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It's a sign! Developing a warning system for New Zealand's pedestrian level crossings

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Abstract

It has been identified that the use of hand-held mobile devices and other distractions may decrease the situational awareness of pedestrians, thereby increasing their risk at level crossings. To mitigate this risk, the concept of an illuminated pavement sign (IPS) to provide extra warning of an approaching train was developed by New Zealand's national operator, Kiwirail. The aim of this research was twofold: to understand crossing users' attitudes towards the concept of the sign, and to develop design principles to advise the sign's layout. To achieve this, three stages of research were conducted. Firstly, a human factors review of initial sign options was carried out by the researchers. This was followed by two workshops involving members of the public, and other related stakeholders who regularly use pedestrian level crossings (Auckland n=11 participants, Wellington n=10 participants). Finally, a series of 11 intercept surveys with crossing users, and a site analysis was conducted at a Wellington site, where prototype LED luminaires have already been installed. This paper discusses participants' attitudes towards the sign, and describes six design principles which emerged from the research. Finally, we suggest two sign layouts that could be trialled at level crossings. It is proposed that an IPS will be naturalistically trialled at actively-controlled level crossings around New Zealand before any wider adoption of the signs in guidelines or standards.

1. Introduction

It has been identified that the use of hand-held mobile devices and other distractions such as wearing headphones may decrease the situational awareness of pedestrians, (Hatfield and Murphy 2007, Nasar and Troyer 2013, Lin and Huang 2017), thereby increasing their risk at level crossings. For example, in a study which surveyed pedestrian behaviour and movement in six West European capital cities, it was noted that when in road traffic, 17% of pedestrians interacted with their smartphones, engaging in activities such as texting, talking, and wearing headphones (DEKRA 2016). In an American study with a similar method, it was observed that 29.8% of pedestrians interacted with their smartphones in some way whilst crossing a street (Thompson, Rivara et al. 2013). Studies agree that those pedestrians who are most likely to engage with their phones in traffic are between 15-35 years of age (Nasar and Troyer 2013, DEKRA 2016). Unsafe road and rail crossing behaviour associated with smartphone use includes failing to look both ways, disobeying road rules, and slower, more unpredictable movements (Thompson, Rivara et al. 2013, Lin and Huang 2017).

The phenomenon of 'distracted walking' is believed to be a factor which contributes to road and rail-related pedestrian injuries (Lichenstein, Smith et al. 2012, Pešić, Antić et al. 2016). In the United States for example, the number of pedestrian injuries needing to be treated in hospital emergency departments have doubled since 2005, despite the total number of pedestrian injuries dropping during the same time period (Nasar and Troyer 2013). Likewise, in New Zealand, the most frequent factor associated with pedestrian fatalities is 'crossing heedless of traffic' (Ministry of Transport 2016). Underlying causes of distraction, such as the use of smartphones may exist in this group.

To combat the associated risks caused by distracted pedestrians near heavier transport modes, as of May 2017, various solutions which incorporate LED technology placed in the pavement are being trialled at at least seven locations around the world. Generally, The aim of these trials is to regain the attention of smartphone users at heavy rail crossings, light rail crossings, and road crossings. The trials currently underway are in: Bodegraven in Holland (installed February 2016), Ausberg (installed April 2016) and Cologne in Germany, Collins Avenue, Tawa in New Zealand (installed September 2016), Melbourne and Sydney in Australia (installed March 2017), and Singapore (installed May 2017).

At the Collins Avenue crossing, seven red and yellow in-ground prototype LED luminaires were installed by KiwiRail at both sides of a pedestrian level crossing (Figure 1). The LED luminaires are connected to the train detection system and flash when a train is approaching. Currently, this is the only known example of pavement-based LEDs to warn pedestrians of an approaching train on a heavy rail line.

