direct question; Where would you see a flashing red man signal? The remaining questions related to other traffic signals such as tramway, pelican and tidal flow signals. As with Part 2, the intention of the remaining questions was to disguise the level crossing questions.

One final question was included as a control measure. Question 35 asked the respondent to state whether they had identified the subject of the questionnaire. A high, correct response would suggest that the purpose of the questionnaire had been identified and the author considered that this would indicate a flawed exercise.

METHODOLOGY EMPLOYED IN UNDERTAKING THE QUESTIONNAIRE

The principal aim of the questionnaire was to gain an understanding of the public's knowledge of the signs and signals in two distinct areas of level crossing incidence. To identify the appropriate areas a combination of the author's general railway knowledge and Quail maps were used to locate the areas of high and low incidence of level crossings.

Currently, there are 32.53 million licensed drivers[6] in England, Scotland and Wales, and a population of 58.8 million[7] of which 46.56 million are 10 years of age or over and the author concluded that the Highway Code should be obeyed or, at least, understood by the majority of the population, both drivers and non-drivers. The author has a personal belief that it is not unreasonable to expect that everyone over ten years old should be aware of the contents of the Highway Code. A decision was therefore taken not to allow children under ten years of age to complete the form. Attempts were made to target small groups of people in each area to allow a comparative analysis of the groups concerned. This was unsuccessful, with only two groups of police officers and one group of sixth formers responding to the author's request. Further targeting was therefore abandoned, due mainly to time constraints in seeking others.

PROBLEMS

After some time, it became apparent that the first part of the questionnaire was causing some minor confusion. The intention of the first four questions was to differentiate motorists from pedestrians and also to identify any foreign nationals amongst the responses so that care could be taken with such responses on the assumption that such people may not be well placed to understand British practice.

Question 4 – Are you a NON-Driver/Pedestrian? caused the confusion as some respondents who answered yes to Question 1, Do you DRIVE? also insisted that they were pedestrians and thus answered yes to both questions. The author's logic in preparing the wording for the questions was that a yes to question one would require a no to question four and vice-versa. All drivers are pedestrians; only some pedestrians are drivers!

AREA OF SURVEY

White (Forms) Areas, General, for Test Appraisal

Questionnaires were answered in London, Birmingham, York and a few miscellaneous places by workplace colleagues who were unaware of the author's studies. The purpose of this appraisal was to ensure that the questionnaire was viable before commencing on the main public runs.

Green (Forms) Areas, where there is a High Incidence of Level Crossings

Questionnaires were answered in the following parts of the country:

- Lincolnshire, East Yorkshire, Norfolk, East Nottinghamshire, Suffolk, Essex, Cambridgeshire, Sheffield, Durham and East Sussex.

Yellow (Forms) Areas, where there is a Low Incidence of Level Crossings

Questionnaires were answered in the following parts of the country:

- Northamptonshire, North Buckinghamshire, Manchester, West Nottinghamshire, Oxfordshire, Carlisle, Reading & London.

ANALYSIS OF RESULTS

The Police

Two groups of police officers took part in the questionnaire; the green group comprising 19 officers from the traffic division in the Grantham, Sleaford and Spalding areas of Lincolnshire; the yellow group from West Nottinghamshire area consisting of 19 officers of various grades.

Overall analysis of both groups of forms reveals the following:

Lincolnshire

- 19 responses
- 0.3% non-answers
- 0% spoilt answers
- 65.79% correct answers (LC questions, average %)
- 10.7% Don't Know (questions 5-34)
- 0% Question 35 (purpose of questionnaire)

Nottinghamshire

- 19 responses
- 0.6% non-answers
- 0% spoilt answers
- 74.21% correct answers (LC questions, average %)
- 8.94% Don't Know (questions 5-34)
- 0% Question 35 (purpose of questionnaire)

Individual Analysis Lincolnshire Police (Green)

Lincolnshire Police scored an overall 65.79% correct answers, averaged over the ten level crossing questions, 8.42% lower than the Nottinghamshire group. None of this group (0%) identified the Flashing Red Man signal (Q27 and Q31). They showed a substantially lower understanding (57.89%) of the St Andrew's Cross (Q19) sign that is always associated with the Level Crossing without Gates/Barriers (Q9) sign. For the latter they gained a near perfect score (94.74%). The score for Level Crossing with gates/barriers (Q7) sign was also low (78.95%) given the number of crossings in Lincolnshire, the bordering area of East Nottinghamshire and the East Coast Main Line. Comprehension of the operational sequence of (Q28) Level Crossing road traffic signals is also low (68.42%), although recognition of the signal (Q34) was perfect (100%).

Individual Analysis Nottinghamshire Police (Yellow)

Nottinghamshire Police scored an overall 74.21% correct answers averaged over the ten level crossing questions. This group gained a high score (42.11% & 36.84% respectively) on the Flashing Red Man (Q27 and Q31) signal, which is surprising given the rarity of this signal and low incidence of level crossings in West Nottinghamshire. Overhead Live Wires at Level Crossing or Tramway Crossing (Q13) was low (63.16%) but there are no overhead electrified railway lines in their immediate vicinity. Comprehension of the operational sequence (Q28) of Level Crossing road traffic signals is far lower than their Lincolnshire colleagues (52.63%), although recognition of the signal (Q34) was nearly perfect (94.74%).

It must be remembered that the police responses are taken from a small sample and thus may not represent a true picture.

Individual Analysis, Public, Green Area

Overall analysis of the forms reveals the following:

- 182 responses excluding police
- 0.84% non-answers
- 0.043% spoilt answers
- 55.33% correct answers (LC questions, average %)
- 18.04% Don't Know (questions 5-34)
- 2.20% Question 35 (purpose of questionnaire)

Individual Analysis, Public, Yellow Area

Overall analysis of the forms reveals the following:

- 181 responses excluding police
- 3.66% non-answers
- 0.13% spoilt answers
- 50.88% correct answers (LC questions, average %)
- 19.17% Don't Know (questions 5-34)
- 5.52% Question 35 (purpose of questionnaire)

Individual Analysis, Public, Test Run, White Area

Overall analysis of the forms reveals the following:

- 48 responses
- 1.73% non-answers
- 0.36% spoilt answers
- 57.71% correct answers (LC questions, average %)
- 16.18% Don't Know (questions 5-34)
- 12.5% Question 35 (purpose of questionnaire)

PUBLIC ANALYSIS CONCLUSIONS

The public have a low range of understanding, at around 50-55%, of level crossing signs and signals. This is slightly better, at around 55%, but not a significantly superior, for those living in areas where there is a high incidence of level crossings. Appendix F (not included within this paper) reveals similar average figures for the remainder of the questionnaire.

