Evaluating Cost-effective Railway Level Crossing Protection Systems

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Abstract

Since improving safety at railway level crossings (RLX) is costly and funds are always limited, it is important to search for cost-effective alternative solutions. There are low-cost innovative RLX-protection systems available worldwide with opportunities for application in Australia, subject to their effectiveness and appropriateness. To date, there is no systematic approach available in Australia to evaluating those systems. This paper sets out a methodology to identify and evaluate suitable technologies in relation to their adoption and adaptation to Australian conditions.

This paper reports on a study which comprises two parts. Firstly, a number of candidate systems were investigated and the engineering requirements were identified. Important criteria for evaluation were identified and each criterion was described and quantified by a performance measure. Multi-criteria analysis technique was adopted to assess the relative merits of the systems. Finally, sensitivity analyses have been performed to short-list priority candidate systems for detailed evaluation.

The future stage of the study will use a traffic simulation approach with behavioural models developed for evaluating the short-listed systems. The tools developed in this study will provide rail authorities and researchers with the means to evaluate RLX-protection systems to improve safety at level crossings.

Keywords:
Railway level crossing, protection systems, multi-criteria analysis, driver behaviour, driving simulator, traffic simulation.

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Acknowledgment:
The authors would like to thank Queensland Rail and the CRC for Rail Innovation for their support.

1.0 INTRODUCTION

Railway level crossings (RLX) create serious potential conflict points for collisions between road vehicle and train which are amongst the most severe in all traffic crash types. It continues to be the largest single cause of fatalities from rail activity in Australia (BTRE, 2002). Traffic collisions at RLX account for a significant loss of life and property. It is estimated that there are around 100 collisions between a road vehicle and a train in Australia each year and about 8% of these collisions result in deaths (Australian Transport Council, 2005; Ford and Matthews, 2002). RLX collisions are amongst the most costly economically. The financial cost of RLX collisions has been estimated at AUD$32M per year excluding rail operators and infrastructure losses (BTRE, 2002; Australian Transport Council, 2003a). In view to these reasons, RLX safety has recently been included in the National Road Safety Action Plan for the first time (Australian Transport Council, 2003b). This Strategy specifically addresses the complex road and rail interface in response to industry and community concerns.

Governments and the rail industry have been applying a variety of countermeasures for many years to improve railway level crossing (RLX) safety. However, improving safety at RLX is costly. Cairney (2003) suggests that the minimum plausible cost of installing conventional active protection in Australia would be in the order of AUD$200,000 per crossing, and an upper order estimate would be in the order of AUD$300,000. The cost of installing conventional active protection at all passive crossings would therefore be between AUD$1.2 billion and AUD$1.8 billion. In addition, on-going maintenance costs would be considerable in view of the remote location of many passive crossings. On the other hand, government funds are limited and need to be applied to the most important uses. Therefore, one of the aspects of RLX safety warrant identified in National Railway Level Crossing Safety Strategy 2003 is applying countermeasures which provide best value for money including treatments proven overseas (Australian Transport Council, 2003a). There are opportunities for immediate application of some low-cost innovative protection systems for RLX available worldwide subject to their effectiveness and appropriateness in Australia. Many protection systems have been invented but the effect on safety is unknown. To date, there is no systematic approach available in Australia to evaluating those systems for implementation in Australia conditions. This paper is structured as follows: Section 2 provides a review of literature and candidate protection systems; Section 3 sets out a methodology to evaluate suitable technologies in relation to their adoption and adaptation to Australian conditions. Finally, Section 4 presents the results of the analysis and Section 5 highlights the main findings and discusses the future stages of the study.

2.0 LITERATURE REVIEW

There are approximately 9400 public railway level crossings (RLX) in Australia. They are protected either passively (64%) or by active or automated systems/devices (28%) and the remainder have other control or protection (Ford and Matthews, 2002). Passive RLX provides only stationary sign regardless of approaching train to the crossing. Their message remains constant with time. Active protection system is a system which starts functioning as it detects a train approaching with automatic warning devices (i.e., flashing lights, bells, barrier, etc.). In Australia, records show improvement with installation of active protection (Ford and Matthews, 2002; Wigglesworth and Uber, 1991). However, to upgrade all the passive crossings with automatic warning system would involve significant investment.

