TRA Trial Site Performance Report

Frauscher FAdC Axle Counters/RCS Level Crossing System
Dacun, Changhua

Version: 1.0
Date: 22 June 2018

Version History:

Version	Date	Revision Details	Prepared	Checked	Approved
1.0	2018-06-22	Initial revision	Neil Popplewell	Richard Ogilvie	Richard Ogilvie

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1 General

1.1 Purpose

The purpose of the trial site is to demonstrate the performance, reliability, availability and maintainability of the Frauscher FAdC Axle Counters and the RCS Level Crossing System.

The key features of the system under trial are:

1. Speed checking of approaching trains so as to minimise the road closed time – especially for trains that stop at stations near a crossing.
2. Implementation of functionality preventing the level crossing from opening to road traffic and then immediately closing again when another train approaches.

The system under trial utilises a SIL4 safety controller and the Frauscher FAdC axle counting system integrated to form the RCS Level Crossing System to provide a high availability level crossing solution which is able to monitor the speed of approaching trains in order to determine the correct time to operate a level crossing. This increases safety and decreases delay to road users.

1.2 Background

The trial site nominated by TRA is an existing level crossing at Yinghua Road, Dacun, Changhua. This level crossing currently has full boom barriers and flashing lights and is located on a double track, bi-directional line. The level crossing operates independently from the signalling system on the corridor.

Due to the proximity of the crossing to Dacun Railway Station, north-bound trains stopping at the station cause long level crossing ringing times. This is because the existing level crossing is unable identify if an approaching train is stopping at the station and therefore assumes that it is traveling at the maximum line speed. The data gathered from the trial shows that for trains stopping at Dacun, the existing level crossing operates on average for 130 seconds compared to the desired warning time of 30 seconds.

The line operates both freight and passenger trains. Freight trains generally travel slower than the passenger trains and this also increases crossing operation time.

To monitor the performance of the Frauscher/RCS Level Crossing system, it has been in a shadow mode whereby it records both its own performance as well as the behaviour of the existing level crossing so as to provide a comparison between the systems.

1.3 References

[1] Frauscher/RCS Level Crossing System - TRA Trial Site Installation Plan, Version 3, 9 November 2017.
[2] Frauscher FAdC TRA Level Crossing Trial Site Report, Version 2

1.4 Trial Site Details

Location:	Dacun, Changhua, Taiwan
Key Dates (history):	**2018-01-31:** Installation of the trial equipment. **2018-02-01:** Commissioning of the trial equipment. **2018-05-25:** End of initial monitoring period for this report.
People involved:	Mr. Mayank Tripathi (Frauscher Sensortechnik GmbH) Mr. Manfred Sommergruber (Frauscher Sensortechnik GmbH) Mr. Thomas Maislinger (Frauscher Sensortechnik GmbH) Mr. Neil Popplewell (RCS Australia) Mr. Richard Ogilvie (RCS Australia) Mr. James S.C. Lin (Alfa Transit Enterprise Corporation)
Installed Equipment:	1. RCS Level Crossing system, including: a. SIL4 Safety Controller; b. RCS Maintenance Touch Screen PC; c. Surge protection; d. 24Vdc Uninterrupted Power Supply; e. Ethernet & 4G cellular communication equipment. 2. Frauscher FAdC axle counters, including: a. FAdC indoor equipment rack; b. FAdC wheel sensors; c. Frauscher GAK track side connection box; d. Frauscher Measurement System (FMS); e. Frauscher Diagnostics System (FDS); f. Frauscher BSI Surge Protection for wheel sensor connections.
Comments:	Power for the system is supplied at 110Vac via the TRA power supply for the level crossing.

2 Installation

2.1 Site Overview

Figure 1 shows a representation of the equipment installed on site.

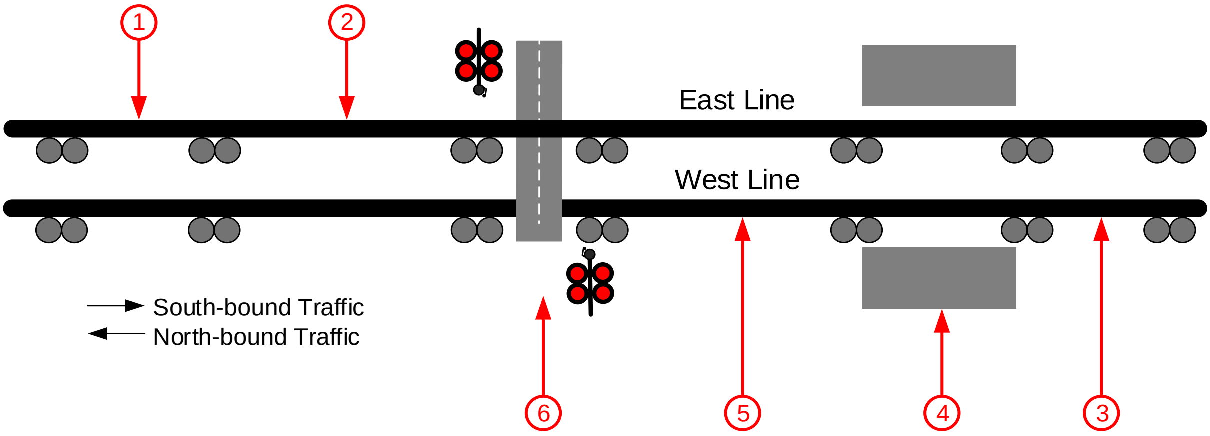

Figure 1 - Site Overview

They key items as numbered in the figure above area:

1. South-bound axle counter Advance Warning/Holding Sections, for both the East (top) and West (bottom) lines. These sections do not active the crossing for the first train but keep the crossing closed for any second train approaching.
2. South-bound axle counter Control Sections. Control Sections activate the level crossing after a delay, which is calculated based on the speed of the train.
3. North-bound axle counter Advance Warning/Holding Sections.
4. Dacun Station platforms, which include North-bound axle counter sections for the East and West platforms. These act as Advance Warning/Holding Sections for North-bound stopping trains, and control sections for North-bound express trains.
5. North-bound axle counter Control Sections.
6. Yinghua Road.

2.2 RCS Maintenance Panel

Figure 2, below, shows the site layout as depicted on the RCS Maintenance Panel Touch Screen PC.

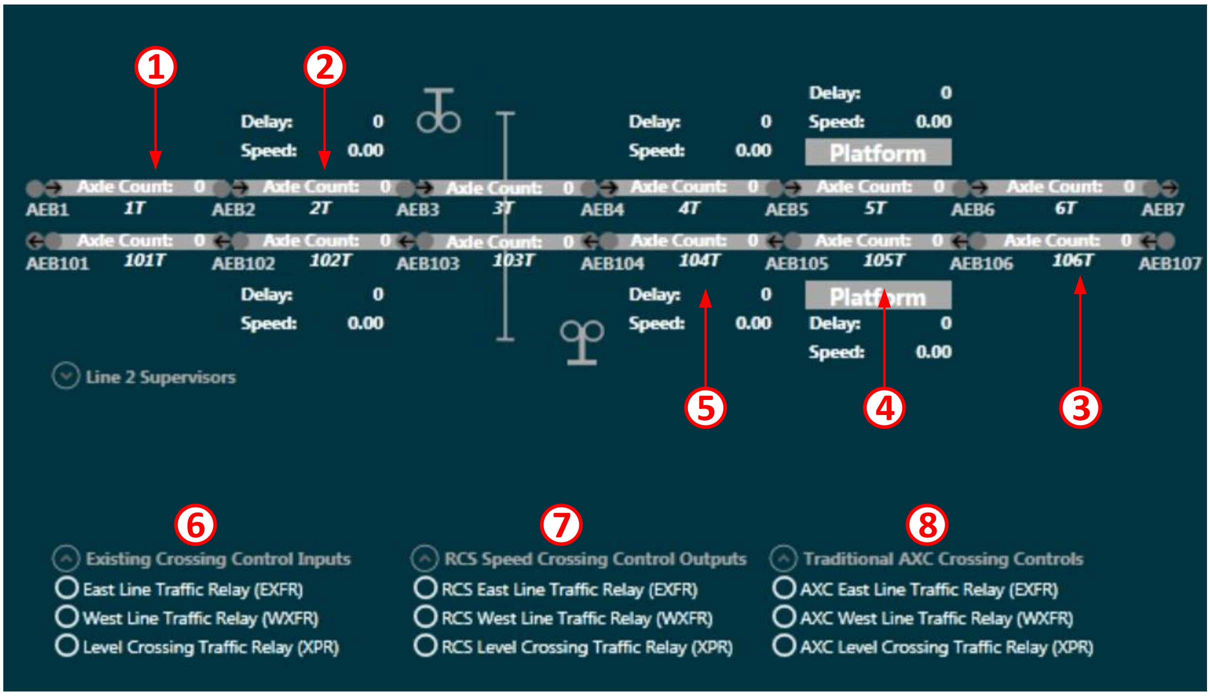

Figure 2 - RCS Maintenance Panel Overview

The key elements as numbered in the figure above are:

1) 1T and 101T provide the Advance Warning/Holding functionality for the level crossing for South-bound trains on the East and West lines, respectively, and initiate the speed monitoring and prediction for the approaching train.
2) 2T and 102T initiate the level crossing for South-bound trains allowing for any Permissible Safe Delay (PSD) calculated on the performance of the approaching train. The PSD is calculated by the SIL4 safety controller of the RCS Level Crossing System based on the detected speed of the train and known performance attributes.
3) 106T and 6T provide the Advance Warning/Holding functionality for the level crossing for North-bound direction trains and initiate the speed monitoring and prediction for the approaching train.
4) 105T and 5T provide two functions based on the detected/predicted speed of North-bound trains:
    a. For trains stopping at the platform, or slow-moving trains, it does not activate the level crossing. In this scenario it instead continues to monitor the detected/predicated speed of the approaching train to ensure that the PSD remains in tolerance. For trains predicted to be stopping at the platform, these sections therefore provide only advanced warning functionality.

   b. For trains not certain to stop at the platform, or for the PSD to go out of tolerance, these sections activate the crossing allowing for any residual PSD which is within tolerance.

5) 104T and 4T provide start the level crossing for North-bound trains allowing for any PSD.
6) Provides the status of existing level crossing East, West and Level Crossing traffic relays.
7) Provides the status of RCS Level Crossing East, West and Level Crossing traffic relays.
8) Provides the status of how a typical Axle Counter Level Crossing East, West and Level Crossing traffic relays, without speed proving, would perform.