The green group scored a higher percentage of correct answers for three of the four principal road signs, (Q7, Q9 and Q14), whilst the yellow group were better on the overhead electrification sign (Q13). Questions 18, 19 and 27 were reasonably balanced with both groups whilst Question 28 must be of great concern with only 28% yellow and 35% green responses understanding the sequence of operation of the LC road traffic signals. Only one respondent commented that these signals were also used elsewhere, eg fire stations. The yellow group scored more on both flashing red man questions than the green group with 10.5% and 9.34% respectively for Question 27 and 16.02% and 14.83% for Question 31. Question 34 mirrors the police response with green group being 10% better at 93.95%. The purpose of the questionnaire was correctly assumed by 2.19% green and 5.52% yellow respondents respectively. The white group was consistently higher throughout and this is assumed to reflect the fact that most have a railway orientated background.

Questions 9 and 19 also give rise to another concern; both questions relate to open level crossings, eg without barriers. Over the whole survey, white, green and yellow, 8.46% (Q9) and 31.18% (Q19) answered 'Level Crossing with gates or barriers'; one could argue that the respondent has recognised a level crossing and using Mackie's theory has answered correctly. However, the author suggests, these respondents are in some danger; they will be expecting to find gates or barriers ahead; if they fail to see the red flashing lights or illegally cross at 27-29 seconds into the level crossing sequence they may well come into contact with the railway vehicle.

It is of very great concern that these figures indicate between 14.5 to 16 million drivers in the UK are lacking the knowledge required to drive safely across level crossings. The figure gets worse if you consider the population as a whole; 20 to 23 million people! – the Highway Code applies to everybody, including pedestrians.

ISSUES AND CONCLUSIONS

The questionnaire has been a worthwhile exercise and, whilst the author has not got the same level of resources as organisations like the TRRL, which might have an effect on the overall accuracy, it seems to suggest that there is a serious deficiency in the relevant knowledge amongst the public. This must be of great concern.

This deficiency in knowledge may be as a result of considerable inconsistency in road signs; some prohibition signs have a 45° stripe through them, others don't, why? Why do we need two level crossing warning signs, when the motorist is required by law to stop at a level crossing, when necessary? Why do we need three types of countdown markers in the UK? Surely one colour scheme would do?

Secondly, and more likely, is the lack of any formal teaching of such information in schools or elsewhere. Most learner drivers are expected to memorise from the Highway Code for the driving test. Pedestrians and non-drivers, therefore, receive little or no education in the Highway Code.

If level crossings are successfully closed, the signage becomes rarer and thus the public are at even greater risk of misunderstanding the signs and signals as they will be seen less frequently.

THE COST OF LEVEL CROSSINGS

INTRODUCTION

The true costs of any level crossing are very difficult to establish, primarily because each level crossing is subject to a number of individually differing characteristics and thus standardisation is next to impossible. There is also the obvious issue of contract confidentiality that exists when such jobs are tendered for.

The characteristics can include, but are not necessarily limited to:

- the road layout;
- side roads and access points;
- pedestrian approaches;
- intensity of traffic; rail, road and pedestrian;
- visibility;
- railway stations where present in close vicinity;
- schools, bus garages, petrol stations et al in vicinity;
- special needs, eg high proportion of blind people in vicinity;
- competitive tendering.

This paper only considers the costs of AHB level crossings. The author believes that ABCL and AOCL level crossings would cost much the same as an AHB within +/- 15% and MCBcctv crossings up to double the AHB costs.

There is strong evidence to suggest that the cost of level crossings has risen to a far greater extent than the inflation rate. Detailed investigations into level crossing costs were carried out as part of the Hixon Inquiry[8] in 1968. Evidence presented to the Inquiry by British Railways indicated a 1968 price range for an AHB as being between £7,850 and £28,000 per crossing, dependent on the crossing complexity. If one assumes that the mid range cost is that of an 'average' AHB level crossing, the 1998 cost should be circa £183k. (Inflation over the period 1968–1998 averaged 8.38% pa.) News items within Professional Institutions (the IRSE) confirm this view with contractors costs increasing to meet performance specifications, directives such as EMC compliance and legislation.

However, Railtrack representatives advised the author during the West Anglia Route Modernisation feasibility study[9] that the average cost of AHB level crossings on the Great Eastern resignalling scheme (1995/6 prices?) that had just been completed was circa £0.5m per crossing, excluding RT project management costs. For the purpose of this paper, the infrastructure owner's project management costs are assumed to be neutral as they would apply equally to bridge construction. This figure was effectively 'confirmed' by a third party estimate for a similar AHB level crossing in another RT Zone shown to the author in confidence, and by professional activity in this field by the author and workplace colleagues. Furthermore, recent discussions with other colleagues have indicated a current estimate price range of £0.5m to £0.75m.

It is assumed then, that a figure of £0.55m represents a fair basis for the current capital cost of completely modernising a typical AHB level crossing at 1998 price levels. It is difficult to establish why the current costs are so much higher than the rate of inflation. It can be presumed that this is related to changes in legislation and the privatisation of the railway network, the result of which involves many more organisations in such work, numerous contractual and safety matters etc.

AHB WHOLE LIFE COST BUILD UP

There are a number of elements that need consideration in order to build up a true comparative cost of an AHB level crossing in order to compare with a simple bridge at the same location. These elements can be summarised as follows:

- the design life of an AHB compared with that of a bridge;
- the capital cost of the level crossing renewals;
- the cost of regular level crossing maintenance;
- the cost of human life, accidents etc;
- the cost of passenger and train delay, and road user delay.

Each of these will be considered in further detail.