Furthermore, recent RLX collision record revealed that 50% of vehicle collisions at RLX happen at active controlled crossing (Australia Transport Council, 2003a). These collisions are reported to be mainly attributed to driver behaviour in response to the protection system (Australia Transport Council, 2003a; Wallace et al., 2008; Chartier, 2000; etc.). Therefore, searching new cost effective technologies or devices becomes essential.

The effectiveness of those alternative protection systems need to be assessed to reflect safety improvements at RLX. There are many efforts made regarding risk assessment at RLX such as Australian Level Crossing Assessment Model (ALCAM). Some other collision prediction models have been developed based on the RLX inventory and historical collision records. However, most of the models do not take into account innovative safety devices.

Considerable research and innovation has occurred in some countries on low cost RLX-protection systems applied at the crossing, on train or in-vehicle. Immediate application in Australia is possible subject to its effectiveness and adaptation to Australian conditions. A comprehensive state-of-the-art survey of international literature related to RLX has been conducted, which has identified approximately fifty different systems. Thirty-two active protection systems which are infrastructure-based at RLX; three innovative protection systems which the train detection information are delivered from sub-system on board the train/locomotive; nine innovative protection systems with in-vehicle (road vehicles) warning; and six innovative passive devices at RLX were studied. Very few of these systems are operating in the field while most of them are in the development stage. A few potential systems which suit the objective of the research will be described briefly in this section. The targeted systems are meant to provide alternative choices for low-cost active warning for passive level crossings in rural area where the justification of conventional active RLX-protection systems is questionable or implementation impractical. There are five protection systems included in this paper as an example for setting up the evaluation methodology, namely O’Conner System, SOLAGARD, HRI System, EV-Alert and Minnesota In-Vehicle Warning. The alternatives identified for analyses in this paper are briefly discussed next.

1. O’Conner System

This system uses solar powered microwave radar sensors to detect the location, speed and direction of approaching trains up to 3 km away and activate the warning device when the train is 25 seconds away. A solar-powered LED “X” sign would be located near the crossing and interfaced to the level crossing protection system. The “X” would ‘flash’ when the radar unit has acquired the train and ‘steady’ when the warning devices (i.e.: flashing lights) at the crossing are activated. If the “X” sign does not operate as described, the train driver will know that the crossing has failed and react accordingly. The system is independent from the railroad signal system, so it will not compromise the railroad’s operational safety. The microwave sensors require only low power, so the system is capable of being self-powered by using solar panels and batteries (Roop et al., 2005). A complete solar-powered system is estimated to cost AUD$50,000 for installation. This system is currently in revenue service (Graham and Hogan, 2008).

2. Solar Powered Railway Level Crossing Radio Warning System (SOLAGARD™)

This system allows both audio and visual warning at a crossing. An electro-magnetic track device detects an approaching train (2-5 kms from the crossing) and actuates a solar powered VHF transmitter located about 3-4 kms from the level crossing. Through VHF Radio Communication Link, the transmitter sends a coded radio signal towards the level crossing. The radio signal is received by a solar powered receiver located at the level crossing which, after decoding the signal, actuates an Audio-Visual Alarm at the crossing for forewarning the traffic. This system operates on its own captive power supply and is under field trials (Central Electronics Ltd., 2008).

