Corporate Responsibility for Pedestrian Risks at Level Crossings

BARRY JOHNSON1, A. KLUTH2 and R. S. BARRATT3

1 Formerly Head of Environment, Jarvis PLC, York,
2 Group Sustainability Director, Halcrow Group Limited
3 Faculty of Mathematics, Computing and Technology, The Open University, UK

(Received on October 08, 2009, revised on August 31, 2010)

Abstract: This paper explores some aspects of communication with rail stakeholders in order to manage risks associated with rail accidents involving pedestrians legitimately crossing tracks at user-controlled crossings. It considers some issues contributing to the risks including human factors, some modelling approaches as well as some potential ways of addressing the problem. Ultimately, a key factor is human behaviour. Modifying this reliably and consistently is difficult, while designing out the risk is likely to be prohibitively expensive.

Keywords: Stakeholder risk, rail accidents, user-controlled rail crossings, human error, risk perception and communication; corporate value; safety engineering

1. Introduction

The performance of a product, system or service is judged in terms of its dependability, which aggregates attributes, like quality, reliability, maintainability, safety etc., but cannot overlook the cost of achieving these attributes. Performability aggregates these diverse attributes, although in reality, while much depends on design and control, the influence of human factors in usage can have significant influence on the risks associated with a system.

Risk and hazard are commonplace words, but risk is ambiguous in business. To the investor, risk may be associated with the potential for financial gain, whereas an engineer may focus on the potential for loss or harm, although this has economic implications. The trick is to manage activities not only to minimize their loss potential, but equally to ensure that, if an incident occurs, appropriate contingency measures are in place. Public opinion must be taken into account in the evaluation and management of risk and responsible communication has a role to play. Communication is a two way process but, despite massive financial investment, political action and steady improvements in health, safety and the quality of life, communication failures mean that threats posed by technology are still perceived as large.

In 1874, Phillips [1] asserted that

'Every train, from its starting to its destination, goes through a series of the most marvelous hairbreadth escapes; and if the travelling public had an inkling of the pitfalls that beset them, comparatively few would venture from home'.
In recent years, major incidents have raised UK public concern about risks of rail travel. Train-related accidents constitute a small proportion of those occurring in transportation compared to road accidents in developed countries such as Great Britain and the United States. Nevertheless, their impact is high in both human and financial terms because, although not all result in serious injury, many cause death or high morbidity such as amputation of limbs. However, managerial approaches need to recognise that there are also financial risks to companies. For example, on 10 May 2002 a train travelling from London Kings Cross derailed at Potters Bar when passing over points 2182A, causing 7 deaths and injuring over 70 people. Three of the four carriages derailed and one ploughed along the platform and struck a bridge. The accident was only a few miles from Hatfield, scene of an earlier fatal crash in 2000. This incident influenced the share prices of companies involved in rail track maintenance (Figure 1 a and b below) while similar companies with little rail involvement showed no comparable decline (Figure 1 c and d).

![Figure 1: Share Prices of Selected Companies following the Potters Bar Rail Crash](image)

Studies have found that such falls may amount to almost 8% of shareholder value and the ability to recover varies considerably between organisations [2]. The impact of such incidents on companies’ share prices initially come from the direct financial cost of the incident in terms of cash flow, with the market adjusting the stock price accordingly. Secondly, the market adjusts the share price in accordance with the confidence of investors that managers have demonstrated their competence to manage the consequences of the incident and recover the effective operation of the company, including its ability to win and retain business. What analysts are rating is not current performance but future expectations.

There are lessons to learn from these incidents. First, that while reputation is difficult to build, it can be harmed in an instant. Secondly, reputation may be protected by planning for incidents and dealing well with communication issues. The underlying principles are well established in current management ideology [3], but have a longer history. For example, Epictetus, a second century Greek philosopher, said in The Enchiridion [4]

*Some things are in our control and others not. Things in our control are opinion, pursuit, desire, aversion, and, in a word, whatever are our own actions. Things not*
in our control are body, property, reputation, command, and, in one word, whatever are not our own actions….

He added

Men are disturbed, not by things, but by the principles and notions which they form concerning things.

Or to paraphrase according to Worcester [5]:

Perception is truth, because people believe it

This paper explores some aspects of communication with rail stakeholders in order to manage risks from rail accidents at a more local level, rather than at the Potters Bar scale which affected the rail industry as a whole. Nevertheless, both have potentially similar impact on individuals and corporate image.

Lobb [6] classified three broad categories of train-related accidents and related research and literature as follows:

(a) major disasters such as derailments, train/train collisions and buffer over-runs;
(b) road/rail crossing accidents in which a motor vehicle collides with a train at a legal crossing point; and
(c) train-pedestrian accidents, the focus of her research.

Incidents in the first category are rare events. Based on incidents predating those noted above, Evans [7] calculated that the mean number of such accidents in Britain was just over one per year with a mean of just under four fatalities per year resulting from them, and his predictions for the next 30 years suggested a reduction to 1.3 fatalities per year, due to anticipated improvements in railway equipment and operating procedures. Lobb [6] added that because this kind of accident sometimes involves a large number of fatalities associated with any one instance, they attract a disproportionate amount of media and research attention. Evans [8] goes into more detail, noting that the number of fatalities in collisions and derailments is very variable, depending on the circumstances. At one end of the scale, 36 out of the 80 fatal accidents in 1967-2003 had a single fatality. At the other end, the worst three had 31 fatalities (Ladbroke Grove, 1999), 35 fatalities (Clapham Junction, 1988) and 49 fatalities (Hither Green, 1967). The average number of fatalities was $\frac{320}{80} = 4.0$, with no apparent trend over time.