With most capital projects, the project concerned would be subject to analysis that considered the rate of return to the infrastructure owner in terms of the cost outlay versus the return on investment. This would normally be achieved by a Rate of Return/Net Present Value exercise. This has been undertaken, but the author believes that, given that level crossings serve no purpose to the railway, they cannot offer a rate of return on the investment; there simply is no advantage to be gained by the infrastructure owner. In effect, the level crossing is a black hole swallowing large quantities of capital outlay, even larger maintenance outlay, added to which one must consider the cost of accidents to the public and the costs of train delays. Whilst this paper is considering the railway as the 'aggrieved' party, one must not forget that substantial delays also occur to the motorist and pedestrians held up by level crossing operation. This is also considered.

If one accepts that a level crossing does not generate a rate of return on the investment, then the only means of comparing the costs is to project current costs forward to offer a comparison. The biggest difficulty in doing so is to judge what an acceptable rate of inflation is likely to be. Given the life of a bridge can be considered to be 125 years this is a difficult task! The current rate of inflation is probably 3% or thereabouts and some commentators believe it will continue to fall; with some areas of industry, eg the computer sector, is currently enjoying deflation.

The author believes that as inflation is such a volatile area of all economies that it is likely to rise again and therefore costs are shown throughout at base cost.

DESIGN LIFE

The design life of typical, modern, automatic level crossings in the UK is generally considered to be 25 years. A bridge is generally considered to have a design life of 120 years[10]. An assumption is made that the bridge will survive for 125 years for this exercise; this is a fair assumption given the number of early railway bridges still in use. It will therefore be obvious that a level crossing will have been renewed five times in the lifespan of such a bridge and will be due for its sixth replacement at +125 years.

ANNUAL MAINTENANCE COSTS OF LEVEL CROSSINGS

Again, maintenance costs are very difficult to quantify, principally as individual items are not costed in the maintenance regimes. Current RT policy on maintenance is to let a multimillion pound contract covering many miles of infrastructure, covering all disciplines. The 1987 Stott report states that there is evidence to support a figure of 7% of the original installation cost per annum based on a review of level crossing subsidy claims made by the BRB. The earlier 1978 report on Level Crossing Protection put the figure at 5%. Since then privatisation has become the norm and the author believes that costs have probably risen, although the figure of 7% annual maintenance is assumed; Similar costs for level crossing maintenance were quoted by German Federal railways in a 1986 safety report.

COSTS OF ACCIDENTS AT LEVEL CROSSINGS

The cost of accidents on level crossings can be calculated by considering the number of annual fatalities and serious injuries multiplied by a 'cost of life' figure and then divided by the number of crossings. Data for such an exercise exists in the Annual Report on Railway Safety by HMRI. Accident data from this source has been considered in relation to automatic level crossings in England Scotland and Wales over the period 1988-1998. Table 2 shows the numbers of fatalities, injuries and the number of automatic level crossings (AHB, ABCL, AOCL and AOCR) for each year. There were no staff fatalities during this period. The author makes no distinction between the value of public or staff life; the cost of dealing with a fatality or treating a major injury does not reduce if staff are involved. The table though excludes trespassers and vandals killed or injured.

Railtrack's 'Valuation of life' figure is £2.65m per fatality involving a train. This is subdivided into ten

Table 2: Fatalities and injuries at automatic level crossings, 1988–1998

Year Ending 31/3	Fatalities	Injuries Public	Injuries Staff	Total Crossings
1988	4	10	2	602
1989	2	11	3	625
1990	5	14	2	631
1991	7	15	2	630
1992	6	61	5	636
1993	5	17	8	663
1994	5	17	6	657
1995	2	14	4	649
1996	5	14	4	639
1997	1	16	2	640
1998	2	11	0	644
Total	44	197	38	7,016
Average (rounded up)	4	19	4	638

major injuries being equal to a fatality and, similarly, 200 minor injuries being equal to a fatality; other railway, non-train fatalities are considered to be around the £900k mark; a road fatality is considered to be £950k. It is assumed that all injuries are major.

Therefore:

- the annual cost of fatalities is equal to **4 x 2.65m = £10.6m**: the annual fatality cost per crossing is equal to **10.6m ÷ 638 = £16,614**
- the annual cost of injuries is equal to **23 x (2.65m ÷ 10) = £6.095m** the annual major injury cost per crossing is equal to **6.095m ÷ 638 = £9,553**
- therefore an annual accident costing of fatalities plus injuries of **£26,167** per crossing is assumed for this exercise. This is an economic cost to the nation.

In addition, and next to impossible to predict, is the cost of damage to the infrastructure and rolling stock. No consideration is given to this figure, but it should be borne in mind that serious accidents such as Hixon and Lockington will cost many millions of pounds to clear up and investigate. Such costs are likely to be 'weighted' by traffic type and frequency.

COSTS OF DELAYS

Road Delays

The delay to the road user has no direct bearing on the railway's costs, however, it is a real cost in terms of the economic performance of the country and should not be ignored lightly. Stott considered this problem as a standard level crossing cost and devised a traffic flow based on that shown in Table 3. The author recorded closure times and the numbers of cars delayed at the level crossings (not included). By taking averages of the closure times, cars delayed and % traffic flows based on Stott's table, a picture of an 'average' number of cars delayed can be built up.

To arrive at a figure for this, a number of assumptions must be made so as to produce figures for an average level crossing

The Value of Time to those people in the cars held up:

- The value of time[11]:
  - assume **£5 per hour**, non-working person
  - assume **£12 per hour**, working person
  - assume **80%** of delayed users are non-working, **20%** working

  Therefore VoT£ = (5 x 0.8) + (12 x 0.2) per hour = **£6.40** or **£0.107 per minute** being an average value of time for the delayed road user.
- Assume level crossing closed to road for **60 seconds** per closure period in an operating period of 18.5 hours (0530 – 2300 hours); two track rural railway with two trains per hour, per direction; therefore **74 crossing closures** per day assuming closed for single trains on each occasion; giving **74 minutes** per 24 hour period.
- Average traffic flow based on cars recorded by the author delayed by level crossing closures during the period 0700 – 1900 hours and that 'assumed' level crossing is on a moderately used 'B' class road An 'A' class trunk road will have substantially higher figures; a 'C' class or unclassified roads, substantially lower figures.
- Average number of cars delayed is **2.64** per LC closure thus **195 cars** per day (2.64 x 74)
- Assume each delayed car has **1.5** occupants

Therefore the daily cost of delay to road users is:

- Closure period x £6.40 per hour x number of cars x 1.5 occupants

  74.00 x £0.107 x 195 x 1.5 = **£2,316 per day**

Thus the annual cost = **£845,340.** This is an economic cost to the nation.