3. Low-Cost Highway-Rail Intersection Active Warning System (HRI System)

This system provides active advanced warning in addition to traditional flashers at the crossings. A typical crossing includes four sub-systems, one on each cross-buck (Master and Slave) and one on each advance warning sign. These sub-systems are all smart and can communicate and check with each other on a regular basis. Digital radios, in conjunction with global positioning systems (GPS) and multiple microcontrollers, are used for train location and detection, flasher activation, fault diagnostics and automatic reporting, data collection, and in-locomotive warning. Advance train detection is accomplished by the sub-systems on board the locomotive knowing its location and sending out a beacon at regular intervals. Any crossing within radio range (up to 5 km) will pick up this beacon and initiate a data exchange session with the approaching locomotive. Overall system cost is estimated at AUD$50,000 per crossing (URS Corporation and TranSmart Technologies, Inc., 2005). A simulated driving study which evaluates driver interaction with the low cost HRI active warning system also supports development of the system for installation at passive RLX (Smith, 2004). Nevertheless, this system is not recommended by Graham and Hogan (2008) due to inability to identify supplier, system complexity and requirement for installation in 100% of rolling stock.

4. EV-Alert

In Australia, an example of a system used by the sugar industry at RLX in Queensland is called the EV-Alert. A radio transmitting device is fitted to all locomotives, and constantly sends out a coded signal. This signal is received by an in-car (or in-tractor) device and decoded to activate a flashing light in the cabin, with a sound to warn vehicle drivers that a train is approaching or that it is in the vicinity of a train. The system can also use the transmitting signal to activate an active crossing (Commonwealth of Australia, 2004).

5. Minnesota In-Vehicle Warning

In this Minnesota project, the system used wireless vehicle and roadside communication antennas that could be built into the familiar crossbuck, "RXR" sign and front vehicle license plate. The trackside unit picked up a signal from the railroad's train detection electronics and transmitted that signal to antenna-signs. The in-vehicle display alerted drivers using both visual and audible signals. A passive train detection system listened for an internal radio frequency communication, called Head-Of-Train (HOT), used by most railroads to coordinate braking between the front and rear of the train. The HOT passive train detectors were installed directly onto the school buses in test, so that no special equipment was needed at the crossing infrastructure (Carroll, 1999; U.S. Department of Transportation, 2001).

Some of these systems are commercial products. Therefore, for analysis purposes, these five systems are identified in subsequent sections as A, B, C, D and E in order to remain anonymous. The following section briefly described the engineering evaluation procedure of the innovative RLX-protection systems.

3.0 METHODOLOGY

In order to implement such systems in Australia, selection criteria of RLX protection systems which suit local conditions are essential. This task evaluates the immediate availability, functionality, costs, reliability, and enhanced safety issues related to the adoption and adaptation of each of the candidate systems to Australian conditions. Multi-criteria analysis technique was adopted to assess the relative merits of the candidate protection systems (Roop et al., 2005; Mendoza et al., 1999). As compare to conventional cost-benefit approach, multi-criteria analysis allows effective comparative evaluation among options and stakeholders over a common set of evaluation objectives. Furthermore, multi-criteria analysis could overcome the limitation of cost-benefit analysis whereby all the costs and benefits have to be expressed in monetary terms. Some evaluation factors are difficult to translate in monetary terms (Roop et al., 2005; Macharis et al., 2009).

In short, the first step of multi-criteria approach is to define the criteria under consideration. The definitions of each criterion are then assigned a 10-Point rating scale (performance measure). Every alternative system under assessment is evaluated according to the definitions and performance measures developed. Meanwhile, a weight is attached to each of the criteria/goals which sum to 100. These weights after multiply with the score of each system allow comparison of the system evaluation. Finally, different sets of weights applied could develop an understanding of the robustness of each system as the weights changed.

Comparative analysis of the five alternative systems described in Section 2, to a set of criteria selected to represent enhanced safety, reduced system cost, installability, reliability and functionality, is performed. The evaluation criteria may be changed depending on the different interest of various stakeholders. Definitions of each criterion were identified and quantified by a performance measure (rating scale) as shown in Table 1. Performance ranges are tabulated from least preferred to most preferred. For instance, two criteria, installation cost and solar powered, have been investigated to reflect reduced system cost. Protection systems with installation cost more than \$100,000 is categorised to be high cost. High installation cost is least preferred followed by medium (\$50,000 < Installation Cost ≤ \$100,000) and low (≤ \$50,000). These three choices were quantified by a 10-point scale with least preferred rated ‘0’, medium ‘5’ and most prefer ‘10’. As for power supply preference, the binary rating of ‘Yes’ for systems which are able to operate on solar power, is desired and therefore rated ‘10’; else, ‘0’ for ‘No’. Each of the five alternative systems was assessed according to this set of criteria as shown in Table 2 and then normalised to the 10-point scale as shown in Table 3. Average value of total scores from each criterion in each goal was adopted as shown in Table 3. The scores are based on information available from the intensive literature search.