The second category of Lobb’s classification concerns road-rail crossing accidents in which a motor vehicle collides with a train when the road crosses the tracks (i.e., at a legal crossing point). These accidents, too, are comparatively rare events, but less so than major rail disasters, and although any one instance involves fewer people, together they account for more fatalities and serious injuries than the first category. In Britain, road-rail collisions account for approximately nine times more fatalities per year than the major rail accidents (calculated from figures provided by Evans [7,9]. Later, Evans [10] identified 4 fatal collisions between main line trains and road motor vehicles in 2005 in the UK, with 4 fatalities, all at level crossings with one road vehicle occupant fatality in each accident. There were also two fatal collisions between main line trains and pedal cyclists. In the period 1996-2000, Cairney [11] estimated that approximately 36 crashes per year occurred at passive crossings throughout Australia, resulting in an average of four deaths and six serious injuries per year. The average annual cost of collisions at railway level crossings was estimated to be at least AUD$24.8 million for all crossings, including AUD$16.3 million for active crossings and AUD$8.3 million for passive crossings. These values equate to about £10.7, £7 and £3.6 million respectively.
The third category concerns train-pedestrian collisions in which a train collides with
a person. Under the Reporting of Injuries, Diseases and Dangerous Occurrences
Regulations 1995 (RIDDOR) there is a requirement to report fatal injuries due to acts of
suicide or trespass on railway systems and this increased the reported number of fatal
injuries to members of the public. Since 1 April 2006, enforcement of safety on railways
has been the responsibility of the Office of Rail Regulation (ORR), which provides the
Health and Safety Executive (HSE) with notifications reported under RIDDOR since that
date. Prior to this date, enforcement was the responsibility of HSE’s Railways
Inspectorate. The incidence of reported near miss and crossing misuse is steadily
increasing. In 2005 there were over 1000 incidents of misuse involving vehicles and 179
near misses, and almost 1400 misuse and 244 near miss incidents involving pedestrians
[12].

Lobb [6] reviewed train-pedestrian collisions, the leading cause of fatality in train-
related accidents worldwide, and observed that it is under-represented in the transportation
literature. She identified just 14 studies referring to train-pedestrian accidents, while
acknowledging that other less accessible reports may be held by railway companies and
local and national government bodies around the world. These studies show, however,
that while train-pedestrian collisions are less common than other forms of pedestrian
accident such as collisions between motor vehicles and pedestrians on roads, they are
more likely to result in death or irreparable damage, such as amputation or paralysis. She
also noted that analysis of accident statistics suggests that these collisions are most likely
to involve trespassers (i.e., people who are illegally on the rail corridor). To put these in
context, Evans [10] shows that the two large groups of accidental fatalities are in the home
and in transport, each accounting for just over 30% of the total. Transport deaths are
dominated by road accidents.

Table 1: Casualties at Level Crossings in 2005 in the UK [15]

<table>
<thead>
<tr>
<th></th>
<th>Passenger</th>
<th>Railway staff</th>
<th>Occupants of road vehicle (including pedal cyclists)</th>
<th>Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protected crossings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual crossings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manually controlled gate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manually controlled barrier</td>
<td>2 injuries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manually controlled barrier Protected by closed-circuit television</td>
<td>1 fatality, 2 injuries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Automatic crossings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic half barrier</td>
<td>3 fatalities</td>
<td></td>
<td></td>
<td>2 fatalities, 2 injuries</td>
</tr>
<tr>
<td>Automatic barrier crossing locally monitored</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic open crossing remotely monitored</td>
<td>1 injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic open crossing locally monitored</td>
<td>1 fatality, 1 injury</td>
<td>1 injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User-worked crossing protected by miniature warning lights</td>
<td>5 injuries</td>
<td>1 fatality</td>
<td></td>
<td>3 fatalities, 1 injury</td>
</tr>
<tr>
<td><strong>Unprotected crossings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User-worked crossings</td>
<td>1 injury</td>
<td>1 fatality, 1 injury</td>
<td>1 fatality</td>
<td></td>
</tr>
<tr>
<td>User-worked crossing with telephone</td>
<td>1 injury</td>
<td></td>
<td>1 fatality</td>
<td></td>
</tr>
<tr>
<td><strong>Open crossings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footpath crossings</td>
<td>1 fatality</td>
<td></td>
<td></td>
<td>1 fatality, 2 injuries</td>
</tr>
</tbody>
</table>
The next largest group is railway trespassers. In addition, it is estimated [13] that over the 7,674 rail crossings in the UK, each year there are

- 680 million vehicle traverses;
- 660 million pedestrian traverses;
- and 109 million train traverses

These data suggest significant potential for incidents at crossings, and various studies confirm the scale. Data from the UK regulatory body reveal that during 2005 there were 27 train incidents at level crossings, compared with 29 in the preceding twelve months, and a total of 16 people were killed in incidents at level crossings (Table 1). In 2006, there were 32 injuries and 10 fatalities, all involving pedestrians [14]. The types of crossing are described in Appendix 1. The greater risks to pedestrians are evident from Table 1 and the report noted that the nine pedestrian fatalities were more than in 2004, but comparable to previous years. Sometimes, the incidents are reported differently. For example and in contrast to Evans’ economic analyses, Wigglesworth [16] views accidents as a public health rather than an engineering or financial problem. Hence the appropriate unit of measurement for public health purposes is not the number of crashes or the financial consequences of those crashes, but rather the actual number of deaths and the death rate as used in Table 2.

**Table 2: Statistics on Crossing Incidents in Australia [11]**

<table>
<thead>
<tr>
<th>Engineering treatment at crossing</th>
<th>Deaths</th>
<th>Average number of crossings</th>
<th>Death rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booms</td>
<td>4</td>
<td>75</td>
<td>6.7</td>
</tr>
<tr>
<td>Flashing lights (rural)</td>
<td>16</td>
<td>259</td>
<td>7.7</td>
</tr>
<tr>
<td>Flashing lights (metro.)</td>
<td>44</td>
<td>78</td>
<td>70.5</td>
</tr>
<tr>
<td>Passive</td>
<td>107</td>
<td>2698</td>
<td>5.0</td>
</tr>
<tr>
<td>Total</td>
<td>171</td>
<td>3110</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Table 2 shows that the largest number of deaths occurred at passive crossings simply because of the large number of these crossings. However, the largest rate arose at the 78 crossings in the metropolitan area that were protected by flashing lights. The death rate at these crossings was 70.5, which was an order-of-magnitude higher than any other category.

While the definition of death rate in the above study was not defined, Cairney [11] also used this statistic and pointed out that with the estimated average of four deaths per year at passive crossings, Australia’s rate is 0.02 deaths per 100,000 population, which is considerably lower than the 173 fatalities at level crossings in 2000 in the US (equivalent to a rate of 0.06 per 100,000 population) and 0.21 per 100,000 population in Finland. The numbers suggest that Wigglesworth and Cairney use different terminology for ‘death rate’.