Figure 1: Prototype pavement-based lights at a pedestrian level crossing. Installed at the Collins Avenue crossing in September 2016

The prototype pavement-based LEDs at the Collins Avenue crossing were introduced as a prototype and seem to be a good starting point in the development of this technology. However, the conspicuity, comprehension, and credibility of the lights, as well as any possible adverse effects are examples of human factors considerations that need to be evaluated. Further, to improve upon the current design, it has been suggested that pre-manufactured pads placed in concrete frames may be cheaper to install and easier to modify.

This paper explains the research process that was used to determine the design principles for the illuminated pavement sign (IPS), and suggests two layout options. Following this research, it is proposed that on-site naturalistic trials of pedestrian behaviour in response to an IPS will follow at crossings around New Zealand with active protection[1]. The sign will warn users that a train is approaching, and will supplement existing "Look for trains" signage.

[1] Crossings with active protection are linked to a train detection system and warn users of an approaching train. This can be achieved through bells, flashing lights, a barrier arm (roads), or automatically closing pedestrian gates.

2. Methods

For this study, data were collected in three stages. Firstly, a human factors review of possible sign layouts was conducted. Secondly, two workshops with level crossing users were held. Finally, a site visit, and a series of intercept surveys with crossing users at the existing in-pavement LED site at Collins Avenue were conducted. Details of each stage of the research are outlined below.

2.1. Human factors review

A human factors review was conducted by the first and second authors. The review took into account NZ Transport Agency Standards, as well as general design principles regarding the usability of an IPS for a range of user types. Specifically, the conspicuity, legibility, comprehension, and credibility of the signs, as well as any potential adverse effects from a pedestrian's perspective were considered. The review informed the design of the workshops by identifying where deeper user enquiry might be needed.

As part of the human factors review a site visit to the Collins Avenue crossing was conducted in conjunction with the intercept surveys. During the site visit, the prototype LEDs were examined. The researchers used the crossing with, and without trains approaching and noted operational features.

2.2. Workshops

Two workshops were held, the first in Auckland and the second in Wellington. The aim of the workshops was to gain an in-depth understanding of the perspectives and attitudes of a range of user types in relation to general level crossing safety, and the meaning, perceived effectiveness, and usability of the proposed IPS pads.

Participants were recruited via e-mail flyers and transport-related Facebook pages. They were screened to ensure that they used pedestrian level crossings at least fortnightly. A range of user types were represented, including people with low-vision, people who use mobility devices, youth, and people who push prams. In total, 21 level crossing users participated in the workshops, with an average age of 43, and ages ranging from 13-75. Eleven males, and ten females participated. Eighteen participants used level crossings at least once a week.

The workshops were held in the evening and lasted approximately two hours. Informed consent was obtained, participants were given a gift voucher for attending, and refreshments were provided.

Workshop participants were engaged in a guided group discussion, followed by individual exercises where they completed a workbook, to assess five mock-up prototypes of the IPS pad (for two examples see Figure 6 and Figure 7). Near the end of each workshop a process of refinement was used to identify preferred sign layouts by the group, acknowledging that group consensus was unlikely. This helped to arrive at the design elements that were likely to be favoured by each of the groups.

2.3. Intercept surveys and site visit

A series of 11 intercept surveys using a convenience sample of pedestrians were conducted at Linden Station, near the Collins Avenue crossing. Pedestrians were asked about their perceptions of safety at this and other crossings, if they had noticed the lights, their interpretation of the lights, and their perceptions of the lights' effectiveness.

3. Results

Some overarching results from the workshops and the intercept survey are given below. Following this, we present the design principles which were created from a combination of the human factors review, workshops, intercept survey, and site visit.

4.1. Workshops

Given the number of participants, only counts are given as statistical analyses cannot be made with these results. In general, participants in both workshops were positive about the concept of the IPS. Thirteen participants stated that they would find the inclusion of an in-pavement sign useful or very useful. In addition, nineteen participants thought it likely or very likely that the sign would influence their behaviour at crossings (Figure 2 and Figure 3). Please note that results are combined from Auckland and Wellington, and that the question related to the concept of a sign, rather than a specific design.