2.3 Indoor Equipment

Figure 3 shows the indoor equipment that was installed in an equipment cabinet adjacent to the existing level crossing control cabinet. The key items of equipment as numbered in the figure below are:

1) Frauscher FAdC SIL4 axle counting system evaluator rack.
2) Frauscher Diagnostics System (FDS).
3) HIMA SIL4 Safety Controller running RCS level crossing software.
4) RCS Maintenance Touch Screen Military Grade PC.
5) RCS Trial Site Status and Axle Counter Reset Panel. This panel allows the axle counters to be reset, and displays the status of the existing level crossing and Frauscher/RCS Level Crossing so they can be easily visually compared during the trial.
6) 24Vdc uninterrupted power supply. Noting this power supply is connected to a 24Vdc battery, which is not shown in the photo.
7) 110Vac to 24Vdc power supply.
8) 110Vac Novaris surge filter to protect from surges on the incoming 110Vac railway power supply.
9) 24Vdc Novaris surge filters (2 of) to protection from surges that may exist on the cable between the trial site equipment and the indications from existing level crossing that are being monitored to help evaluate the performance compared to the existing system.
10) Westermo Ethernet switch.
11) Westermo 4G Cellular Router to allow remote monitoring of the trial site.

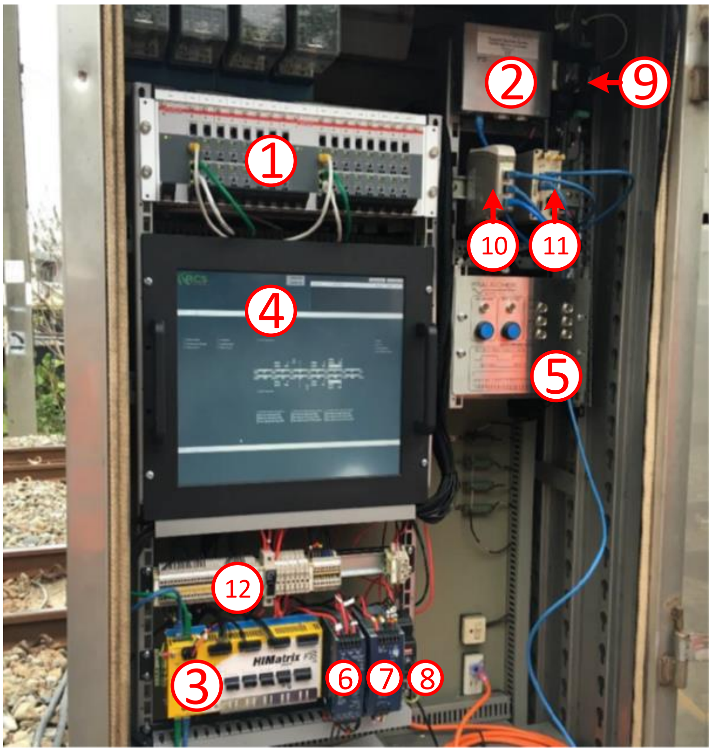

Figure 3 - Indoor Equipment

The following indoor equipment is not shown in picture above:

1) The Frauscher BSI Surge Protection devices for each wheel sensors. These were installed on the rear side of the equipment cabinet.
2) The battery for the UPS. This was installed in the battery compartment at the bottom of the equipment cabinet.

2.4 Outdoor Equipment

Figure 4 shows an example of the outdoor equipment that was installed. The key items of equipment as numbered in the figure below are:

1) Frauscher wheel sensor, which is mounted on the east line using a Frauscher rail claw.
2) Frauscher wheel sensor, which is mounted on the west line using a Frauscher rail claw.
3) Frauscher GAK trackside connection box, which is used to connect the tail cable from the wheel sensors to the main cable going back to the equipment cabinet.

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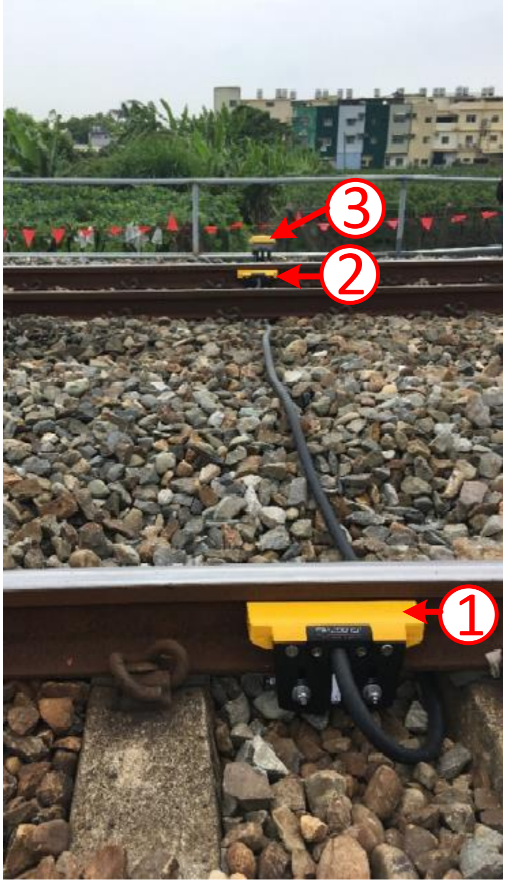

Figure 4 - Outdoor Equipment

3 Results

3.1 Data Captured

3.1.1 Quantity of Trains

On average 165 trains per day went through the level crossing during the trial. This equates to approximately 23,750 trains between 2018-02-01 and 2018-05-25.