Rail Delays

When an automatic level crossing fails, it requires the operators to caution all trains passing over the failed level crossing and to get an operating official to site to control the level crossing manually; this leads to a delay to the timetabled operation of the train as it has to slow down to a speed where it can stop short of any obstruction on the level crossing and then, having confirmed it is clear, re-accelerate back to line speed. A review of AHB failures on Northern Ireland Railways automatic level crossings revealed an average failure period of **189 minutes** per failure.

Table 3: Stott assumptions of hourly traffic, from Stott Report page 34.
'Author recorded %' refers to a 12-hour study carried out at Ramsey Road AHB LC in Whittlesea, Cambridgeshire

Hour beginning	% of daily traffic	Author recorded %	Hour beginning	% of daily traffic	Author recorded %
0700	5	11.78	1600	9	5
0800	7	6.43	1700	8	8.57
0900	6	3.21	1800	5	5
1000	7	6.07	1900	5	–
1100	7	5.36	2000	5	–
1200	6	6.43	2100	4	–
1300	6	1.07	2200	3	–
1400	7	3.93	2300	2	–
1500	8	18.21	2400 – 0600	0	–

NIR, a rural network, have an annual average AHB failure rate of **1.78 failures** per level crossing, with the vast majority of level crossings being under ten years old. It is therefore assumed that similar level crossings on rural parts of RT would have similar failure statistics, although large numbers of RT level crossings are more elderly, therefore a figure of **2 failures** per annum is assumed. In the current Railtrack track access regime, such delays result in penalty payments ranging from **£25** to **£75 per minute** delay. Discussions with NIR signalmen indicate an average delay of **5 minutes** per train until an operating official is on site and **3 minutes** per train thereafter. Similar RT figures are assumed.

Therefore the following assumptions are made: two track rural railway with two trains per hour, per direction, two trains delayed five minutes each, 10.4 trains delayed three minutes each.

Accordingly the total delay per level crossing failure is **41.2 minutes.**

Assume a figure of £35 per minute track access penalty[12] (lower end of scale, rural railway): thus train delay cost is 35 x 41.2 = **£1,442** per failure, giving an annual failure cost of £1,442 x 2 = **£2,884**. This is a financial cost to the railway, per crossing.

The second aspect of the delay is the Value of Time to those passengers on the trains held up.

- The value of time:

  As stated above; **£6.40 per hour** or **£0.107 per minute** being an average value of time for the delayed road user

  Assume a typical two car DMU (Sprinter Class 150) train with a seating capacity of 146 seats with say, an average occupancy of 35% over the daily service. Thus **51 passengers** are delayed.

  51 x £0.107 x 41.2 x 2.00 = **£450** per annum thus the total train delay cost figure is £2,884 + £450 = **£3,334** per annum

  Added to this, one must take into account the delay cost to road users affected by failures; Using the same figures as shown above this aggregates to:

  - (delay time x cars per minute x number of occupants) x (delay time x cost per minute) hence (82.4 x 2.64 x 1.5) x (82.4 x 0.107) = **£2,878** per annum giving a total failure cost of **£6,212** per annum. The track access penalty cost is a financial cost to the railway; the delay costs are economic costs to the nation.

WHOLE LIFE COSTS

From the information above, a picture of the whole life costs can be built up, assuming a 125 year lifespan. Maintenance costs form an ongoing annual expenditure. Accident and delay costs similarly, but it has been assumed that they stay at an average level as shown. However, with increasing traffic on the roads, and potentially, railways, it must be accepted that delay costs will rise. This is not related to inflation which is not considered for the present calculation. The costs are separated into two sections; those that are financial costs to the railway and those that are economic costs to the nation. See Table 4 for details of Whole Life Costs.

Table 4: Level Crossing
whole life costs over 125 years

Railway Financial Costs	Base Cost
Modernisation of level crossing @ 0, 25, 50, 75 and 100 years, base price £0.55M (see note below)	£2.75M
Cumulative maintenance costs @ 7% pa, base £38,500 pa	£4.81M
Cumulative railway delay costs, base £2,884 pa	£360.5k
Total Railway Costs for 125 years	**£7.92M**
Economic Costs to Nation	
Cumulative fatality/injury costs, base £26,167 pa	£3.27M
Cumulative rail delay costs; rail passenger and road user, base £3,328 pa	£416k
Cumulative road user delay costs, base £845,340 pa	£106M
Total Economic (non-railway) Costs	**£109.69M**
GRAND TOTAL	**£117.61M**
Note: At 125 years renewal will be required for both level crossing and bridge	

NET PRESENT VALUE TESTS

Four Net Present Value tests over a 125 year period have been carried out on the above figures as follows:

- LC1: Pure rail costs - at 10% commercial rate of interest
  Renewal every 25 years at £550k
  Annual maintenance costs at £38.5k pa
  Annual access penalty charge at £2,884 pa
  Result: **-£1.06M** Railway Financial Cost
- LC2: Road/Rail delay costs, failures – at 6% government rate of interest
  Annual failure delay to passenger (rail) and road users at £3,328 pa
  Result: **-£58.75k** Economic Cost to Nation
- LC3: Road delay costs, normal LC operation – at 6% government rate of interest
  Annual delay to road users at £845,340 pa
  Result: **-£14.9M** Economic Cost to Nation
- LC4: Accident, Fatality/Injury costs, failures – at 6% government rate of interest
  Annual accident costs at £26,167 pa
  Result: **-£462k** Economic Cost to Nation

It can be argued that the costs to the nation are passed on in the form of higher charges to customers, however this can only be considered for those commercial organisations who are delayed etc. Such an argument cannot be applied to non-working housewives, *for instance.*

The NPV test offers the benefit of a comparison that allows an organisation to compare the cost of a project against the future value of money that could be invested. Thus it can be determined if a project is of a greater value to the organisation than an equivalent cash investment.