Figure 2: Would you find the signs useful? (Combined responses from Auckland and Wellington)

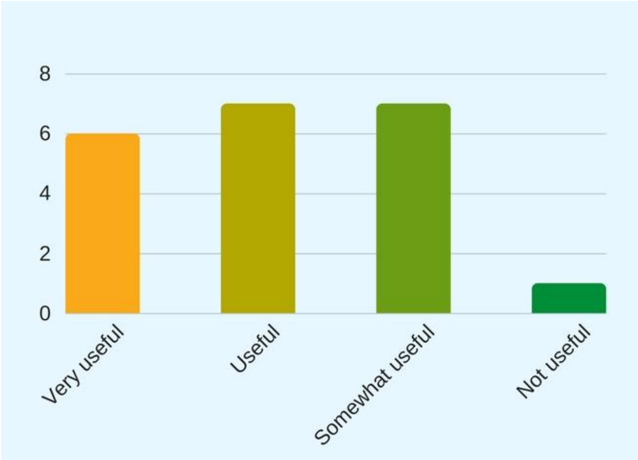
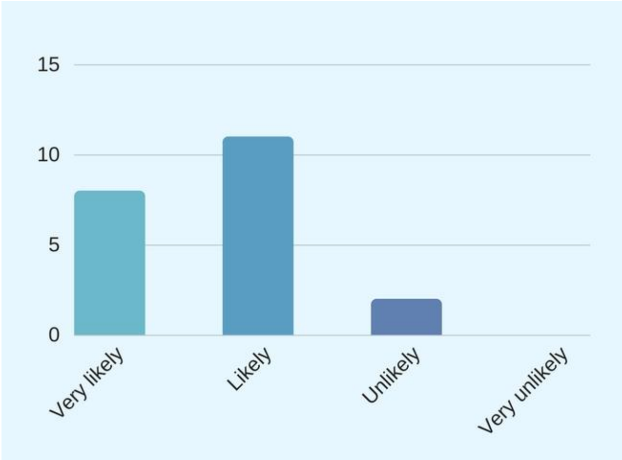


Figure 3: Would the signs influence your behaviour? (Combined responses from Auckland and Wellington)



At an active crossing, the IPS needs to convey the message that a train is approaching. Therefore, for a sign to be effective, the instruction that pedestrians must stop and wait for the train to pass before continuing over the level crossing must be clearly conveyed.

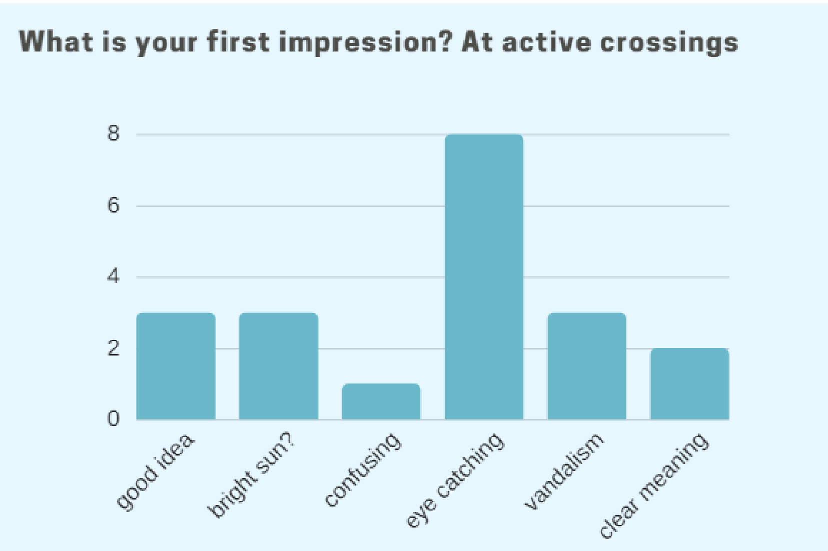
Workshop participants were shown an image of how an active IPS may look 'in-situ' (Figure 4). In the projection that participants saw, the yellow circles in each corner turned on and off to depict flashing lights.

