THE EFFECTIVENESS OF SAFETY MEASURES AT RAILWAY LEVEL CROSSINGS ON ROAD USER BEHAVIOUR

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ABSTRACT

As part of a large-scale project to improve the safety at railway level crossings in the Netherlands, a number of safety-improving measures has been implemented. Commissioned by Railinfrabeheer B.V., TNO Human Factors conducted a study to determine the effectiveness of these measures with respect to road users’ behaviour.

The measures included the extension of a barrier at pedestrian and/or bicycle paths, conspicuous marking of the cross section, rumble strips, speed humps, solid white centre lines, or physical medians. At low-volume flashing light railway level crossings simple barriers with a clearance area of 2 or 1.5 m were applied.

At 16 railway level crossings behavioural observations were conducted based on video-recordings on the spot in a before-and-after study. The video-recordings were analysed quantitatively by determining the speed of free-driving passenger cars and by conducting a time analysis of non-stopping/stopping behaviour of pedestrians, bicyclists and motorists. The behavioural analyses also included the rating of conflicts between road users.

Most measures as implemented at railway level crossings improve the behaviour of road users. For some measures further improvements are recommended. Rumble strips nor solid white centre lines are effective in improving road users’ behaviour and are therefore not recommended. The separation of slow and fast road traffic is counter-productive for speed reduction at the railway level crossing.
INTRODUCTION

Railned Railway Safety has conducted a study to explore possibilities for measures to reduce risks at AHOB railway level crossings (Griffioen, 1999). The Netherlands has about 900 AHOB railway level crossings, crossings that are protected by automatic half barriers. In the period between 1985 and 1997, a yearly average of 37 train-road user collisions, 435 road user-crossing obstacle, 15 fatalities and 13.4 injuries occurred.

As part of a large-scale project to improve the safety at railway level crossings in the Netherlands, a number of measures has been implemented by Railinfrabeheer B.V. For example, at all crossings the road signals were replaced by much more conspicuous LEDs. Other measures included the extension or placement of barriers for pedestrians and bicyclists, speed-reducing measures (rumble strips, speed humps), active warning systems for traffic queues, and separation of two-way traffic by solid centrelines or physical medians. At railway level crossings protected by flashing lights only, a small barrier (mini-AHOB) was also tried out.

Railned Railway Safety developed a methodology to evaluate effects of these measures on the safety at railway level crossings. Elements of this methodology included behavioural observations by video, speed measurements, interviews with road users, and conspicuity measurements. Under commission of Railinfrabeheer B.V. TNO Human Factors conducted a study to determine the effectiveness of these measures with respect to the expected road user behaviour.

METHOD

Recordings

According to the Railned evaluation plan (Schenk, 2000), for each measure two locations were selected. At each location behavioural observations were conducted based on video recordings on the spot in a before-and-after study design. For both the before and the after measurement, video recordings were made during two days from 7 a.m. to 7 p.m.. In total 48 hours of video recordings are available for each location (24 hours during the before period and 24 hours with the measure implemented). By applying time-lapse video with a reduction factor of five, a 12 hours period was recorded on one tape (Super VHS). The time was displayed visually in the image with an accuracy of 1/25 s and could also be read automatically with an accuracy of 1/50 s. We applied black-white video cameras because of the better resolution and higher light sensitivity compared to colour cameras.. The video recordings were made from a high camera-standpoint (unobtrusively mounted at a height of at least at 4.5 m). To accommodate accurate speed measurements, real-time video-recordings were also made during one day between 7 and 11 a.m.

At 16 railway level crossings video observations were made in the period May 2000 till March 2001.

Analysis

In close cooperation with Railned, we defined for each measure what was to be expected with respect to the behaviour of road users and what we had to focus on for the analysis of
the video recordings. Moreover, traffic volumes were determined each quarter of an hour, distinguished by type of road user and direction. We made use of the commercially available software package OBSERVER specially developed to analyse the behaviour of people in the time domain. Together with the semi-automated video analysis equipment VIDARTS of TNO Human Factors, the registration of exact moments relevant events occurred was conducted. With VIDARTS the moments of activation of the railway level crossing were determined automatically by detecting the onset of the red signal and/or the descent of the barrier. These moments were stored and used in a second round to detect the active periods for further analysis. By slowly moving the tape, the moments of passing the red signal by pedestrians, bicyclists or motorists were indicated by an operator and stored. The severity of running the red signal was categorised in the following risk categories with respect to the moment of crossing:

- **A** between the moment of descent of the barriers and the moment the barriers are fully down,
- **B** between the moment the barriers are closed till 5 s before train arrival,
- **C** 5 s before arrival of the train,
- **D** in between two trains,
- **E1** within 5 s after the train has left the intersection area,
- **E2** within 5 s after the second train has left the intersection area,
- **F** between 5 s after the train and the opening of the barriers
- **G** during the opening of the barriers (till the barriers are up and the red signal is switched off).