At this point it is also appropriate to define other terminology. Railway accidents are traditionally classified as train accidents, movement accidents or non-movement accidents. Train accidents are those in which a train is damaged and casualties may occur; movement accidents are those in which a person is injured due to the movement of a train, but the train itself is not damaged; non-movement accidents are other injuries on railway property. Table 1 also distinguished between different types of level crossing that cut across the UK railway network, on both public and private land [17].

Crossings may be either active, where the level crossing user is made aware of the presence of a train, or passive, where the level crossing user is responsible for detecting the presence of an approaching train and making the decision to cross. On average
incidents at level crossings result in 11.6 fatalities and weighted injuries per year which represents 6% of the total railway risk. While much has been done to look at accidents involving road traffic and locomotives at crossings, here the focus is on uncontrolled crossings and the risk to pedestrians rightfully crossing the tracks rather than trespassers as is a key feature of Lobb’s and other research. While there may be some ambiguity in these classifications, this paper explores some issues contributing to the risks including human factors, as well as some potential ways of addressing the problem.

2. The Problem Defined

In terms of equivalent fatalities a year for all types of rail incidents, the groups most at risk in percentage terms have been identified as:

- Pedestrians on user-worked crossings – 32%
- Motorists and vehicle passengers (on all road crossings) – 19%
- Rail users on trains colliding with road vehicles on road crossings – 15%
- Pedestrians on protected crossings – 15%
- Pedestrians on footpath crossings – 11%
- All other categories – 8%

So despite the focus on other rail incidents, which include the rare major disasters as noted previously, pedestrians on user worked crossings are an important group to consider. Research was commissioned by Railway Safety[19] to explore the hazards and risks at ‘passive’ level crossings and specifically to examine the relationship between user perception of risk and location factors such as traffic movement. The aim of the study was to facilitate the development of improved risk control strategies at passive level crossings and to inform the development of Railway Group Safety Plan objectives. The results of the work provided evidence for the influence of certain ‘risk factors’, i.e. crossing and user characteristics that influence the risks at passive level crossings. The results also provided recommendations for improving risk controls and data collection.

The study highlighted the importance of the users’ perceived risk at level crossings, how this influences their behaviour, and the consequent actual risk to which they are exposed. The interviews conducted reveal that users generally perceive crossings:

- to be ‘dangerous’ where there are fast trains and sighting is poor; and
- to be ‘safe’ where there is good sighting, and trains are slow and infrequent.

The analysis provided little evidence that crossings with poor sight times were associated with the occurrence of accidents. This is counter to the intuitive view that providing good sighting at passive level crossings is the most important factor in risk control.

These perceptions underlie the risk compensation behaviours which explain the weak correlation between poor sight times and occurrence of accidents. Crossing users who are aware of poor sight times will respond by crossing more rapidly with greater vigilance. To a lesser extent where trains are infrequent (two or fewer per hour) regular users may not regard the risks as so significant, and behave less cautiously [20].

Further research in this area was commissioned in 2004 by the Rail Safety and Standards Board (RSSB) [21] and was particularly concerned with how much sighting time is necessary to ensure user safety, and the risks associated with miniature warning lights (MWLs) [22]. Table 3 draws on this work and indicates the pedestrian crossing time derived from the data for key crossings.
### Table 3: Example of UWC Sighting Times and Traverse Times

<table>
<thead>
<tr>
<th>Crossing Name</th>
<th>Sighting Time (Sec.)(^b)</th>
<th>Length of Crossing (feet)(^a)</th>
<th>Traverse Time Pedestrian (Sec.)(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castleton Farm</td>
<td>10.6</td>
<td>421</td>
<td>108</td>
</tr>
<tr>
<td>Church Lane</td>
<td>12.8</td>
<td>85</td>
<td>21.9</td>
</tr>
<tr>
<td>Englemere</td>
<td>7.7</td>
<td>566</td>
<td>145</td>
</tr>
<tr>
<td>Mill Farm</td>
<td>8.2</td>
<td>60</td>
<td>15.3</td>
</tr>
<tr>
<td>Recreation</td>
<td>3.1</td>
<td>86</td>
<td>22.1</td>
</tr>
<tr>
<td>Smiths</td>
<td>3.7</td>
<td>429</td>
<td>110</td>
</tr>
<tr>
<td>Vale Wood</td>
<td>25.9</td>
<td>528</td>
<td>135.5</td>
</tr>
<tr>
<td>Applehurst Lane</td>
<td>28.6</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Bog Hall Farm</td>
<td>31.7</td>
<td>69</td>
<td>18</td>
</tr>
<tr>
<td>Brind</td>
<td>8.0</td>
<td>70</td>
<td>18</td>
</tr>
<tr>
<td>Carters</td>
<td>27.3</td>
<td>30</td>
<td>7.7</td>
</tr>
<tr>
<td>Gainsborough Road</td>
<td>6.82</td>
<td>30</td>
<td>7.7</td>
</tr>
<tr>
<td>Green Lane</td>
<td>23.6</td>
<td>45</td>
<td>11.5</td>
</tr>
<tr>
<td>Market Garden</td>
<td>8.2</td>
<td>62</td>
<td>15.9</td>
</tr>
<tr>
<td>Marsh Lane</td>
<td>20.5</td>
<td>21</td>
<td>5.4</td>
</tr>
<tr>
<td>Old Brickyard Cottage</td>
<td>8.2</td>
<td>82</td>
<td>21</td>
</tr>
<tr>
<td>Pennys</td>
<td>26</td>
<td>39</td>
<td>10</td>
</tr>
<tr>
<td>Philip Lane</td>
<td>28.1</td>
<td>43</td>
<td>11</td>
</tr>
</tbody>
</table>

\(^a\) Imperial units are the convention in the rail industry.
\(^b\) Sighting Time calculated from RT/LS/S/012 ‘Inspection and risk assessment forms for UWC, footpath and bridleway level crossings’ Railtrack Company Standard, 2002. For example Sighting Distance (875 yards =0.497mile) x Permitted Line Speed in miles/h (60) = 30 seconds, minus 10 seconds to be in a position of safety = 20 seconds sight time. (Railtrack, 2002).
\(^c\) Traverse time and sighting time are calculated according to Railtrack Company Standard. For example Sighting Distance in feet (30) ÷ Crossing speed (feet per second) Pedestrian (3.9) = 7.69 seconds, [24].