Table 1: Definitions and performance measures of criteria for engineering evaluation of innovative RLX-protection systems.

Goal	Criteria	Performance Ranges	Definition	Performance Measure
Enhanced Safety	Improvement observed/Expected	Low	Test results show low compliance/no impact to motorists. Or, the system has not tested for motorists' responses.	0
		Medium	Test results show positive comments from the motorists/residents.	5
		High	Test results indicated the system is effective in warning the motorists/residents.	10
	Fail Safe design	No	The system does not detect failure. Or, no information available indicating it is fail safe.	0
		Yes	The system detects failure and activates warning.	10
	Provide adequate warning	No	The system does not comply with 'Yes' as described below.	0
		Yes	The system activates warning device minimum of 20 s prior to arrival of a train.	10
	Provide train information	No	The system only detects approaching train at certain distance without knowing its speed, etc..	0
		Yes	The system detects the location, speed and direction of train; thus possibly provide such information.	10
Reduced System Cost	Installation cost	High	Installation cost > $100,000.	0
		Medium	$50,000 < Installation cost ≤ $100,000.	5
		Low	Installation cost ≤ $50,000.	10
	Solar powered	No	The system is not capable to operate with solar powered.	0
		Yes	The system can be operated solely on solar powered.	10
Installability	Immediate availability	Development stage	The system is in development stage.	0
		System tested	The system or the prototype has been tested.	5
		Product	The system is in revenue service or advertised as product.	10
Reliability	Failure rate	High	The tested system shown high failure rate. Or, no information available indicating it has no/low failure rate.	0
		Medium	The testing shown several failures.	5
		Low	The system is in service. Or, system failure was controlled.	10
Functionality	Ease of implementation	Hard	The implementation involves major modification to the existing system/infrastructure.	0
		Moderate	The implementation involves minor modification to the existing system/infrastructure.	5
		Easy	No modification to the existing system/infrastructure is required.	10
	Compatibility	Low	The system required installation of new control system/train detection system.	0
		Moderate	The system required installation of independent control system and warning devices without hardwire connection between them.	5
		High	Existing control system/track circuit for train detection can be used and only single component (i.e., warning devices) need to be installed.	10

Table 2: Ranking of System A, B, C, D and E according to the selected criteria.