Figure 4: Mock-up of an in-situ active crossing IPS pad

The workbook asked participants a series of questions about their impressions of the sign. This was done prior to any group discussion to ensure individuals' attitudes were not influenced by the group.

Participants were generally positive towards the concept of the sign, particularly in relation to its visibility (Figure 5). Some participants raised the concern that it could be at risk of vandalism, whilst others thought the lights might not be obvious in bright light conditions.

Figure 5: Participants' first impression of the sign (Combined responses from Auckland and Wellington)



There was a consensus that the signs would be effective for smartphone users, but would also aid people looking downwards, people wearing headphones who may not hear the crossing's bells, children, and cyclists. There was some concern that people pushing prams may not see the sign as the immediate footpath in front of them is obscured.

3.2. Intercept survey

Eleven people responded to the intercept survey which was held near the Collins Avenue crossing. Six female and five males were interviewed, with ages ranging from teenagers to mid-50s. Eight respondents used the Collins Avenue crossing at least once a week.

The survey showed that the existing prototype LED luminaires are well-recognised and well-understood by crossing users. Eight respondents volunteered information about the in-pavement lights, and, when prompted about the lights, ten respondents understood that flashing lights indicated an approaching train and that they should stop and wait for the train to pass. Six respondents suggested that this crossing was safer than other crossings in Wellington. These responses indicate that the next iteration in the development of the IPS may have an equal, or stronger effect on crossing users.

3.3. Design Principles

Six themes emerged from the data. These themes have informed design principles which may guide the IPS pad layouts for trial.

3.3.1. Lights

A critical feature of the IPS layout is the configuration and luminosity of the LED luminaires. Responses from the workshops, and results from the human factors analysis showed that more than six LED luminaires may be confusing and disorienting, especially for users with low vision (Figure 6). A preferred option was to have fewer lights, which would still send the correct message to users without being overwhelming (Figure 7).

Figure 6: Numerous lights may be disorienting and confusing
Source: 3i Innovation

Figure 7: Fewer lights accurately convey the message without being overwhelming
Source: 3i Innovation

The luminance of the LEDs was raised during the workshops and considered during the site visit. There was concern that the luminaires may be too bright at night time, and not visible enough in bright sun (Figure 8 and Figure 9). It is suggested that a light-detection sensor be included in the final IPS design that can control the level of luminance depending on the lighting conditions.

Figure 8: Collins Avenue in the afternoon
Source: Jamie's Rail Photography, YouTube: https://www.youtube.com/watch?v=TqgxjKBFHAU&t=4s

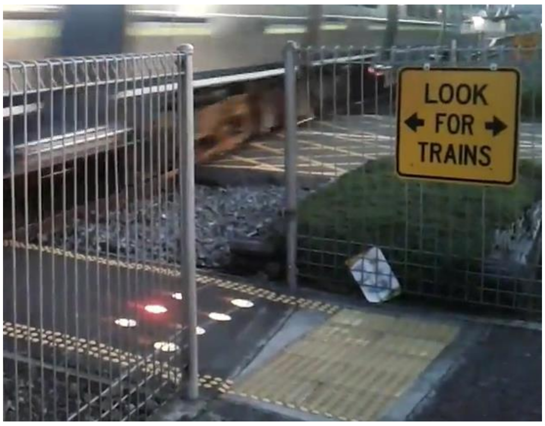


Figure 9: Collins Avenue at night
Source: Jamie's Rail Photography, YouTube: https://www.youtube.com/watch?v=TqgxjKBFHAU&t=4s

To provide a good range of visibility, especially for people pushing prams, the lights should appear on the top and bottom of the pads. To ensure they are attention-grabbing, we suggest the lights flash in a diagonal sequence. Consideration should be made so that the lights do not flicker at a rate that may trigger seizures (Grenier, Timofeev et al. 2003). We recommend using the NZ Transport Agency's guideline for LED signs of 1 Hz (NZ Transport Agency 2012).