Network Rail’s estimates are used to determine whether the warning time provided at a UWC is adequate. No crossing protection other than the standard warning signs, described in the HMRI Guidance document, is required where the permissible line speed is less than 100mph, if the warning time is 20 seconds or more, and at least 5 seconds greater than the time taken by users to traverse the crossing. At footpath and bridleway crossings the warning time must merely be greater than the time required by users to cross from decision point to decision point, unless other protection is provided.

The warning time is defined as the shortest possible time between a train being seen or heard and its arrival at the level crossing. Calculations are based on sighting times available at the crossing (i.e., the furthest distance a user is able to see along the tracks) and the maximum permissible line speed through the crossing. For example, the warning time is 38.6 seconds at a crossing where sighting distance is 850 yards and permissible line speed is 45mph. According to Network Rail’s estimates, all types of user would be able to traverse this crossing safely without further protection, as long as the distance across the tracks was no greater than 37 feet. [24].

Human Engineering) Derivation of the data uses a line speed of 60 miles/h although, as the average impact speed of the trains in all accidents for which information is available is 75 km/hour (47miles/h) [25], arguably the sight times in the table gives worse case scenarios. However, there are instances where the line speed is much higher (Figure 2), in which case the data in Table 3 are optimistic and the risks from even lower sight times are increased.
The data reveal several locations at which the traverse time for pedestrians exceeds the sighting time. This has to be put in the context of the Rule Book [26] setting out mandatory requirements for direct application in the workplace. It states that no one is allowed ‘on or near the line’, on the railway or within 3m of the nearest rail, unless they have completed the Personal Track Safety (PTS) course and have an in date Sentinel Competency Card, (Sentinel is an integrated management system for some safety critical competencies on the railway in the UK). Exceptions to this rule include station platforms and authorised crossings. However, there are areas on the operational railway where even PTS trained staff are not allowed to work unless all train movements have been stopped. Such areas, called Red Zones, include inspecting track infrastructure and are in places where it is not possible to set up a safe place of work. This is because the sighting distance is obstructed by, for example, a bend in the track, or structures and the speed permitted on that section of line. Clearly, the public are allowed access to cross tracks under track conditions of a standard where professional rail staff are not. It is also noteworthy that traverse time is a simplification: access to a place of safety is the key issue rather than traverse time, and this is conditioned by the probable human response – to run, but is that forwards or backwards? The nearest place of safety may be behind.

2.1.1 Behaviour at User Worked Crossings

The diversity of human risk perception, level crossing types and the environments around the crossing raise many human factors issues. Various studies have explored these factors associated with incidents at crossings, although most concentrate on rail/vehicle crossing scenarios. For example, Caird et al [27] identified a taxonomy of contributors to accidents as:

- Unsafe actions – risk taking, not looking, distractions
- Individual differences – age, gender, exposure
- Train visibility – weather, obstructions, track and road alignment, crossing elevations
- Passive signs and markings – advanced warning signs, pavement markings, crossbucks
- Active warning systems – gates, flashing lights, intelligent transportation system
- Physical constraints – time, space kinetics.

They noted that safety at crossings is influenced by human actions (including individual limitations and impairments) and individual differences that interact with the roadway environment (including traffic control devices) as well as train visibility, physical constraints, and effectiveness of traffic control devices (warning systems, signs and markings) together with environmental conditions such as weather and darkness. There are similarities in the findings of recent research on pedestrian crossing decision-making, where it was found that the role played by the environment in pedestrian
violation of rules about crossing has to be interpreted in terms of topographical features, infrastructure, control systems and the pedestrian’s primary task or objective [28]. In the context of rail crossing accidents, in each case where fatalities and injuries have occurred a full description of weather conditions has been considered so that that may be excluded as the key factor. Thus, for example, the risk from level crossing equipment failures and incidents relating to weather conditions remain constant at around zero to two percent of the total risk. [24]

The research by Human Engineering [21] focussed on determining when the final decision to cross is made and how much sighting time is therefore necessary to ensure user safety. Over the research period, 104 UWCs were studied. A total of 1968 observational surveys and 736 questionnaires were completed successfully. CCTV footage from two crossings was also examined to provide a more objective picture of user behaviour. The quantity of information collected made this the largest user worked crossing survey carried out in Great Britain [22]. It was found that user decision points were regularly determined by the physical characteristics and environmental surrounding of the individual crossing. Vegetation often partially obscured users views down the track (due to lack of maintenance or position of the gate) until adjacent to the line. Only here can a decision to cross be made safely. This was not always in a position of safety. Users at crossings with a minimum sighting time of less than 20 seconds were almost twice as likely to make the final decision to cross adjacent to the tracks as users at crossings with a minimum sighting time of greater than 20 seconds. Users generally perceived crossings to be safe. Users who thought the crossing was dangerous did so mainly because of poor sighting or perceived frequency of trains. Users also tended to overestimate the time required for a train to reach the crossing from the point at which it is first visible, thus underestimating the risk to them.

Although evidence suggests that most users adopt safety-conscious behaviour, the data were seen as insufficiently consistent to disprove the need for substantially more warning time. However, this and previous research suggests that increasing warning times would have the effect of reducing user perception of risk at crossings, and inducing less cautious behaviour. Increasing warning times substantially may not therefore succeed in improving safety at these crossings [22]. This seems counter to the suggestion by Bibby and Regan [29]. Their research on behalf of HSE on behaviour and environmental factors that affect the correct use of UWC prompted them to suggest that the physical attributes of crossings rather than behaviour are responsible for crossing incidents, and that there was confusion over the point at which a decision should be made to cross in safety. So, increasing warning time by cutting back vegetation, would also remove the confusion over the location of the final decision point.

Judgment under uncertainty is one of the most difficult tasks for a human to make well and is covered both extensively and controversially in the literature. Contributions to error of judgment may be analyzed in a number of ways and Reason [30] provides one framework for this with three levels of distinction as outlined in Figure 3 below.
All errors are considered to represent some kind of deviation in preferred action or outcome. Defining error as a ‘failure of planned actions to achieve their desired goal’, Reason argued that error could generally be classified in two ways as represented in Figure 4 below that includes slips and lapses, which may be particularly relevant to crossing accidents.