3.1.2 Summary of Performance

The system logs show the system operated the level crossing safely at all times and that no safety critical faults occurred at any time since the original commissioning on 1 February 2018.

3.1.3 Maintainability

The RCS Level Crossing System operated correctly and safely throughout the trial. RCS Australia was able to monitor the system remotely using the touch screen maintenance panel, HIMA Safety Controller and Frauscher diagnostic tools. Remote access to the site was available throughout the trial.

3.2 Frauscher Axle Counter System

Initially the Frauscher axle counter system was installed with RSR180 wheel sensors. On 2018-04-25 these wheel sensors were replaced with RSR123 wheel sensors.

This replacement was performed to allow the performance of both wheel sensor types to be evaluated, and because the RSR123 wheel sensors were determined to be more suitable for TRA's future rolling stock requirements and so are consistent with the future plans for axle counter deployments elsewhere on the network.

The RCS Level Crossing System operated correctly and safely with both wheel sensors types.

Some external disturbances were observed while both types of wheel sensors were installed. These influences included external interference from maintenance events near the wheel sensors. During these events, a conventional axle counter level crossing would have failed and caused the crossing to operate continuously until an external manual reset could be performed. However, the smart features of the Frauscher FAdC and RCS Level Crossing System were able to ensure any single disturbance event did not cause the level crossing to fail, and instead the level crossing system was able to automatically self-heal or enter a degraded mode of operation until the disturbance could be investigated and reset.

These events helped to demonstrate the smart features of the RCS Level Crossing system and how it helps to improve the reliability, availability and safety of the level crossing. Details of the disturbances are furthered described in the Frauscher FAdC TRA Level Crossing Trial Site Report [2].

3.3 RCS Level Crossing System

3.3.1 General Performance

1. The RCS Level Crossing system detected and safely operated for every train.
2. The RCS Level Crossing system provided a guaranteed minimum 30 seconds warning time for every train. On several occasions, for fast trains the existing level crossing system provided less than 30 seconds warning time. This shows that the RCS Level Crossing system was able to act quicker than the existing level crossing system and safely give 30 seconds warning time for trains of all speeds.
3. On 2018-02-07 at approximately 10:12am the 110Vac power was lost for approximately 8 minutes. The 24Vdc Uninterrupted Power Supply (UPS) worked correctly and as a result the Frauscher/RCS Level Crossing system continued to operate through this period.
4. The installation of the RSR123 wheel sensors on the 2018-04-25 was automatically detected by the RCS Level Crossing System and no re-calibration or setting changes were required.

3.3.2 Speed Proving Performance

Analysis of the speed detection and prediction functionality throughout the trail period showed accurate speed capture and prediction for each train. The Permissible Safe Delay applied for every train in the trial operated safely and ensured that all trains were provided with not less than 30 seconds warning time for the crossing and that slow/stopping trains received significantly reduced warning time than provided by the existing system.

3.3.3 Advanced Warning/Barrier Holding Function

The RCS Level Crossing System detected on average one occurrence a day during the trial where a second train was about to operate the level crossing just as a first train had cleared it. The operation of the advanced warning/barrier holding section function meant that the RCS Level Crossing System would have held the barriers closed in each case rather than allowing them to begin to open and then immediately close.

There were no situations where the advanced warning function failed to operate.

3.3.4 Following Trains

The trial site data did not indicate any events where a second train approached the level crossing whilst a first train was still at/near the crossing on the same line. However, during factory acceptance testing, the scenario of closely following trains was rigorously tested to show that the RCS Level Crossing System will always correctly maintain the crossing closed for each subsequent following train.

3.4 Detailed Results

3.4.1 Speed Proving Function – Permitted Safe Delay

The results provided have been produced using the log files that were recorded since the RSR123 wheel sensors were installed. This has been done to provide accurate information on the wheel sensor type proposed for use on the TRA network. Analysis of all log files, for both wheel sensors, showed RSR180 and RSR123 results to be consistent and the RSR180 results can be provided on request.

3.4.1.1 Level Crossing Warning Times

Figure 5 shows the average warning times for both the East and West lines. These show:

a) The Frauscher/RCS Level Crossing System (RCS) had an average warning time of 42.94 seconds.
b) That the existing level crossing (LX) system had an average warning time of 65.76 seconds.