Possession costs and the infrastructure owner's project management costs are assumed to be neutral; both level crossing and bridges will require possessions, probably more for the LC works as a result of the testing of the signalling component of the project.

CONCLUSION

The view that level crossings are cheap can be laid to rest.

THE COST OF BRIDGES

INTRODUCTION

If a bridge is to be built in place of the level crossing, certain basic assumptions must be made:

- the minimum height above railway should allow for future overhead electrification, if the line concerned is not electrified. This will eliminate the need to rebuild the bridge if the line is subsequently electrified. This therefore requires a minimum clearance height above rail level of 4.780m, therefore, rail height assumed at ground level, 0 metres; underside of span at +4.780m; road surface on top of span assumed at +6.0m. (It is unlikely many rural railways can present a business case for electrification.);
- a minimum width between abutment wall and gauge rail of 3m should be allowed to give a safe cess on both sides of the track;
- the carriageway width should not be of greater width than that required at the AHB level crossing, 6.1m, or 5m if the actual daily road vehicle user is less than 4,000;
- the footpath width should be of no greater width than that required at the AHB level crossing, 1.5m or reduced to 1.0m if the actual daily pedestrian user is Category C (Rural areas, assume minimum pedestrians);
- the span is over a double track railway with two 3m cesses giving an 11m span; if railway is single track, then in most cases, the design should allow for possible future double tracking;
- the approaches to the bridge should be at a gradient of 1 in 10;
- the embankment on the approaches should have a slope of 1:1.5 to the height of the embankment;
- the bridge is built alongside the existing crossing; the bridge will be at 90° to the railway; if skewed, there is an increase in span and therefore cost. Some bridges, will by necessity, be skewed;
- land take is kept to a minimum; the bridge is on railway land; approaches on purchased land, existing redundant roadway exchanged at similar rate/area; possibility of such is minimal and has not been considered in figures;
- design life of 120 -125 years;
- the site is on level ground;
- bridge and approaches designed to tie in with the existing road with minimal alterations to road at bridge approach extremities.

THE COST OF BRIDGES

As with level crossing costs, the actual costs of any bridge are very difficult to establish, for the same basic reasons as those mentioned in the previous chapter for level crossings. These include:

- the road layout and pedestrian approaches;
- side roads and access points;
- stability of the railway track whilst bridge construction is being undertaken;
- ground conditions will affect the type of foundation required;
- weather conditions can affect the construction of bridge approaches and, particularly, earthworks;
- railway traffic;
- competitive tendering.

The costs of the civil engineering works involved have been calculated from Spons Civil Engineering and Highway Work Prices Book[13], with an adjustment of 6% made for inflation since publication to bring the data up to 1998 prices. This publication enjoys wide use in the civil engineering field for such pricing. The cost of land take has been taken from the Property Market Report published by the Valuation office.

FOOTPRINT OF BRIDGE AND LAND TAKE

Presupposing our bridge to be wide enough for a 6.1m road and 1.5m footpath, it will be seen from the aerial view of the sketch (Figure 2) that the approach footprint on one side of the bridge will require an area of land of approximately 1,615 square metres, and thus both sides will require 3,230 m² which equates to 3,863 yd²; approximately 0.8 of an acre. It is therefore assumed that one acre of land would require purchase. The smaller bridge with a 5m road and 1 metre footpath will require 445 m² less. This is not considered to be significant. Table 5 shows the average price of agricultural land in the UK. It will be noted that this ranges from £1,670 to £5,090 per acre, dependent on the location and type of agricultural use. For this exercise, a figure of £3,700 per acre will be used.

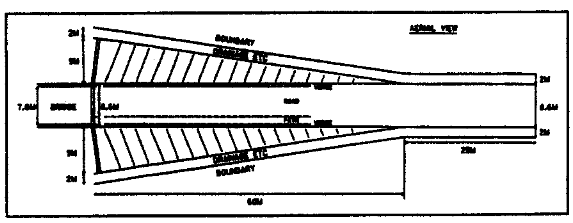

Figure2: Sketch showing the length of proposed land take from abutment to a tie-in point on the existing road *(CAD sketch: Chris Dawson)*

Table 5: Cost of agricultural land in the UK
(Valuation Office, Spring 1998)

Average cost of agricultural land per acre	Arable	Dairy	Mixed
England/Wales	£3,384	£3,338	£2,957
Scotland	£2,568	£2,417	£1,665
Northern Ireland	£3,892	£5,083	£3,225

CONSTRUCTION COSTS

The cost of agricultural land is insignificant when compared with the engineering costs. Four principal components are required:

Construction of the Reinforced Concrete Bridge

Excavation, foundations, abutments, wing walls, reinforcement, formwork, concrete, bearings, expansion joints, precast beams, deck, waterproofing, deck finishing and parapets.

Generally the cost of such a bridge can be estimated by calculating the area under the required span between abutments. Therefore:

Small bridge **11m x 6m = 66m²**

Large bridge **11m x 7.6m = 83.6m²**

Current costs are in the range £1,000 – £1,060 per square metre of span, dependent on the type of foundation, with piled foundations probably adding another £250 – £300 per square metre if required. Taking the median, £1,030, the cost of the bridge will be **£67,980** or **£86,108** for the small and large bridge respectively.

Earthworks

Land clearance, removal and temporary storage of topsoil over the footprint of approach ramps, filling of any soft spots on ground below removed topsoil, import of suitable well graded fill material, compacting of fill, testing of embankment shear strength during construction, replace topsoil and seed with appropriate grasses. (labour, plant, materials inc).