**Figure 3:** Distinctions within ‘Error’

Reason argues that these occur in the context of routine tasks often executed automatically; they often link to failure in attention by the subject. In the current context, a ‘recognition failure’ could be the incorrect identification of noise due to road or aircraft traffic rather than an approaching locomotive. A pedestrian forgetting to check if the track is clear may be classified as a ‘memory failure’. In contrast, a problem, (anything that requires a change to the current plan) is associated with a ‘mistake’ and ‘mistakes’ occur when actions go entirely as planned, but the plan itself deviates from the desired path. ‘Mistakes’ involve higher order cognition such as planning, formulating intentions and judging. ‘Mistakes’ can be classified as rule-based or knowledge-based. The former could relate to the use of a ‘bad’ rule or the non-use or inappropriate use of a ‘good’ rule, while knowledge-based mistakes are characterized by conscious reasoning in relation to what is often an inaccurate and incomplete ‘mental model’ of the problem and its causes.

**Figure 4:** Classification of Errors
Reason also distinguishes errors and violations. Errors tend to result from problems where information is forgotten, incomplete, incorrect, or unknown, whereas violations are deviations from safe operating practice, procedures, standards, or rules, and may be classified as routine, optimizing, or necessary (situational) as illustrated in Figure 5. Improvements in education and training help in preventing errors, but violations require organizational and motivational solutions.

![Figure 5: Violations in Error](image)

Reason’s third element in the analysis of error relates to the active or latent nature. Active human error is such that the result of the error is negative and immediately, or almost immediately, known involving unsafe acts (errors or violations). For example, failing to look for an oncoming train may be characterized as an ‘active error’. Similarly, failing to assess that the sight time is insufficiently long for the track conditions may miss recognition of a need for greater vigilance, resulting in a greater risk.

Conversely, latent failures result from decisions made or by positions taken by organisations as a whole, where the damaging consequence may lie dormant for some time, only becoming evident when local triggering factors overcome the organisation’s defence mechanisms. Such a failure could be at a location where the line-speed is 125 mph. As noted previously, the rail industry only allows work to take place under a full possession, i.e., when the engineers have control of all train movements over that section of the railway. However, the Countryside and Rights of Way Act 2000 permits the general public to cross the railway at such locations and where the sighting distance is less than recommended for safe working.

Combination of these principles may be seen in other representations of human factors such as Figure 6. Where would a calculated gamble fit into this model? Would that be an error if it went wrong? Reason does not appear to consider a situation where a person makes a best information judgment where there is uncertainty. He addresses planning and management errors in what appears to be essentially deterministic models but does not appear to address this point explicitly. As this is a key issue in some of the decision-making about crossing lines described above, it is questionable whether this model covers all that it should.
Targoutzidis incorporated such human failures into a simplified version of the ‘bow-tie’ risk assessment approach [31] and this has been adapted to generate Figure 7. The bow-tie approach is argued to be one of the most powerful and increasingly popular risk assessment techniques. It evolved from the Cause Consequence Diagram from the 1970s and the Barrier Diagram of the 1980s and was originally conceived as a tool for studying safety cases in the oil and gas industry. In 2004, the US Federal Aviation Authority (FAA) mandated that its regulated entities employ the ‘bow-tie diagram’ as the main mechanism for ‘safety analyses’ [32]. A ‘bow-tie’ starts with a fault tree analysis (FTA), where potential incidents are analyzed in terms of pre-conditions for the top event at the centre of the bow-tie. After identifying these ‘root causes’ of the incident, an event tree analysis (ETA) follows in the opposite direction to identify possible chains of events leading to undesired consequences. Safety barriers may be identified in both directions, either to prevent the incident from happening or leading to undesired consequences. So, Figure 7 represents a left hand side of a bow-tie and builds on Figure 6 by adding motivation.

**Figure 6:** The Taxonomy of Human Failures [30]

**Figure 7:** The Taxonomy of Human Failures

Now we have motivational factors such as the ‘gamble factor’ made more explicit in the model. We can liken this sort of behaviour to the ‘risk taker’ described in the context.
of the extended parallel process model (EPPM) model that we outline later after some consideration of ways to address the risks including communication techniques.

**Addressing the Problem**

Approaches for improving risk controls, and for improving incident reporting and data collection activities, which in many cases are required in order to gain a better definition of the extent of risks emerged from studies for Network Rail [33]. Risk controls include:

- Rail traffic moment\(^1\) is a key factor and must be monitored closely to ensure that any potential increases in level or type of use are anticipated and appropriate risk controls implemented before incidents occur, such as increases in traffic volume and line speed.
- At certain crossings where gate abuse is a problem the development of alternative technical solutions include:
  - Pneumatically or electrically driven barriers that can be operated from a push button (interlocked with the railway).
  - Advanced warning systems using new technologies.
- Level crossings on lines with low train frequencies (e.g. less than 2 per hour) should not necessarily be regarded as ‘low risk’. Consideration should be given to sounding the whistle on approach to such crossings.
- Development of a device that automatically activates the whistle on approach to crossings would ensure that whistles are sounded consistently by all trains.

Increasing the visibility of trains [11] is another option, while additional recommendations could include:

- When opening the gate onto the crossing the user should be made fully aware that they are entering a potentially hazardous environment.
- Automatic gate lock preventing access onto the crossing but allowing egress off the crossing when a train is approaching.
- Visual warnings, together with audible warnings, should be employed on all crossings.
- Painted areas to define decision points could clearly mark hazardous (red) and safe (green) areas.
- Reports from drivers, and/or other rail staff of any near miss incident
- Some scenarios are summarised in Table 4 with recommended risk controls from this research as described above.

These are just a few scenarios and others could be considered. For example, an implication from the data in Table 3 is that line speed could be regulated according to sighting time. However, modern practice is to maximize line speed and in addition, varying speeds (braking and acceleration) are hardly environmentally or organizationally sustainable, and so is unlikely to be a priority recommended control measure. Even relatively straightforward moves suggested in Table 4 may be controversial as was pointed out in relation to train whistles. Their use and acceptability depends on the balance of risk (to the user) and noise nuisance (to the nearby residents). Where changes are made, consideration should be given to awareness campaigns (probably targeted for maximum effectiveness) to deal with transition risk, otherwise regular users may be at heightened risk shortly after the change [35].