Goal	Obj./Criteria	A	B	C	D	E
Enhanced Safety	Improvement observed (Low/Medium/High)	LOW	MEDIUM	In general, a small number of residents near tested crossing were interviewed. Their responses are: the system would greatly increase safety and would be worthwhile to very worthwhile. MEDIUM	It was apparent that the use of a flashing red light would not quickly attract the attention of the driver, especially as the driver became more familiar with the use of this light. LOW	Analysis of bus approach speed, stopping location, stopping time, and driver scanning behaviour found few statistically significant differences between the study area and the baseline areas. Results from interviews and surveys of bus drivers indicate the system is effective in warning them. The majority of the drivers felt the in-vehicle signing system should be installed on their bus permanently. HIGH
	Fail-Safe design (No /Yes)	If the system does not operate as required, it is designed so that the train driver will know the crossing has failed and able to approach at a safe speed. YES	No information recorded it is fail-safe. NO	The warning system provides notification of its status to the train in time to stop. YES	No information recorded it is fail-safe. NO	No information recorded it is fail-safe. NO
	Provide adequate warning (No /Yes)	The system continuously updates the estimated time of arrival (ETA) of the train at the crossing and activates the Flashing Lights (or other road user warning display) when the train is 25 seconds away. YES	This system is for providing early warning of the approach of a train at a crossing. YES	The active warning system accurately tracked daily train movements and provided adequate warning times. YES	YES	Some adjustments need to be made to get consistent warnings at the same crossings. Sometimes it works and sometimes not. NO
	Provide train information (No/Yes)	It is capable of detecting the location, speed and direction of travel of a train up to 3km away. YES	It is suitable for providing Audio & Visual Alarms at the Gate activated by the approaching train when it is on approach at a preset distance range of 2 to 5 km from the gate. NO	The system provides active advanced warning in addition to traditional flashers at crossings. NO	Type of warning: road side warning red and amber flashing lights, in car flashing warning light. NO	It provides two types of information on crossings: the bus's proximity to an crossing and whether or not a train is present at or near the crossing. Both visual and variable audio signals are given. NO
Reduced System Cost	Installation Cost (High/Medium/Low)	Installation Cost: AUD$50,000. LOW	MEDIUM	Estimated AUD$50,000. LOW	AUD$3100. LOW	LOW
	Solar Powered (No/Yes)	All components are fully solar powered. YES	It uses Solar Photovoltaic Power source for charging the batteries. YES	Power is supplied to the system through solar panels and batteries. YES	This system can be powered by solar rechargeable batteries, or by mains voltage. YES	NO
Installability	Immediate availability (Development Stage/System tested/Product)	This system is currently in revenue service. REVENUE	The ruggedized system is under field trials. DEVP	The project partners of the system felt the current state of the HRI System has not yet matured to be a marketable product. TESTED	It is in use by sugar industry in Queensland, Australia. PRODUCT	There are few field deployed operational tests that address the effectiveness of in-vehicle signing systems. This evaluation provides qualitative and quantitative information on the performance of a fully deployed system. TESTED
Reliability	Failure rate (High/Medium/Low)	It is in use. LOW	No information indicating failure rate. HIGH	The results of the 80-day field operational test showed no system failures. No activation failures were uncovered during the 80-day period. Severe electrical storms were found to initiate false activations. MEDIUM	It is in use. LOW	The system is fairly reliable; there were some crossing warning failures. MEDIUM
Functionality	Ease of implementation (Hard/Moderate/Easy)	The remote sensors are mounted on standard masts and small foundation for installation. EASY	It uses specially designed electro-magnetic Track devices for the detection of approaching train, a VHF transmitter located about 3-4 km from the crossing sends a coded radio signal to a receiver located at the crossing which actuates an Audio-Visual Alarm for forewarning the traffic. MODERATE	The system must be installed on all locomotives. All rolling stock would need to be equipped. Island detection circuit is required. Multiple new technologies will require significant training. HARD	EASY	EASY
	Compatability (Low/Moderate/High)	The system is independent from railroad signal system. The system is normally shipped assembled and ready for installation at the site. MODERATE	It uses specially designed electro-magnetic Track devices for the detection of approaching train. LOW	The train based component is not readily adaptable to different locomotive types. Island detection circuit is required. LOW	MODERATE	The system does not replace or interfere with the existing traffic warning devices; the system is purely supplemental. Elements such as flashers, gate arms, and signing were not modified. HIGH

For comparison, a weight is attached to each of the criteria so that the total weights sum to 100 as presented in Table 4. A dominating weight of 50-point was assigned goal to goal from ‘enhanced safety’ to ‘functionality’ in turn. As an example, different sets of weights (Trials 1 to 5) were developed in order to perform sensitivity analyses. These weights define the relative importance of the criteria to the overall system scores. The weights could vary depending on the stakeholder. This analysis allows assessment of the performance of each alternative system under different assumptions regarding the weights of each criterion.

Table 3: Scores of System A, B, C, D and E in 10-point rating scale based on ranking results from Table 2.