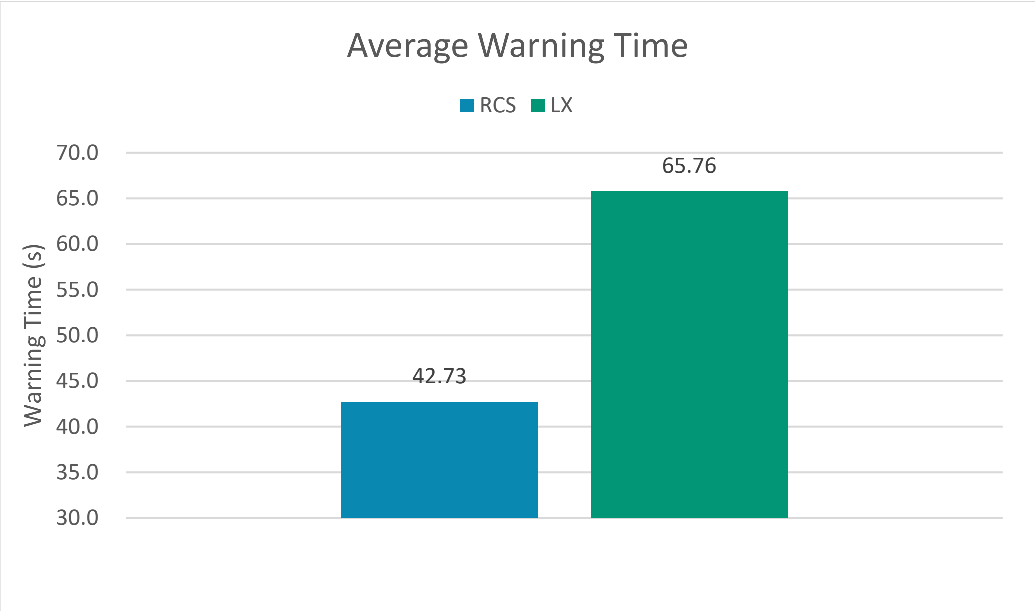

Figure 5 - Average Warning Time

Figure 6 shows the average warning time when considered for the West line only for both stopping and express trains. This shows that the RCS Level Crossing system performed significantly better than the existing level crossing system. The RCS Level Crossing system was able to detect whether each approaching train was slowing down to stop at the platform and delay the activation of the crossing until the stopping train departed the platform.

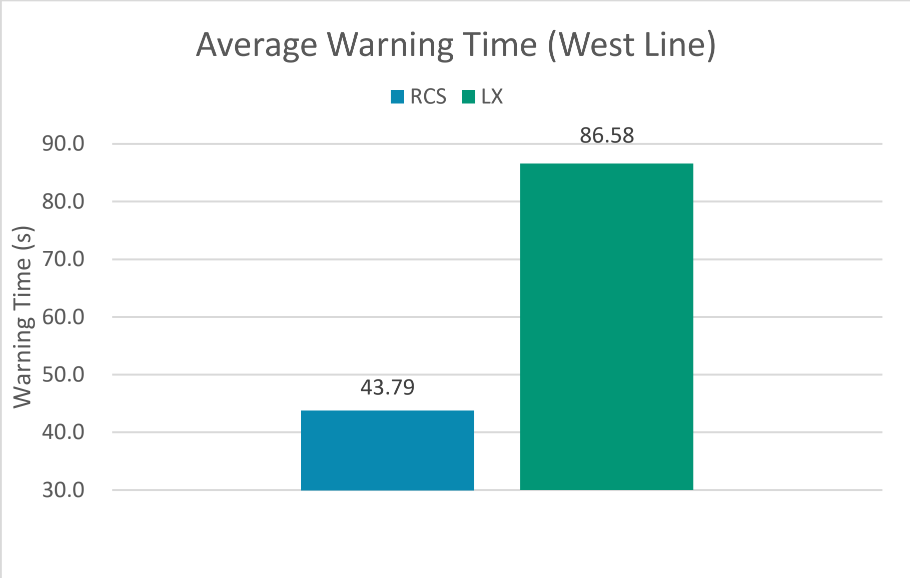

Figure 6 - Average Warning Time for The West Line

Figure 7 below shows the average warning time on the East line. The East line was predominately used by south-bound trains with no platform on the approach and generally uniform speeds of trains.

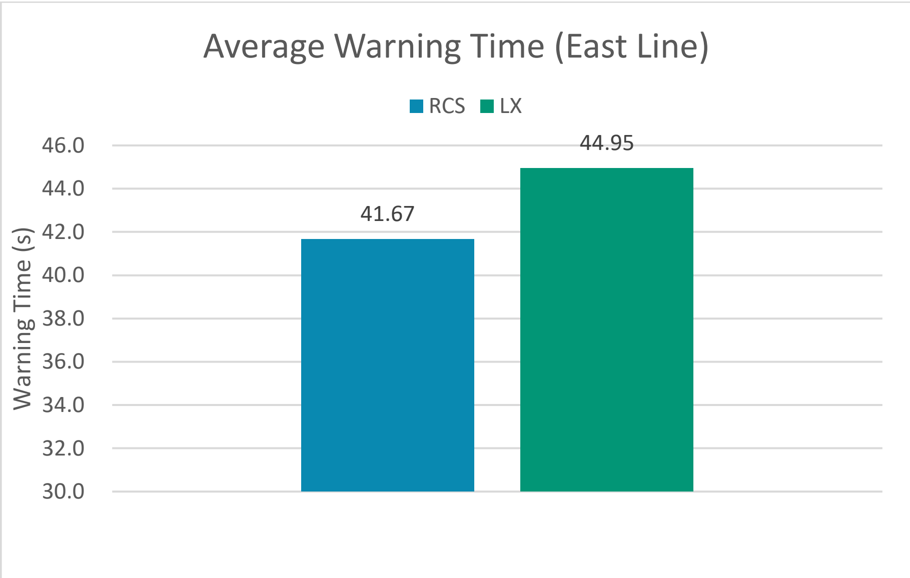

Figure 7 - Average Warning Time for The East Line

Figure 8 shows the warning time when considered for stopping trains. This shows that the RCS Level Crossing system performed significantly better than the existing level crossing system when trains stopped at Dacun station, with an average time benefit ratio of 160%.