---

\(^1\) ‘Traffic moment’ is the number of road vehicles using the crossing multiplied by the number of trains passing in a given period
Table 4: Risk Scenarios with Possible Risk Controls from this Research (adapted from Little [34])

<table>
<thead>
<tr>
<th>Scenario Description</th>
<th>Sequence of Events Leading to Accident</th>
<th>Crossing Features</th>
<th>User Characteristics</th>
<th>Recommended Risk Controls</th>
</tr>
</thead>
</table>
| 1 'Nip across' – user crosses in front of approaching train but misjudges time | User at crossing and sees approaching train  
Begins to traverse quickly  
User misjudged the speed of the approaching train or time traverse - unable to get out of the way | Good sight time  
Variable train approach speeds  
Straight track (more difficult to judge speed)  
High train frequency | Familiar users short of time –use for going to work / jogging /etc.  
Poor judges of speed | Auto gate locks  
Train whistle  
Visual warning |
| 2 'Disregard' - user fails to acknowledge risk of crossing | User at crossing unaware of danger  
Begin to traverse at normal pace without looking for a train  
May see train as it gets close but the user is then unable to get out of the way | Low train frequency  
Nearby distractions  
Gates left open or no barriers | Distracted  
Regular user with low perception of risk (few trains)  
Unfamiliar with crossings, unaware of risks | Auto gate locks  
Train whistle  
Visual warning  
Clearly marked hazardous and safe areas |
| 3 'Stuck' - user gets 'stuck' or otherwise takes longer to cross than expected | User at crossing and takes care to stop, look and listen for a train  
Begin the traverse at a normal pace  
During traverse gets stuck or fall, chase a dog that is off the lead  
The train approaches and the user is unable to get out of the way | Uneven surface  
Queues develop on crossing  
Exit gates difficult and close to the line | Encumbered with bicycle, pram, or elderly and infirm  
Dog walkers with dogs off lead  
Livestock handlers | Instructions to allow more time when crossing  
with encumbrance  
Improve maintenance of crossing surface  
Improve sight time |
| 4 'Unseen train' – user caught out by negative sighting time | Arrives at crossing and takes care to stop and listen for a train  
The train either does not sound its horn or is not heard by the user  
Begins the traverse moving quickly as aware of the short sight time  
A train comes into sight and unable to get out of the way before the train arrives at the crossing | Short sight time  
Long traverse time (surface, many tracks, angle, exit not opposite entrance) | Take longer to traverse than sight time | Improve sight time  
Train whistle  
Visual warning  
Improve maintenance of crossing surface |
| 5 'Second train comes' – user waits for train to pass but is caught out by second train from opposite direction | Arrives at crossing and sees an approaching train  
Wait for the train to pass  
Fail to look in the opposite direction for another train, or view blocked by first train  
The second train arrives at crossing and the user is caught by surprise | Double track  
Many trains  
Trains scheduled to pass (e.g. near station)  
Track curvature conceals second train | User fails to check both directions i.e. thinks it is safe to cross when a train has passed | Auto gate locks  
Train whistle  
Visual warning |

2.1.2 Some Limitations on Possible Interventions

Lobb [5] states that research on interventions to reduce train-pedestrian accidents is sparse. She cites previous research on road pedestrian behaviour suggesting that educational and awareness-raising interventions have limited, if any, effectiveness in reducing unsafe road crossing. Similarly, she mentions that warning signs have been shown to be insufficient to reduce unsafe behaviour in drivers approaching uncontrolled road-rail crossings.

There is some evidence to suggest that physical changes in the environment of the crossing may increase safe pedestrian behaviour [36]. For example, the angle, relative to the railway, of the approach path and the crossing itself as well as the relative quietness of
the combination of a modern train and track together with the level of background noise at
the crossing were contributory factors identified in a recent accident investigation.
Additionally, the surface of the crossing was slippery [37]. However, Lobb et al. [38] found that the reason given most frequently for trespassing on the tracks was
convenience—the safe and legal route across an overbridge took more time and effort.
They cite studies suggesting that pedestrians crossing a road will weigh perceived safety
of a route against the time and effort required to use it. Just how this balance is struck is
not clear from the research, however. They also note that the road-pedestrian literature
includes studies showing that pedestrians choose the shortest path; others suggest that
pedestrians tend to choose the simplest path even if it is not the shortest.

Network Rail in the UK introduced a ‘Level Crossing Policy and Strategy’ in
2002/03, aimed at reducing crossing risk by 15% by the end of 2005/06 financial year.
During 2005 the focus of this strategy included:

• a reduction in the number of level crossings;
• effective operation and maintenance;
• a programme of risk assessment to identify further reasonably practicable
  reduction measures; and
• ongoing communication with users and other stakeholders to promote the safe
  use of level crossings.

Network Rail continued its programme of level crossing closures, upgrades and
renewals in 2005, with all territories undertaking a range of mitigating actions at crossings
identified as high risk. For example: the London North West territory commissioned
telephones at 65 user worked crossings and issued mobile telephones to users of 15 other
UWCs; the Western territory closed several crossings, including the CCTV crossing at
Silk Mill (which has been replaced by a road bridge); and Scotland enhanced some of its
automatic crossings by introducing improved signage, fencing and anti-slip surfaces. In
early 2006, Network Rail also began to transfer responsibility for level crossing
inspections to maintenance staff. Initial indications are that this major change has
introduced new discipline into the system, with more rigorous checks against
specifications, standardised practices, and new guidance material thereby improving the
risk assessments advocated earlier.. Initiatives relating to human factors issues underlying
crossing risk and appropriate risk mitigation measures have continued [39].

Aiming to ensure that no new permanent crossings are introduced other than in
exceptional circumstances, the strategy follows a programme of closure of existing
crossings, where feasible, and improvements in crossing safety where reasonably
practicable. During 2006 Network Rail moved into the second phase of its strategy
through targeted education, engineering, enabling and enforcement actions. In 2007 the
All Level Crossing Risk Model (ALCRM) was launched on Network Rail's information
management system. This was developed to replace separate assessment methods for
different types of crossing with one that covers the whole network. It also provides a
standard means for collecting, storing and recalling data on individual features of level
crossings.