Goal	Criteria	A	B	C	D	E	IDEAL
Enhanced Safety	Improvement observed (Low/Medium/High)	0	5	5	0	10	10
	Fail-Safe design (No/Yes)	10	0	10	0	0	10
	Provide adequate warning (No/Yes)	10	10	10	10	0	10
	Provide train information (No/Yes)	10	0	0	0	0	10
	Average	7.5	3.75	6.25	2.5	2.5	10
Reduced System Cost	Installation cost (High/Medium/Low)	10	5	10	10	10	10
	Solar Powered (No/Yes)	10	10	10	10	0	10
	Average	10	7.5	10	10	5	10
Installability	Immediate availability (Development Stage/System tested/Product)	10	0	5	10	5	10
Reliability	Failure rate (High/Medium/Low)	10	0	5	10	5	10
Functionality	Ease of implementation (Hard/Moderate/Easy)	10	5	0	10	10	10
	Compatibility (Low/Moderate/High)	5	0	0	5	10	10
	Average	7.5	2.5	0	7.5	10	10

Table 4: Weighting Assignments for Multi-criteria Analyses

<table>
<tr><th>Goal</th><th>Criteria</th><th>Trial 1</th><th>Trial 2</th><th>Trial 3</th><th>Trial 4</th><th>Trial 5</th></tr>
<tr><td rowspan="4">Enhanced Safety</td><td>Improvement observed (Low/Medium/High)</td><td rowspan="4">50</td><td rowspan="4">10</td><td rowspan="4">10</td><td rowspan="4">10</td><td rowspan="4">20</td></tr>
<tr><td>Fail-Safe design (No/Yes)</td></tr>
<tr><td>Provide adequate warning (No/Yes)</td></tr>
<tr><td>Provide train information (No/Yes)</td></tr>
<tr><td rowspan="2">Reduced System Cost</td><td>Installation cost (High/Medium/Low)</td><td rowspan="2">20</td><td rowspan="2">50</td><td rowspan="2">10</td><td rowspan="2">10</td><td rowspan="2">10</td></tr>
<tr><td>Solar Powered (No/Yes)</td></tr>
<tr><td>Installability</td><td>Immediate availability (Development Stage/System tested/Product)</td><td>10</td><td>20</td><td>50</td><td>10</td><td>10</td></tr>
<tr><td>Reliability</td><td>Failure rate (High/Medium/Low)</td><td>10</td><td>10</td><td>20</td><td>50</td><td>10</td></tr>
<tr><td rowspan="2">Functionality</td><td>Ease of implementation (Hard/Moderate/Easy)</td><td rowspan="2">10</td><td rowspan="2">10</td><td rowspan="2">10</td><td rowspan="2">20</td><td rowspan="2">50</td></tr>
<tr><td>Compatibility (Low/Moderate/High)</td></tr>
<tr><td colspan="2" align="right">Total</td><td>100</td><td>100</td><td>100</td><td>100</td><td>100</td></tr>
</table>

4.0 DATA ANALYSIS

Results from the multi-criteria analysis with varying weighting trials are presented in the form of stacked bar chart in Figures 1. An “ideal” system which achieves a perfect score on all the measures was included to indicate the weight of each criterion. The scores for the ‘ideal’ system and the coloured legends displayed on the right of each chart show the degree to which the different weightings impact the results. Figure 1(a) shows the results of Trial 1 which ‘enhanced safety’ has been emphasised. From Trial 1, comparison shown that System A ranked the first, followed by System C and D. Similarly, from Trial 2 to 5, dominating weight of 50-points was shifted goal by goal from ‘reduced system cost’ to ‘functionality’. In Figure 1(b) which ‘reduced system cost’ is emphasised, System A, D and C rank as first, second and third respectively. Although system cost is the overall focus of the study, attention should be given to other performance measures to avoid bias in associating with safety and system reliability. This influence is clearly observed through comparing results of Trial 2 and 4, for instance, where System E outperformed System C in Trial 4 when ‘reliability’ is emphasised, as tabulated in, Figure 1(b), 1(d) and Table 5. Overall, System A scores highest followed by System D. Therefore, System A and D are short-listed for further evaluation in the next stage of the study.