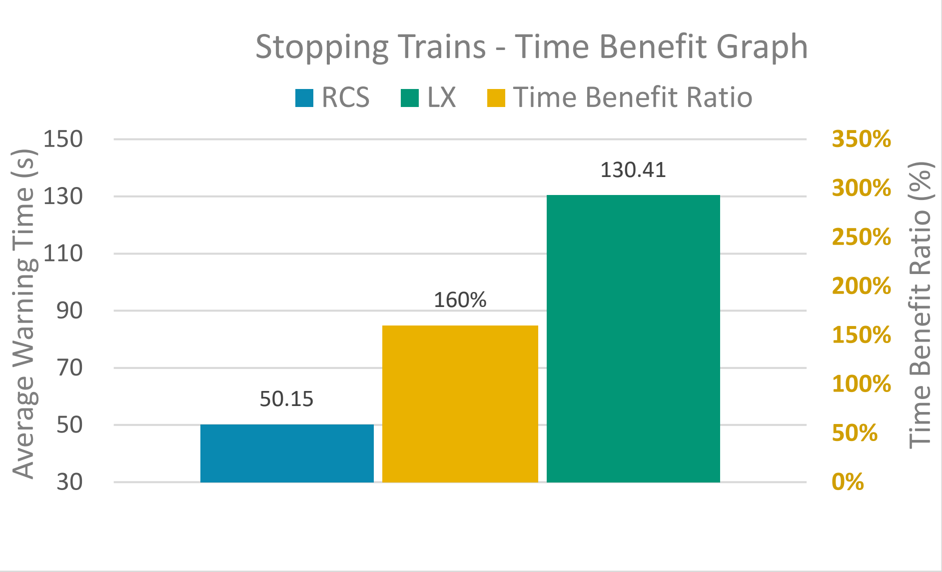

Figure 8 – Stopping Trains - Time Benefit Graph

Figure 9 shows the warning time and time benefit ratio of the RCS Level Crossing System when considered for express trains of various speeds. This shows that the RCS Level Crossing system performed better than the existing level crossing system for all express trains that travelled less than the line speed.

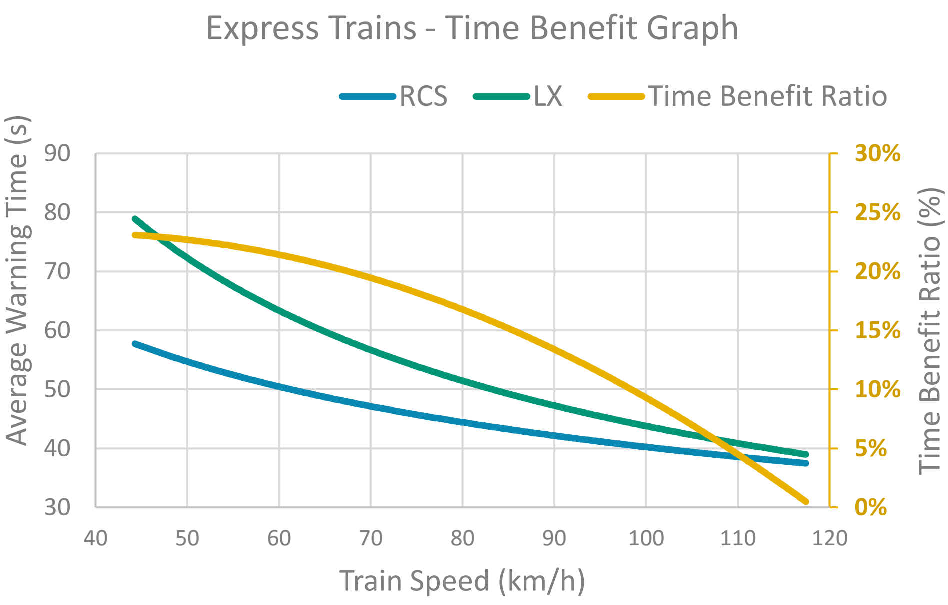

Figure 9 - Express Trains - Time Benefit Graph

Figure 10 and Figure 11 below show the performance on the East line prior to and after the 80km/h speed restriction on the down side of the crossing was increased to 100km/h, respectively. This shows that the RCS Level Crossing system was able to provide a consistent warning time for 80km/h and 100km/h speed trains, whereas the existing level crossing provided an undesirable increased warning time while the 80km/h speed restriction was active, and in all circumstances the RCS Level Crossing system performed significantly better than the existing level crossing system.