The model can calculate both the risk to the crossing user and the collective risk to
the exposed population (the user and anyone else who may be involved in an accident,
such as train staff and passengers). This makes it possible to see the spread of risk across
all crossings and target resources effectively. In some cases a crossing can be closed and
an alternative route provided. Other measures include providing additional protection at
the crossing, educating users and working with the police to identify and act against
people who deliberately act in a way that endangers others.
Communication through signs and other media are evident in recommendations in Table 4. Communication strategies follow from Reason’s model and the role of awareness raising in preventing certain errors are relevant. The study for Railway Safety [40] highlights the importance of the users’ perception of the risk at the level crossing, how this influences their behaviour, and therefore the extent of risk to which they are exposed. Most communication campaigns either intentionally or unintentionally raise anxiety or fear in audiences, because they focus on a health, physical, or social risk. The study of what makes effective vs. ineffective risk messages is formally called ‘fear appeal’ research. Fear appeals are persuasive messages that scare an audience into adopting a recommended response and are frequently used by politicians, advertisers, and those involved in health education. Research into fear appeals has shown them to be potent persuasive devices, but only in certain conditions. The extended parallel process model (EPPM) was described in a study by Witte and Donohue [41]. While this dealt with vehicle crashes with trains at crossings, many of its principles can be translated to behaviour of pedestrians at user-worked crossings. Their results indicate that 10 - 20% of the motoring population is most likely to engage in risky behaviours around railway crossings. This risk seeking population is most likely to try to ‘outrun a train’ for the thrill of it. Scenario 1 of Table 2 could include this behaviour pattern, although the ‘risk seeker’ is not specifically identified.

According to the EPPM, which has been used in various safety domains, evaluating a threat initiates two judgments that result in either danger-control or fear-control processes. So, individuals assess the seriousness of a threat (e.g. ‘will collision with a train harm me?’) and their susceptibility (e.g. ‘is it possible that I will collide with a train?’). The greater the perceived threat, the greater fear is aroused and individuals move to the second assessment, which is to evaluate the effectiveness of response. In doing so, they assess the principle (e.g. ‘will abiding by safety rules prevent train collisions?’) and the personal effectiveness (e.g. ‘can I abide by safety rules or do I have control over my behaviour?’). When the threat is regarded as trivial or irrelevant, there is no motivation to consider the issue further; the effectiveness of the recommended response is evaluated superficially, if at all, and cautionary messages generate nil response. If people do not feel at risk or do not feel a threat to be significant, they simply ignore information about the threat and do not consider persuasive messages any further.

An individual who perceives both threat and effectiveness highly will be motivated to control the danger and follow the recommended response. Danger control processes are primarily cognitive processes where individuals

(a) believe the threat is serious and that they are at-risk of negative consequences from it (high perceived threat);
(b) fear a serious and significant threat and are motivated to protect themselves;
(c) believe they can deter the threat effectively (high perceived effectiveness); and
(d) deliberately confront the danger (e.g. ‘I will stop and wait whenever there is a warning indicator at rail crossings’).

So, when people perceive themselves to be vulnerable to a serious risk, and they believe they can do something to avert that risk effectively and easily, their fear is aroused and they are motivated to protect themselves against the threat. Hence the risk perception and risk motivation branches in Figure 7.

However, if an individual realizes that they cannot prevent a serious threat from occurring, either because they believe the response to be ineffective and/or because they believe they are incapable of responding appropriately, then fear-control processes begin to dominate over danger-control processes. Such emotional processes are where people respond to and cope with their fear, not to the danger. Defensive motivation is elicited by
too much fear arousal, which occurs when the perceived threat is high and perceived effectiveness low, and produces responses that control fear by defensive avoidance or reaction. Witte and Donohue acknowledge studies showing that fear appeals with high levels of threat and low levels of effectiveness result in rejection of the message, and people even do the opposite of what is advocated. An analogy is described by Diamond [42] relating to people living near dams and their concern about the likelihood of the dam bursting. Concern increases as one approaches the dam until just under the dam when it drops to zero, possibly because the implications are so great that people stop assessing them. Diamond describes this as ‘psychological denial’. So, when an individual thinks they may be vulnerable to a significant threat but believe that there is nothing they can do to address the threat effectively, they deny they are at risk, defensively avoid the issue, or respond reactively. Hence, fears about a threat can inhibit action and risk messages may backfire.

So, according to the EPPM, threat and/or fear motivate action whatever that may be, while perceived effectiveness determines whether the action taken controls the danger (which is protective) or controls the fear (which inhibits protective behaviour).

In terms of safety communication campaigns in the context of this theory, it appears that because of habituation ‘risk takers’ do not perceive that they are personally susceptible to being in a collision. As they will not respond to a risk message if the threat is perceived as either trivial or irrelevant, risk-takers may perceive a collision as serious, but they do not believe it will happen to them. This perception is reinforced each time they beat the train successfully. Such individuals will not process any communication messages about railway safety because they do not view these messages as being relevant to them. Based on this, Witte and Donohue concluded that an effective communication campaign has to promote strong perceptions of susceptibility both vividly and realistically while simultaneously reinforcing safe behaviour. However, if Diamond’s interpretation is correct, the threat should be described in reasonable terms which the user can appreciate on a personal basis, rather than overwhelming terms where the level of threat is so great that they stop considering it as a factor. The findings of Witte and Donohue also suggest that prior personal experiences have a greater impact on behaviour than do environmental constraints, especially prior experiences that were frustrating. This led to representations of frustrating experiences with a railway crossing:

- **Knowledge.** No significant differences emerged between risk seekers and the risk averse for knowledge of railway safety rules.
- **Biased judgments.** Risk seekers exhibited significantly stronger biased judgments toward beating the train as compared with the risk averse.
- **Risk profile.** Risk seekers scored significantly higher on a risk profile than did the risk averse, suggesting a cluster of risky behaviours linking alcohol, smoking, risky driving, etc.
- **Sensation seeking.** As expected, risk seekers scored significantly higher on all four sensation seeking subscales (i.e. seeking thrills and adventure new experiences, lack of inhibition, and boredom susceptibility) than risk averse people.

From this it was suggested that communication campaigns need to target risk seekers. They appear to have become habituated to high levels of fear due to prior close calls with trains and frequent (and often frustrating) experiences with railway crossings (e.g. been blocked, had trouble seeing train, stopped at flashing gates but no train in sight, etc.). Communication messages need to address these frustrations specifically, and the
best way to prevent railway accidents may be to prevent (perceived) frustrating experiences for high sensation seekers.

It has been noted that problems and accidents occur when transport users do not obey rules, but road safety regulations, as an example, impose few restrictions on pedestrians [28]. This may be considered analogous to the situation where pedestrians cross railway tracks. Cambon de Lavalette et al [28] conclude that where the environment provides constraints such as a refuge or clear signals, the pedestrian uses those signals. Adherence to railway safety laws by the rest of the population (other than risk seekers) may call for more traditional campaign messages that realistically and accurately portray the negative consequences of unsafe railway behaviour.