3.3.2. Shape and size

In regards to the ideal shape of the IPS pad, consensus was not reached in the workshops. Whilst many workshop participants indicated that the sign would be most effective if it ran the full width of the crossing, others noted that a sign less than the full width, but placed in the centre of the crossing would be sufficient. Others stated that a sign which ran the full width of the crossing would be distracting.

The human factors analysis ascertained that it was not necessary for the sign to cover the full width of the crossing. With a combination of colour and lights, a sign of at least half the width of a standard crossing of 1800mm (NZ Transport Agency 2012) would still be effective in gaining pedestrians' attention, and would fit most existing crossing widths in New Zealand.

3.3.3. Combination of information

Workshop and the human factors review findings indicated that using a combination of information (i.e. lights, symbols, bright background, and words) would be most effective in accurately conveying the desired message to a variety of users. For non-English speakers in particular, the train symbol may provide necessary information.

3.3.4. Train symbol

Workshop participants expressed their bemusement in relation to the existing steam train symbol used throughout New Zealand (NZ Transport Agency 2016). Participants suggested that the sign was outdated, and whilst recognisable, it did not reflect their everyday experience of the rolling stock.

In UK-based research on road level crossing sign comprehension and risk perceptions, Basacik, Cynk et al. (2014) found that compared to five other symbol options which included modern train symbols, the existing steam train symbol (Figure 10) rated poorly. With regards to comprehension, the symbol most closely associated with a road level crossing portrayed a forward-facing modern train approaching a side-on car (Figure 11). In relation to the symbol that most influenced participants' perceptions of risk, the three options depicting a train and a car rated the highest, followed by a forward-facing modern train (Figure 12).

Figure 10: Existing steam train symbol in the UK (Basacik, Cynk et al. 2014, p.2137)

Figure 11: Symbol most clearly associated with a road level crossing (Basacik, Cynk et al. 2014, p.2142)

Figure 12: Forward-facing modern train symbol (Basacik, Cynk et al. 2014, p.2142)

Interestingly, despite their being in service at the time of the study and therefore containing latent recognisability, the two existing level crossing signs in the UK were perceived by participants as conveying the least amount of risk of all six symbol options.

We suggest KiwiRail consider adopting a modern train symbol in the IPS pad to bring the company's signage in line with 21st Century train design. However, to ensure consistency with the rolling stock, we suggest KiwiRail consider retaining the steam train symbol for use on Heritage train lines. However, further research to identify if a disparity in level crossing signs could result in a lack of public understanding is suggested.

3.3.5. Surface

The prototype pads that were displayed in the workshops comprised of a raised tactile surface, smooth lights, and a coloured surface (for two examples, see Figure 6 and Figure 7). When tested with low-vision and blind users, it was suggested that the tactile surface of the prototype pads may be misinterpreted as the yellow tactile pavers which indicate where pedestrians should wait for a train. It was considered that a potential risk of a tactile IPS surface could lead to confusing some users into standing at an unsafe proximity to the train. Therefore, we suggest the pads be made of a non-slip surface without raised tactile markers.

3.3.6. Colour

In the final IPS pad layouts suggested below, we use a combination of lights and static sign components. In the workshops, there was some discussion about the colour choice of the static element in the IPS pad, particularly with relation to people with low-vision. Yellow is currently used as a guidance colour in road signs and is consistent with the existing "Look for trains" signs and tactile pavers at crossings. Therefore, using yellow in the IPS may be beneficial as its use would be consistent with existing signage and would be recognisable. However, some workshop participants suggested that people with low-vision may mistake the yellow in this sign for the tactile pavers, thereby potentially bringing them closer to the train. This may be mitigated by the presence of the black symbol, wording, and lights in the IPS pad, coupled with the absence of a tactile surface. However, this identified risk could be user-tested in the proposed trial.

4. Suggested IPS pad layouts

The design principles were used to guide the design of the sign layout options presented below. Whilst all features may not necessarily be possible due to manufacturing parameters, they should nevertheless be considered as a guide.