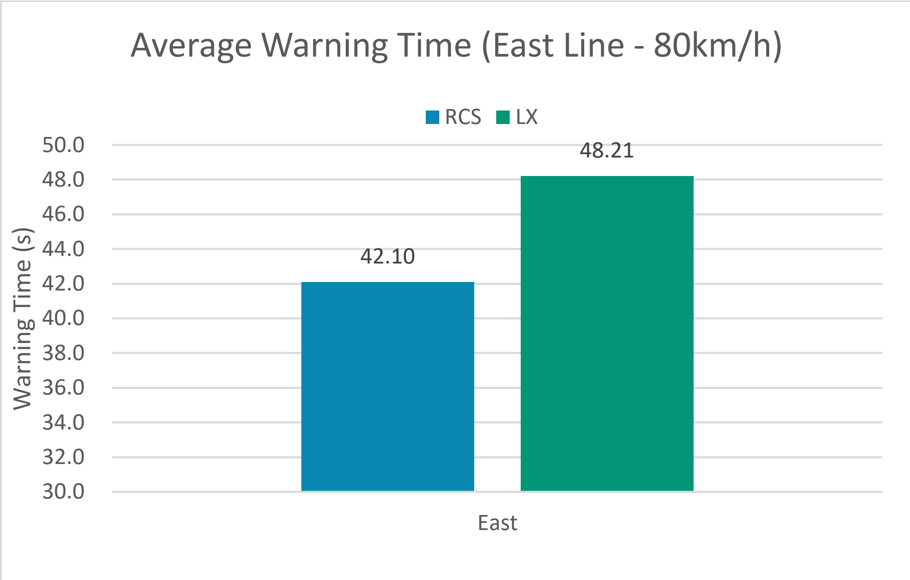

Figure 10 - Average Warning Time for The East Line Prior to the Speed Restriction Removal (i.e. 80km/h speed restriction)

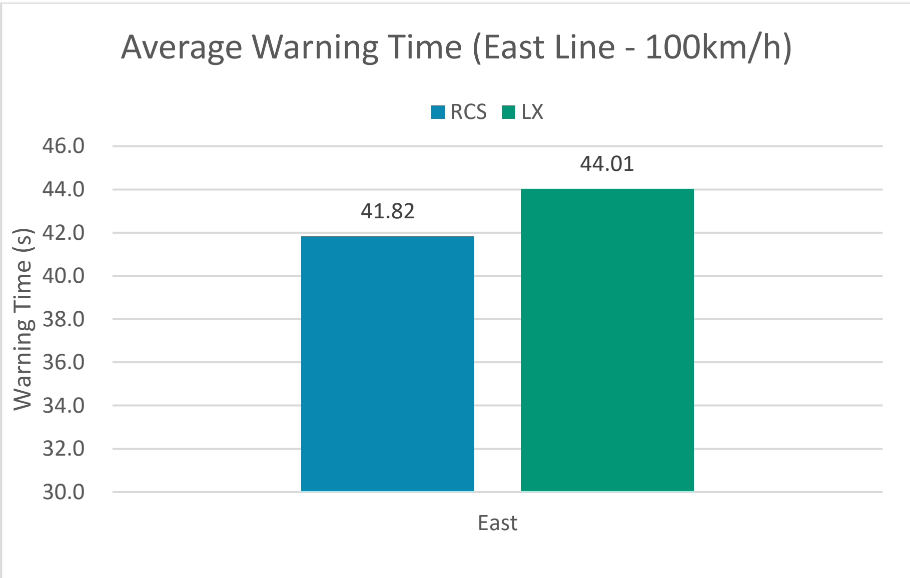

Figure 11 - Average Warning Time for The East Line After the Speed Restriction Removal (i.e. 100km/h speed restriction)

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Figure 12 below shows the Minimum Warning Time for both the East and West Lines. It shows that RCS Level Crossing System always maintained at least a minimum warning time of 30 seconds. The existing level crossing gave a minimum warning time of slightly less than 30 seconds on five occasions, all of which occurred on the West line. As the sensor locations which trigger both the RCS Level Crossing System and the existing crossing are approximately in the same position, the differences can be attributed to the RCS Level Crossing System being a very high-performance system that was able to identify and respond to the fast moving trains sooner to always ensure the minimum warning time was met.