Category D is to be regarded as the most risky one, whereas A and G are less risky but also then one consciously makes the decision to cross during the red signal. In case one is crossing while the barriers are opening and then close again because of a second train, this event is counted as a G and not as a D.

Where relevant, the character and severity of encounters were scored according to the criteria of the conflict observation technique DOCTOR (Kraay, van der Horst & Oppe, 1986). A conflict is a situation where two road users approach each other in time and space such that a collision is imminent when course and speed remain unchanged. The severity of a conflict depends on the time margin that is left (Time-To-Collision TTC or Post-Encroachment Time PET) and the estimated resulting injury impact. The severity scores range between 1, 2 (slight conflicts) and 3, 4 or 5 (serious conflicts). Serious conflicts have the most direct relationship with accidents. The results on conflicts are not further discussed in the context of the paper. For this, the reader is referred to Van der Horst, Martens and Bakker (2001).

Quantitative speed measurements were made from video recordings (50 fields/s) with the help of VIDARTS. The speed of a vehicle is measured by determining the passing moments of two electronic lines that have been mixed in the video image at a known street distance. In most cases an accuracy of better than 1 km/h could be achieved. Only free-driving (having at least a headway of 5 s to a lead vehicle) vehicles were included in the speed analysis. Fig. 1 gives an example of a video image with the electronic lines mixed.
RESULTS

Extension of barriers for pedestrians

At location L01, see Fig. 2, the barriers for the sidewalks (Dutch ‘voetpad’) were extended to close the whole gap. Fig. 3 gives the number of pedestrians that are crossing during red in the directions 3 and 7 (see Fig. 2). The number of risky crossings (category B-F) decreases from 11 to 2. Also the number of pedestrians that start walking while the barriers are opening (cat. G) decreases (from 22 to 14). However, there seems to be a migration effect to the other side of the road, since the number of pedestrians crossing during red in the directions 1 and 9 (no measure taken at this side) increases for the risky categories (B-F) from 7 to 15 (see Fig. 4). Related to the total number of pedestrians, the number of risky pedestrian crossings increases from 0.5 to 1.2%. The number of less risky crossings during red also increases at this location from 1.3 to 1.7% Apparently, part of the pedestrians that were crossing in the direction 3 or 7 in the before situation decide to cross at the open side at the other side of the road. Pedestrians that are crossing intentionally during red are difficult to stop.

Fig. 1  Speed measurements from video with electronic lines at a known distance mixed in the image.
Fig. 2  Situation at location L01 (Bloemendaal) with the extension of the barriers on the sidewalks ("voetpad" in Dutch).

<table>
<thead>
<tr>
<th>Risk category</th>
<th>Number of passing pedestrians during activated crossing</th>
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<tbody>
<tr>
<td>Loc. 1 (direction 3+7)</td>
<td></td>
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<tr>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
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<td>A</td>
<td>B</td>
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<td>C</td>
<td>D</td>
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<tr>
<td>E1</td>
<td>E2</td>
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<tr>
<td>F</td>
<td>G</td>
</tr>
</tbody>
</table>

Fig. 3  Number of pedestrians crossing during red at location L01 by risk-category for the directions 3 and 7 (confronted with the measure of extending the barriers).
Fig. 4  Number of pedestrians crossing during red at location L01 by risk-category for the directions 1 and 9 (no measure taken).

Bicycle path at open side 3/4 (Diemen) or 4/4 closed (Hoorn)

At two locations (Diemen and Hoorn) the barriers at the open side of the railway level crossing were extended over the bicycle path, in such a manner that the bicycle path was closed for 3/4 or 4/4, respectively. Fig. 5 gives the number of bicyclists that pass during red relative to the given risk-categories. The 3/4-closing (Diemen, Fig. 5a) does not give clear effects, but the presence of the barrier for the 4/4-closing (Hoorn, Fig. 5b) reduces the number of red runners in the risky categories considerably, from 51 to 6. Also for the most risky category D (crossing in between two trains) the number is reduced from 7 to 3.