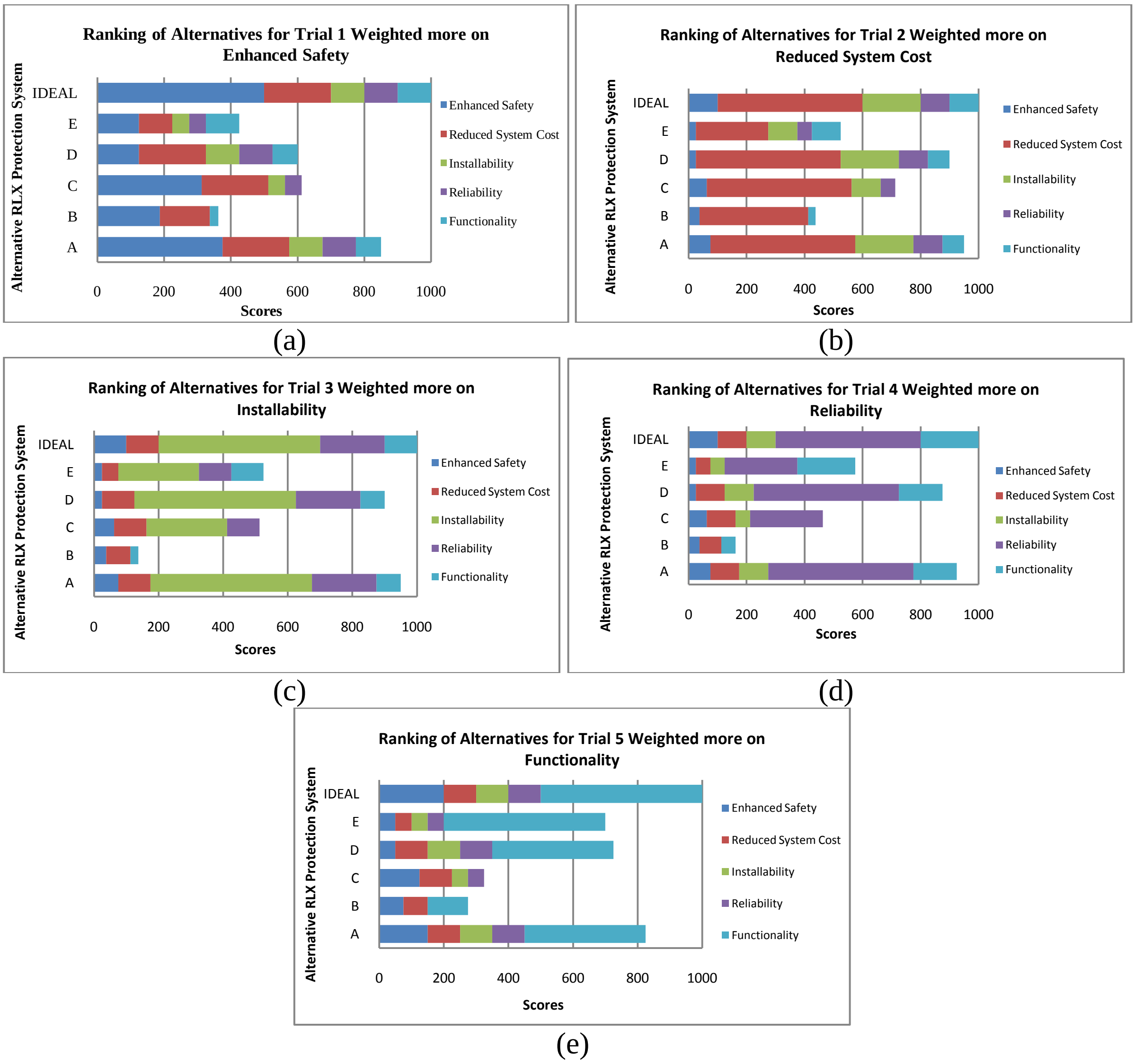

Figure 1: Ranking results of System A, B, C, D and E with different weighting assignments.