With reference to the sketch (Figure 3), the main ramp of one the approach embankments has a volume of:

Small bridge **60m x 6m x 7.5m ÷ 2 = 1,350m³**

Large bridge **60m x 6m x 8.6m ÷ 2 = 1,548m3**

Therefore the ramps require **2,700m³** or **3,096m³**

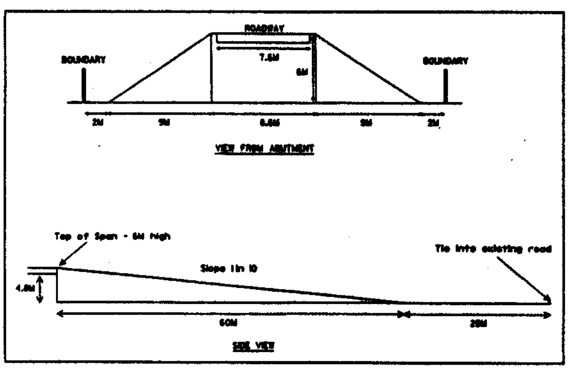

Figure 3: Sketch showing the road approach looking from the bridge abutment and maximum width of land take at abutment
(CAD sketch: Chris Dawson)

fill material respectively. In addition, each embankment side slope requires a further 536.25m³, thus; 4 x 536.25 = **2,145m³** plus the volume of topsoil removed from 'footprint'; thus; (60m x 7.5m x 0.25m) + (60m x 9m x 0.25m) = 247.5m³ per side; 247.5m³ x 2 = **495m³** for small bridge. For the large bridge a further **33m³** is required giving a total fill requirement of 2,700 + 2,145 + 495 = **5,340m³** for the small bridge; 3,096 + 2,145 + 528 = **5,769m³** for the large bridge.

Therefore assume a fill requirement of **5,400m³** with the recovered topsoil being reused on the embankment slopes:

- Land clearance, nominal: **£500**;
- Excavation of topsoil: £0.44 x 495m³: **£218**;
- Import selected graded fill material: £11.95 x 5,400m³: **£64,530**;
- Compacting of fill (90%): £0.26 x 4860m³: **£1,263**;
- Compacting of fill (10%) around concrete works: £0.43 x 540m³: **£232**;
- Testing of compacting, nominal: £1,500: **£1,500**;
- Replacement of topsoil: £0.42 x 495m³: **£208**;
- Seeding: £0.48 x 1,430m²: **£687**;
- Total earthworks cost: **£69,138**

Highway Works, Road/Footpath

Earthworks, structures, drainage, pavements, footways, signs, lighting, fencing, barriers, including an allowance for accommodation works, statutory undertakings, and landscaping.

The 5m wide roadway will cost circa **£699 per metre**; the 6.1m wide roadway will cost circa **£845 per metre**.

With a requirement for **182m** of roadway on either size bridge, this will cost **£127,218** and **£153,790** for each width respectively.

Other Costs

Include the following which are generally priced as percentages of the construction costs.

Design, Supervision and Planning Supervisor (CDM) 8%; Site preliminaries, hut, telephone, toilets, small tools, vehicles, 12%; Head office costs, estimating, accounts, marketing, 8%; Profit, risk, 10%; Bad weather contingency, 10%; Finance, cash flow, late payment, 2%; A total of 50% of construction costs must thus be added to arrive at the overall cost (see Table 6).

Table 6: Construction cost of bridges and associated highway works

	5.0m Road	6.1m Road
Landtake	£3,700	£3,700
Bridgeworks	£67,980	£86,108
Earthworks	£69,138	£73,918
Roadworks	£127,218	£153,790
Other Costs	£134,018	£158,758
Total Costs	**£402,054**	**£476,274**

MAINTENANCE COSTS OF BRIDGES AND HIGHWAY

Assessing the cost of maintenance for one small bridge, earthworks and 182 metres of rural highway is also difficult to establish. The Department of Transport publish a transport statistics report[14] that shows the annual expenditure by local authorities on all aspects of highway maintenance throughout the country. This expenditure covers highway renewals, structural, bridges, earthworks, re-surfacing, fencing, footpaths, drainage, road sweeping, lighting, winter weather precautions and etc.

Table 7 shows the total expenditure per kilometre of non-principal roads from eight local authorities with largely rural areas within the UK. These figures have been taken from the DoT publication mentioned above and adjusted to 1998 prices. This gives an average annual maintenance expenditure of around £2,968 per km. From the same publication, separating bridge maintenance specifically accounts for circa 6.03% of the per kilometre figure. It will be noted that the bridge maintenance figure varies widely between counties.

Table 7: Local Authority
Road Maintenance Expenditure

Local Authority	Annual maintenance expenditure per km, non-principal roads	% on bridge maintenance
Lincolnshire	£2,576	1.85%
Cambridgeshire	£4,381	15.41%
Cornwall	£2,702	5.60%
Devon	£3,059	3.03%
Somerset	£1,955	5.42%
North Yorkshire	£2,886	1.88%
Suffolk	£3,358	13.41%
Gloucestershire	£2,829	1.60%
Average	**£2,968**	**6.03%**

Therefore the annual cost per kilometre of highway maintenance excluding bridges is **£2,968 – 6.03% = £2,789**. With 182 metres of highway to maintain as a result of the bridge construction a typical annual maintenance figure of **£508** would appear to reasonable. Given that the road length if taken over a level crossing is only slighter shorter than that over the proposed bridge, the highway maintenance costs are not likely to increase.

The DoT figures do not indicate how many bridges are maintained within these counties and therefore it is not possible to deduce a cost per bridge. Table 8 shows the views of several authorities and their estimated cost of annual bridge maintenance expressed as a percentage of capital construction cost, including allowance for investment and renewal. The source of this information is Bridge Management[15].

Research in Sweden has suggested that the cost of maintenance is relative to the age of the bridge, climatic and geographical conditions, amount of de-icing salts spread and traffic density. The research concentrated on four city authorities and the national road administration. The average cost of maintenance (adjusted to 1998 figures) was deemed to be **£6.75 per m²** of span.

Assuming the highway authority uses the OECD figure, maintenance of the proposed bridge and highway would range between £2,547 and £3,091 per year (see Table 9).

Table 9: Maintenance cost range for
proposed small/large bridge

Type of Maintenance	Small	Large
Per square metre span	£445	£564
European average 1.49%	£1,013	£1,283
OECD 3% recommendation	£2,039	£2,583

BRIDGE WHOLE LIFE COSTS

Table 10 shows the accumulated costs for both the small and large proposed bridges. One could argue that the accident costs, rail and road delay costs should be deducted from the overall total. This would instantly give a negative cost of building the bridge.

NET PRESENT VALUE TESTS

Two Net Present Value Tests at 10% have been carried out on the bridge figures.