Fig. 5  The number of bicyclists that cross in opposite direction after installation of the extended barriers, bicycle path for 3/4 (Fig. 5a) or 4/4 (Fig. 5b) closed.
For pedestrians who make use of the bicycle path in opposite direction, the number that crosses during red in the risky categories (category B-F) before and after do not differ at the location with the 3/4 barrier (Fig. 6a). A 4/4 closing reduces the number of pedestrians crossing during red in categories B-F from 11 to 1 (Fig. 6b). However, the number of passing pedestrians when the barrier is opening (category G) increases (from 1 to 7). So, there seems to be a shift to a less risky behaviour.

![Fig. 6](image)

**Fig. 6** The number of pedestrians that make use of the bicycle path to cross during red with a 3/4 (Fig. 6a) or 4/4 (Fig. 6b) closed bicycle path.

The extension of the barrier at the open side of the bicycle path actually reduces the number of bicyclists who cross riskily during red. It does not influence the number of pedestrians crossing during red that much although there is a shift to less risky categories. Pedestrians that intentionally want to cross during red are difficult to stop. At the 4/4 closed bicycle path the enclosure of both bicyclists and pedestrians between the barriers does actually occur (van der Horst, Martens & Bakker, 2001) and especially countermeasures should be taken to give bicyclists a safe place to stay waiting.

**Speed-reducing measures**

**Rumble strips**

Transversal rumble strips do not appear to work for reducing the speed of free-driving passenger cars, neither on 50 nor on 80 km/h roads. Cumulative speed-distributions did not differ significantly before and after installation of these rumble strips.

**Speed humps**

At two locations in built-up areas speed humps were installed near the railway level crossing to reduce the speed of motorised traffic at the crossing and to increase the attention level of motorists. At one location the speed hump was located at about 20 m distance from the stop-line, at the other location a raised plateau of about 5 m in length was installed close to the stop-line. At each location speed measurements were made in the before situation and twice in the after situation (after a few weeks (after1) and a few months (after2)). Fig. 7 gives the resulting cumulative distributions of free-driving passenger cars at both locations. At both locations the speed humps reduce the speed considerably (minus 9-15 km/h). At both locations the two after measurements do not differ from each other. Although the speed-reducing effect at the second location (L13) was even greater, other behavioural
measures (number of emergency stops, place of stopping, number of conflicts) indicated that it is to be preferred to place the speed hump a bit away from the stop-line (about 20 m) to make the passing of the speed hump and the passing of the railway level crossing two separate events (van der Horst, Martens & Bakker, 2001).

Fig. 7 Cumulative speed distributions of 100 free-driving passenger cars at location L12 (Heiloo, speed hump at about 20 m distance) (top) and at location L13 (Wezep, speed hump close to stop-line) (bottom).
CONCLUSIONS

The approach of behavioural observations with video in a before-and-after study design with (wherever possible) 2 locations for each measure appeared to be effective. For some relatively seldomly occurring events a period of 2 days (each 12 hours) was too short to draw firm conclusions. But, in general, by systematic analysis of road users’ behaviour from video a good indication about the functioning of the measures to improve safety at railway level crossings could be achieved.

The extension of a barrier at pedestrian and/or bicycle paths improves the behaviour of pedestrians and bicyclists, but does not prevent the crossing of pedestrians who ignore the red light on purpose. Rumble strips don’t give a speed-reducing effect, neither in built-up nor in rural areas. Speed humps reduce the speed of free-driving motorists drastically by about 9 to 15 km/h, but do not influence the number of red-runners.

Other results, not discussed in this paper but part of the study as well (Van der Horst, Martens & Bakker, 2001), include:

Conspicuous marking of the cross section area somewhat reduces the chance on a queue at the railway level crossing, but much more effective is an active queue-warning system.

Within built-up areas (speed-limit 50 km/h), a solid white centre line to separate two-way traffic at the railway level crossing reduces the speed with about 2.5 km/h but does not prevent slalom manoeuvres or centre-line crossings. A physical median reduces the speed with about 2.5 km/h, and reduces the number of line crossings as well as the severity of bicycle-car overtaking conflicts. Removing slow traffic from the carriageway increases the speed of free-driving motorists with about 3 km/h. A barrier with a clearance area of 2 or 1.5 m at a flashing light railway level crossing improves the behaviour of road users during red. There is a slight preference for the short barrier with a clearance area of 2m.
REFERENCES