Other relevant observations come from studies on perceptions of speed and distance in crossing roads. Connelly et al [43] show that pre-adolescent school-age children, particularly those under 10 years, have relatively poor skills at reliably setting safe distance gap thresholds, and thus do not consistently make safe crossing decisions. Their capacity for making such decisions safely progressively declines as vehicle approach speeds exceed 55 km/h (34 miles/h). Their paper goes on to say that child pedestrian safety is more likely to be at stake when children are impulsive, distracted, or delay decision-making to the last moment before suddenly attempting to cross. It is in these circumstances that they are more likely to make last-moment crossing decisions in which the threshold becomes critical, a misjudgement possibly exposing them to risk of serious injury or death.

A consequence of the children’s primary dependence on distance judgments is a greater chance of unsafe last-moment decision as vehicle approach speeds increased. In addition, the variance in judgments suggests that, even where the averages indicated safe decision-making, the children were neither reliable nor consistently good decision makers.

What these findings show is that children cannot be relied upon to make safe last-moment decisions, regardless of their age. Furthermore, they suggest that, rather than placing the primary responsibility on the children to make better decisions, especially given the ineffectiveness of educational initiatives in the child-pedestrian field, efforts should be directed toward reducing vehicle approach speeds.

The authors expressed considerable concern that their findings show that children frequently made unsafe decisions, even under almost optimal conditions which included relatively light traffic densities, unobstructed view, few distractions, making decisions about traffic travelling in only one direction and not necessarily for every vehicle in the stream, and while being under constant adult supervision. In the actual street-crossing context the child has to consider traffic approaching from both directions and cope with many distractions, as well as with obstructions to a clear view, any or all of which may further reduce accuracy of judgments. They also may have to make these judgments in the absence of adult supervision. There are clear parallels with uncontrolled rail crossings which, as we have shown, may not have optimal conditions.

3. Conclusions

For an overview of the problem, it is possible to return to the bow-tie approach. The technique places emphasis on the linkage between risk controls and the management system, ensuring that risks are managed rather than just analysed. It forces practitioners into a comprehensive and structured approach to risk assessment and is also offered as an excellent means of communicating risk issues to non-specialists as it can give a clear picture of what are often complex safety management systems. A bow tie for the scenario of this paper (Figure 8) illustrates the hazard, some causes, consequences and controls to
minimize the risk – called defences in Reason’s model. Some elements in Figure 7 have been condensed here.

**Figure 8: Bow Tie Representation of the Overall System**

Figure 8 also identifies critical tasks to assure the continuing integrity of risk controls. High-level tasks include setting and reviewing policies for management systems and corporate social responsibility. Lower level tasks include inspections, testing and maintenance procedures as well as communication across all stakeholders – on both sides of the bow tie. Essentially this may be seen as a hierarchy for performability. Ultimately, however, the human factor has to be addressed by modifying behaviour of individuals crossing tracks or designing out the risks of them doing so. Neither is an easy option.

**References**


[37]. Rail Accident Investigation Branch (December 2008), Fatal accident at Moor Lane footpath crossing, Staines, 16 April 2008, Report 27/2008, Rail Accident Investigation Branch, Department for Transport.
[41]. Witte, K annd. Donohue W. A Accident Analysis & Prevention Volume 32, Issue 1 , January 2000, Pages
Corporate Responsibility for Pedestrian Risks at Level Crossings

127-139 doi:10.1016/S0001-4575(99)00061-5  Preventing vehicle crashes with trains at grade crossings: the risk seeker challenge.


Appendix 1: Level Crossing Types in the UK and Abbreviations [44]

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manual crossings</strong></td>
<td></td>
</tr>
<tr>
<td>Manually controlled gate</td>
<td>Access is protected by gates. As a train approaches a railway employee closes the gates across the road to allow the train to pass. The gates are then opened to allow the free flow of road traffic. The operation of the barriers is initiated automatically as the train approaches. The barriers close automatically when the train has passed, unless there is another train approaching. Crossing equipment condition is monitored remotely when the railway line is open. In addition, telephones are provided for public use and connected to the monitoring point.</td>
</tr>
<tr>
<td>Manually controlled barrier</td>
<td>Protected by barriers, across both carriageways of the road and are operated by a railway employee. The operation of the road traffic lights signals and audible warning devices is linked to the signalling system. Typically, the crossing operator is situated within a 50m clear view distance of the crossing. The crossing is designed to close the barriers or gates in the event of a trapped person or vehicle. Crossing equipment condition is monitored remotely when the railway line is open. In addition, telephones are connected to the monitoring point.</td>
</tr>
<tr>
<td>Manually controlled barrier</td>
<td>Similar to a joint UWC, but with the addition of telephones for the crossing user. Typically, where the crossing is monitored by the train driver. There is only one such crossing in the UK at Rossane, near Keith, in the Scottish Highlands.</td>
</tr>
<tr>
<td>Automatic half barrier</td>
<td>Access prevented by half-barriers that block road traffic, but not the exits leaving an escape route for trapped motorists. The primary protection is a combination of road traffic light signals, audible warning devices and the half-barriers. The operation of the barriers is initiated automatically as the train approaches. Crossing equipment condition is monitored remotely when the railway line is open. In addition, telephones are connected to the monitoring point.</td>
</tr>
<tr>
<td>Automatic open crossing</td>
<td>No barrier protection, but road traffic light signals and an audible signal warn road vehicles drivers and pedestrians. The warning sequence is initiated automatically by the approach of a train and stops when the train has cleared the crossing. The equipment is monitored at a when the line is open. In addition, telephones connected to the monitoring point are available for the crossing user.</td>
</tr>
<tr>
<td>User worked crossings</td>
<td>These are provided where the road is quiet and rail speed low. The interface between the railway and the road is open with no barriers or gates, with protection by signs warning road users to give way to any oncoming train. The crossings are such that there must be sufficient sighting for the road vehicle users to stop in time to allow the passage of the trains. In addition, the train speed is limited to 10mph or there is a requirement for a train to stop (at a stop board) before proceeding across the crossing. All user worked crossings are private and are only for authorised users. However, in some cases public pedestrian access is provided at these locations by means of public footpaths and/or bridleways.</td>
</tr>
</tbody>
</table>