- B1: Pure rail costs – at 10% commercial rate of interest
  Construction of small/large bridge etc at £402,054/£476,274

Table 8: Annual bridge maintenance costs

Authority	No. of Bridges	Annual % Cost	Notes
Surrey County Council	1,573	0.45%	1.0% renewal allowance
Swedish National Road Auth	11,000	3.6%	1.0% renewal allowance
Finland National Road Auth	12,000	2.4%	
Scotland Trunk Roads	not stated	0.28%	
Scotland Non-Trunk Roads	not stated	0.07%	
Tamar Bridge	1	1.15%	including 25 year major refurbishment (0.5%)
Netherlands	4,000	1.0%	assumed
UK	c 150,000	3.0%	OECD recommendation; actual expenditure estimated at 0.3%
Average		**1.49%**	

Table 10: Bridge whole life costs over 125 years

Railway Financial Costs	Base Cost
Small/Large Bridge	S/L Bridge
Construction of bridge, earthworks and roadworks, base price £402,054/ £476,274	£402,054 £476,274
Cumulative bridge maintenance costs @ £2,547/£3,091 pa	£318,375 £386,375
Cumulative road maintenance costs, base £508 pa	£63,500 £63,500
Cumulative railway delay costs, base £2,884 pa	£0 £0
Total railway costs for 125 years	**£783,929 £926,149**
Economic Costs (saved) to Nation	
Cumulative fatality/injury costs, base £26,167 pa	saving £3.27M
Cumulative rail delay costs; rail passenger and road user, base £3,328 pa	saving £416k
Cumulative road user delay costs, base £845,340 pa	saving £106M
Total Economic Savings to Nation	**£109.69M**
GRAND TOTAL	**£783.9k £926k**
Note: At 125 years renewal will be required of bridge	

Annual maintenance costs at £3,055/£3,599 pa
Result: **–£432.6k/–£512k** Railway Financial Cost

- B2: Pure rail costs - at 10% commercial rate of interest
  Construction of small/large bridge etc. at £402,054/£476,274
  Annual maintenance costs at £3,055/£3,599 pa
  Minus railway savings:
  No LC construction costs at £550k every 25 years
  No LC maintenance costs at £38.5k pa
  No track access penalty at £2,884 pa
  Result: **+£625k/+£545k** Railway Financial Benefit

Similar tests were undertaken on the economic figures at 6% and all are directly inverted from those shown above, at +£58.75k (LC2), +£14.9M (LC3) and +£462k (LC4) respectively.

CONCLUSION

The bridge is very substantially cheaper over whole life cost than the level crossing. The vast reduction in costs can be attributed to an initial capital cost that is around 20% less than the initial level crossing cost. The level crossing has to be modernised another 4 times to meet the bridge lifespan. Secondly, the bridge maintenance charges are only approximately 8% of the level crossing costs over the 125 year period.

BASE CASE – NORTHERN IRELAND RAILWAYS

Like many other rural railways NIR has a high number of level crossings, 61; particularly north of Antrim where there are some 38 level crossings in 69 miles of route! It will be appreciated that this puts considerable strain on very scarce resources. The base case considers some of the level crossings in turn and proposes realistic, but possibly harsh options to reduce the number of level crossings, and thus expenditure on the NIR system.

CONCLUSION

Thirty-two level crossings could be closed without much difficulty. A further three could be considered for closing by buying the landowners out and a further five be downgraded to Signalman released, User Worked Gates with telephones or by padlocked gates and telephone arrangements with the local signalman, given the very low traffic volumes. This equates to 65% of the current public level crossings.

SAVINGS

If one considers the NIR level crossings that can be closed easily it will be seen that 29 AHB level crossings can be permanently closed with a need to build nine bridges, and approximately 1.25km of new connecting highways. Over the 125-year design life of the bridge the outlay on the nine bridges would be:

Capital costs:

1 @ £402k £402k

8 @ £476k £3,808k

1.250km highway at £845 per metre: £1,056k

Land for highway construction 3.09 acres at £3,700: £11.4k

Maintenance costs (annual x 125years):

Highway: 1.250km @ £2,789 per km: £437.5k

Bridges: 1 @ £2,039, 8 @ £2,583: £2,837.5k

Total investment: £8.552M

The savings to the railway in closing the level crossings would be:

29 x £7.92M = £229.6M

Undertaking an NPV test on these figures assuming construction of the bridges in the first year and closure of level crossings in the second year, the following result is obtained: **+£21.2M**

An Internal Rate of Return test gives a positive result of **175%**.

CONCLUSIONS

THE QUESTIONNAIRE

In overall terms the questionnaire has shown a low level of understanding of the Highway Code, particularly with respect to level crossings in areas with large numbers of level crossings and areas with minimal numbers of level crossings. When the sample is considered with respect to the total UK number of licensed drivers and population this must be a matter of great concern. The Railway Inspectorate noted such concerns in their annual report in 1994/95[16] stating; '*the lack of understanding of road traffic signs by road vehicle users is of concern to the Inspectorate and ways of educating the public to improve their understanding are being considered*'.

The Police were generally better than the public in correctly identifying the various signs and signals, although, as the sample size is minute, care has to be taken with the police responses. It was notable that Lincolnshire Police were not as good as their Nottinghamshire colleagues; this is also worrying as Lincolnshire has a higher proportion of level crossings and they were traffic police officers, who would be expected to have a more thorough understanding of any road signs and signals. On an anecdotal note, the Nottinghamshire Police officer who kindly assisted the author by getting his colleagues to participate told the author that 'filling in the forms would be a pointless exercise as Police officers have to learn the Highway Code parrot fashion, and thus a 100% correct response would be a worthless exercise'!

Whilst reviewing the road traffic publications relevant to the questionnaire it became apparent that there is some considerable inconsistency within the Highway Code. Also of great concern are the results from Questions 9 and 19 relating to open level crossings: the respondents who thought the correct answer was a gated or barrier equipped level crossing may be at some risk if they decide to jump the red lights as they may expecting to find gates or barriers when in fact none exist; choosing the wrong moment in the sequence to jump the lights may result in a collision with a train[17].

Constructing a questionnaire is a difficult task; one has to ensure that the questions are not misleading, confusing or lead the respondent into a particular answer. Unfortunately, Question 4 confused some respondents and the results from this question had to be disregarded.