For all options we recommend:

- A rectangular sign of approximately 600x1000mm to be placed in the centre of the footpath;
- Three LED luminaires equally spaced at the top and bottom of the pad;
- The LED luminaires would flash in sequence at a rate of 1 Hz;
- To avoid triggering seizures, the LED luminaires would not flicker, or would flicker at a rate above 100Hz;
- The pads would not be a slip or a trip hazard;
- The pads be connected to a light-detector sensor at the controller which would allow the lights to be brighter during sunny conditions and dimmable at night;
- Use of a modern train symbol; and
- The luminaires should be approved for use as listed by the NZ Transport Agency (2017).

At an active crossing, the IPS needs to convey the message that a train is approaching. The instruction to pedestrians is that they must stop and wait for the train to pass before continuing across the level crossing. However, when no train is approaching, the presence of that message may be misleading and may cause pedestrians to learn to ignore the message, even when danger exists. Therefore, we suggest that if words are incorporated into the IPS pad, they only be used in an active capacity.

We suggest two options that could be trialled at active level crossings. They are presented and described below.

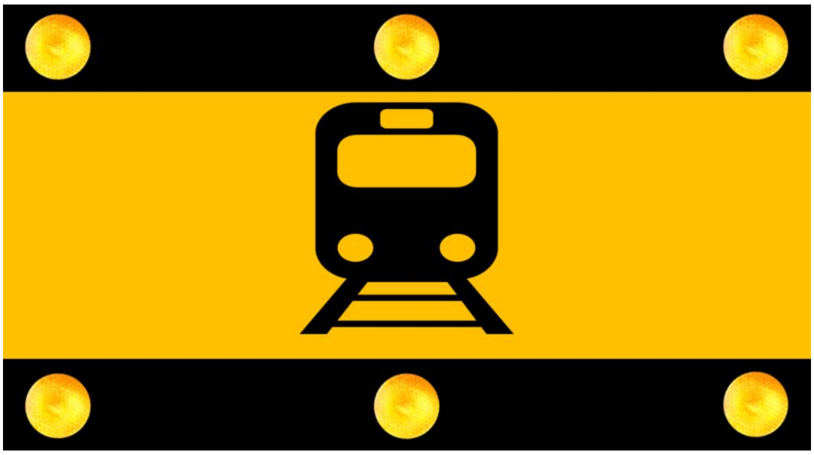
4.1. Option 1

Figure 13: Active crossing sign, Option 1

Option 1 features a yellow background the full width of the pad with a black border. It contains a static train symbol and an active message reading “Stop and wait”. The message “Stop and wait” is not static, and would be illuminated when the train detection system is activated. This would ensure the credibility of the message. The train symbol would be centred in the IPS pad and is static. Having the symbol always present is a good reminder to pedestrians about the risk associated with the crossing.

4.2. Option 2

Figure 14: Active crossing sign, Option 2



In the case where it is not practical for the message “Stop and wait” to illuminate when activated by the train, we suggest that no message is used as it may cause confusion for infrequent pedestrians, and may be ignored by frequent users. Therefore, a static train symbol with sequenced flashing lights at the top and bottom of the pad is suggested as Option 2 for active crossings.

5. Discussion and Conclusions

This paper has described the background and context behind the development of IPS which will be trialled at level crossings in New Zealand. In addition, it has outlined specific design principles for consideration for the IPS layouts, and suggests two sign options to be trialled. Overall, it seems that IPS have the potential to tangibly improve pedestrian level crossing safety.

The next stage of this research is to trial the effectiveness of the IPS pads at a number of level crossings around New Zealand. A suggested format for the trials is to conduct a video analysis of naturalistic pedestrian behaviour at pedestrian level crossings prior to the installation of the IPS pads (baseline condition), and some weeks following IPS installation (follow-up condition). Analysis of this data would identify if changes in crossing behaviour exist (e.g. more head checks, increased frequency of stopping). In addition, a survey of crossing users’ attitudes to the baseline condition and the follow-up condition may also be carried out to determine pedestrians’ attitudes towards the IPS pads.

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