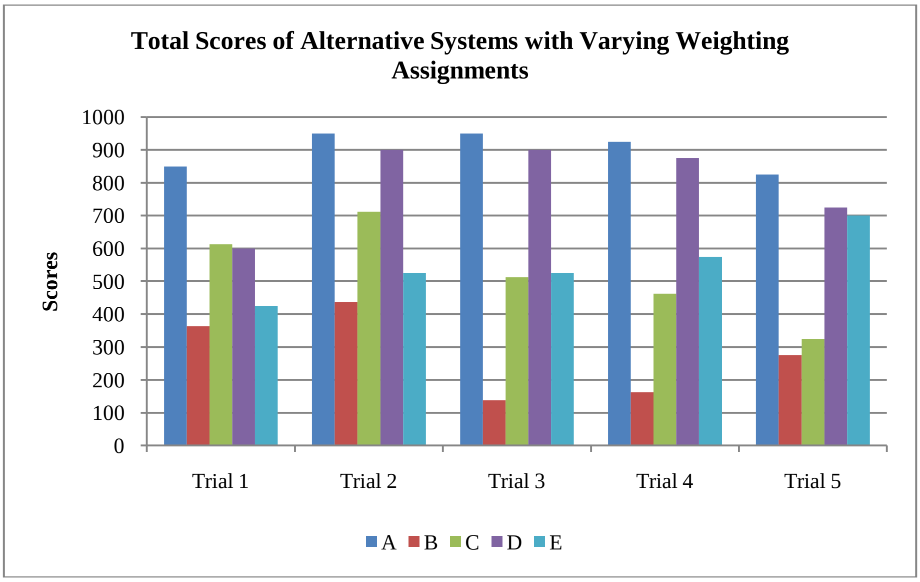

Figure 2: Comparison of scores of System A, B, C, D and E among trials with emphasis across the major goals of the criteria.

Table 5: Rankings of System A, B, C, D and E.

System	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Overall
A	1	1	1	1	1	1
B	5	5	5	5	5	5
C	2	3	4	4	4	3
D	3	2	2	2	2	2
E	4	4	3	3	3	4

5.0 CONCLUSIONS

The multi-criteria analysis conducted on candidate RLX-protection systems provided a ranking from an engineering perspective. Changes of criteria and/or weightings from different stakeholders may affect the final results depending on the robustness of the candidate systems across the required criteria. Major goals selected include 'enhanced safety', 'reduced system cost', 'installability', 'reliability' and 'functionality'. The dominating weight of 50-point was first assigned to 'enhanced safety' with the total weight of all criteria sum to 100. This dominating weight of 50-point was shifted to the next goal until each goal was emphasised in turn. As a comparison of results from this analysis, the rankings developed recommended that System A should be short-listed for further evaluation in the next stage of the study, followed by System D.

The main motivation of this study is to identify low-cost RLX solutions. This initiative would tend to favour system with highest score in 'reduced system cost' emphasis and under-justify other performance measures, such as the safety and system reliability aspects. In order to prevent this bias when many candidate systems are included, separate grouping and analysis of systems with prescribed cost ranges can be applied. Besides, another alternative could be allowing only systems to be considered for further analysis if they achieve minimum scores in certain criteria.

A RLX-protection system needs to be effective from a safety perspective, as well as being 'driver-compliant'. Different countries have different conditions especially with respect to driver behaviour. A comprehensive review and survey of international and national literature and research regarding driver behaviour at RLX at varying environment has been undertaken. In the next stage of the study, behavioural evaluation of the short-listed innovative RLX-protection systems will include a study of the interaction between the human and the system using a driving simulator. Driving simulator is an elaborate tool that uses a combination of seat, steering wheel, and foot control to provide a driving environment for human factors research. A sample of drivers will be invited to test their response to the simulated existing RLX-protection systems and short-listed innovative protection systems to observe their driving behaviour towards different scenarios at RLX. Behavioural data collected on existing protection systems via video recording from a few level crossings in Queensland will be used to validate results of responses towards existing protection systems from driving simulator. Driver behavioural models will be interfaced into microscopic traffic simulation models to command the simulated groups of driver-vehicle-unit to follow behavioural rules developed. The models developed will provide rail authorities and decision makers with a modelling tool for testing and evaluating new technologies aimed at improving the safety of level crossings.

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