LEVEL CROSSING AND BRIDGE COSTS

The actual costs of level crossings and bridges can only be shown in an averaged range estimate, as each level crossing or bridge is an individual project with individual problems at each site. When actual level crossing base costs are considered over the design life of a bridge, they appear to be about ten times the base cost of a bridge with a similar capacity and associated construction. This is largely caused by the need to renew the level crossing every 25 years and substantially higher annual maintenance costs. NPV tests confirm that the level crossing is a bigger drain on resources.

In addition to the construction and maintenance costs, there is also a substantial economic cost to the region or nation in terms of accident costs and, to a far greater extent, delay costs caused by the normal daily operation of the level crossing holding up the flow of road traffic. All such costs are non-existent with a bridge.

Modern electronic level crossing control systems are not yet established sufficiently in the UK to determine costs. It is likely that such processor based systems will reduce the installation costs to a reasonable degree although the down side is that such systems will have a shorter lifespan, given the pace of technological development in the electronics industry. However, this may still be an attractive option to the infrastructure owner as it will show a financial saving over the costs of a conventional level crossing control system. The principal cost of renewing the level crossing every 25 years, or perhaps more frequently will remain. Maintenance costs will not reduce significantly as the items requiring the greatest levels of maintenance will still exist; track circuits, road traffic signals, vegetation, barrier machines and booms.

The generic costs considered strongly support the replacement of level crossings with bridges. Armco bridges are slightly cheaper and are far less obtrusive than concrete bridges.

THE BASECASE

Careful study of Northern Ireland Railways based on personal knowledge, photographs and study of the Ordnance Survey of Northern Ireland has shown that 65% of their level crossings could be closed without much difficulty. This would cause some minor lengthening of road users' travelling patterns to reach the nearest alternative railway crossing; this should not be much of a problem, given that the people who live in rural areas already have a relatively inconvenient lifestyle.

The cost savings to the infrastructure owner would be very substantial, although an initial outlay to build

Figure 4: Modern reinforced concrete bridge at Lambeg, NIR

Figure 5: Uttoxeter MCBcctv LC; PERMANENTLY CLOSED!

a small number of bridges would be required. Accident costs and road delay costs would also diminish dramatically.

The public's civil and legal rights of access should not be reduced lightly. However, as the user of such facilities, the public should be required to meet the major part of the costs in keeping the level crossing on the basis of 'the user pays'. Legislation should be changed in favour of the railway in such a manner that the railway would have the right to close a level crossing if there is an alternative existing point of crossing within a reasonable distance.

FINAL CONCLUSION

Level crossings should be closed; there is substantial evidence highlighting the dangers of level crossings. The cost of bridges is less onerous to the railway infrastructure owner than previously assumed. The infrastructure owner should not have to subsidise rural settlements, although taking this line of action will require legislative change and political support.

ABBREVIATIONS

ABCL	Automatic Barrier Crossing Locally Monitored
AHB	Automatic Half Barrier
AOCL	Automatic Open Crossing Locally Monitored
AOCR	Automatic Open Crossing Remotely Monitored
BRB	British Railways Board
cctv	Closed Circuit Television
DMU	Diesel Multiple Unit
GNER	Great North Eastern Railway
LC	Level Crossing
MCB	Manually Controlled Barrier
NIR	Northern Ireland Railways
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
RT	Railtrack plc

SOURCES

1 Level Crossings Act 1983; Level Crossing Regulations 1997; A guide to the Level Crossing Regulations 1997, Appendix 2, page 8, paragraph 2(a), HSE, 1997, ISBN 0 7176 1261 9.

2 Section 116, Transport Act 1968, page 134, Part VIII, Chapter 73, Statutes in Force, HMSO, ISBN 0 11 804653 5.

3 Royal Commission on Transport 1929.

4 Statutory Instrument No 1519, The Traffic Signs Regulations & General Directions 1994, HMSO, 1994 ISBN 0 11 044519 8.

5 Flashing Lights & Barriers at Grade Crossings; present problems and directions for the future, E Hauer, Report No TP5308E, Toronto University, 1984.

6 Question to DVLC, figure as of 5.4.98 excluding Northern Ireland.

7 Mid-1996 figures, from Marketing Pocket Book, NTC Publication, 1997, ISBN 1 899314 82 2.

8 Report of the Public Inquiry into the Accident at Hixon Level Crossing on 6th January 1968, Page 85, HMSO, Cmnd. 3706. ISBN 10 137060 1.

9 Statement made on typical, average AHB costs incurred by RT on Great Eastern resignalling scheme during discussion between author and Railtrack Signal Engineer, East Anglia Zone, regarding level crossing costs during author's estimating work on West Anglia Route Modernisation Feasibility Study. Substantiated by a confidential 'sight' of a third party estimate for an AHB crossing elsewhere on the RT network. In addition, the author undertook a Level Crossing Development study for RT Scotland and is aware of tender prices quoted. Also, confidential discussion with colleague in the industry on recent estimates prepared for RT; Confirmation of the Contractor's costs (and losses!) on two simple renewal jobs from another source.

10 British Standard BS5400.

11 Department of Transport Highway Economic Note 2.

12 Confidential RT source; delay costs for rural Lincolnshire £30–£40 per minute; thus £35 assumed.

13 Spons Civil Engineering and Highway Works Price Book, 1998, ISBN 0 419 23050 5.

14 Transport Statistics Report: Local Road Maintenance Expenditure in England and Wales 1993/94, Department of Transport, HMSO, ISBN 0 11 551704 9.

15 Bridge Management, Inspection, Maintenance, Assessment and Repair, J E Harding, G A R Pyke and M J Ryall, Elsevier Applied Science, 1990, ISBN 1 85166 456 4.

16 Railway Safety, HM Chief Inspecting Officer's Annual Report on the safety record of the railways in Great Britain 1994/95, paragraph 160, HSE/HMRI, 1995, ISBN 0 7176 1047 0.

17 During the author's 12-hour period of research at Ramsey Road LC, at Whittlesea, he noted around 12 occasions of motorists illegally going through red road signals as trains approached, and on one occasion five motorists doing so during one LC closure.