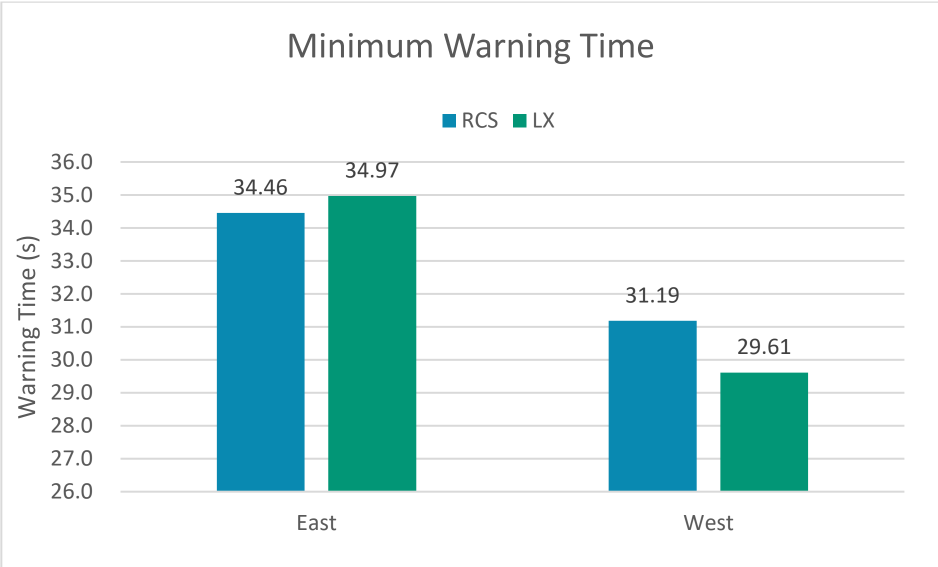

Figure 12 - Minimum Warning Time for the East and West Lines

Figure 13 shows the Warning Times for each train during the trial period plotted against the time of day. This helps to show how same timetabled train services performed across different days, and how the speed proving of the Frauscher/RCS Level Crossing system performed against the existing level crossing. It shows East line trains warning times as positive values, and West line trains as negative values. This graph clearly shows the difference in performance between the Frauscher/RCS Level Crossing system and a non-speed proving level crossing system. The stopping trains on the West line showed the biggest performance increase - typically providing at least a 60 second reduction in warning time.

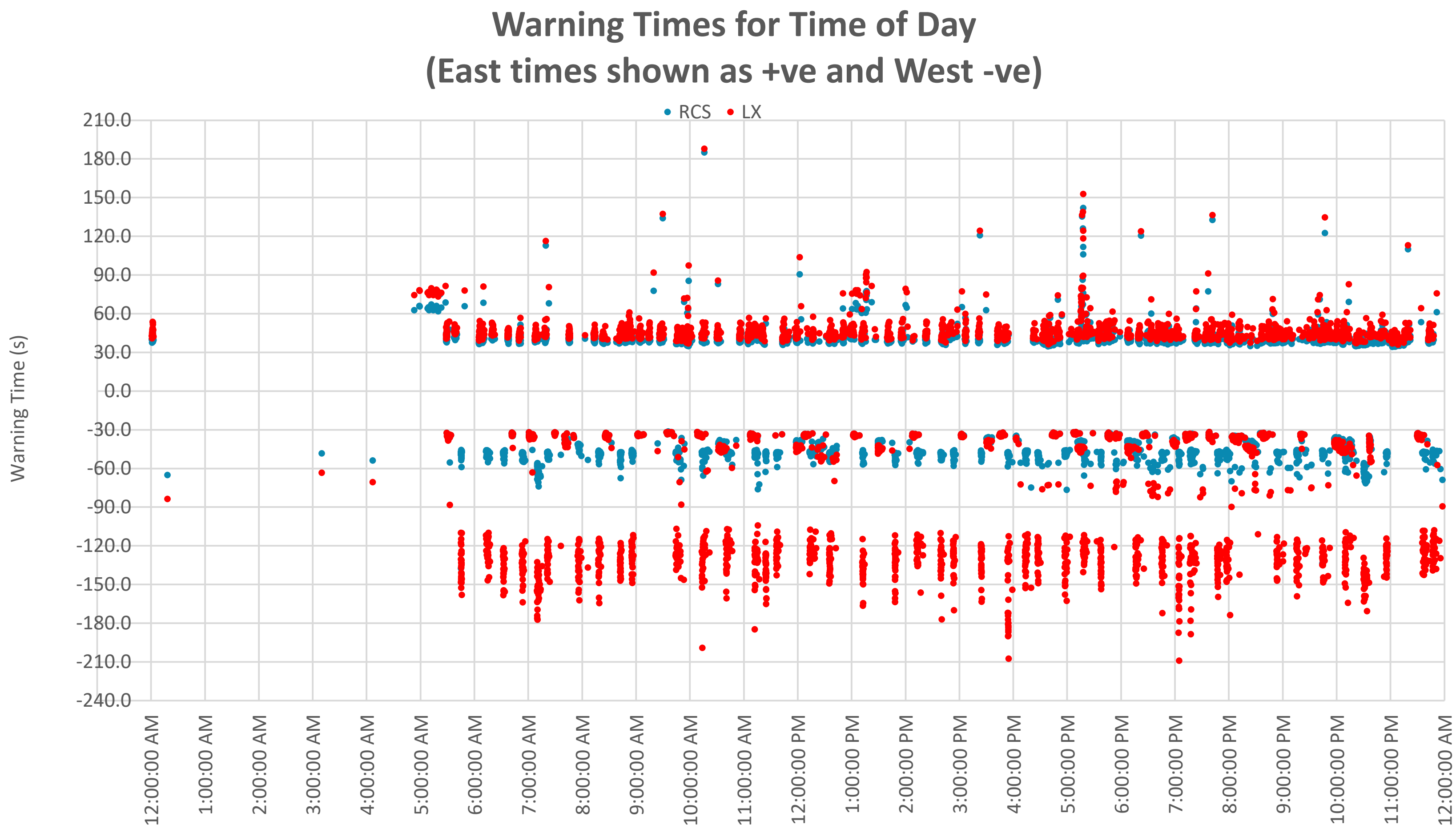

Figure 13 - Warning Times for Each Train

3.4.2 Application of Advance Warning/Holding Section Function

Figure 14 below shows the Advance Warning/Holding Section events, including their date, time of day, and the number of seconds the RCS Level Crossings system would have held the boom barrier down for a second train between 2018-04-25 and 2018-05-25. In total there were 29 Advance Warning/Holding Section events during this time, where the level crossing would have remained closed because another train was about to approach the crossing. This equates to approximately one train per day where the RCS Level Crossing system would have prevented the boom barriers from partially rising again for a second train.

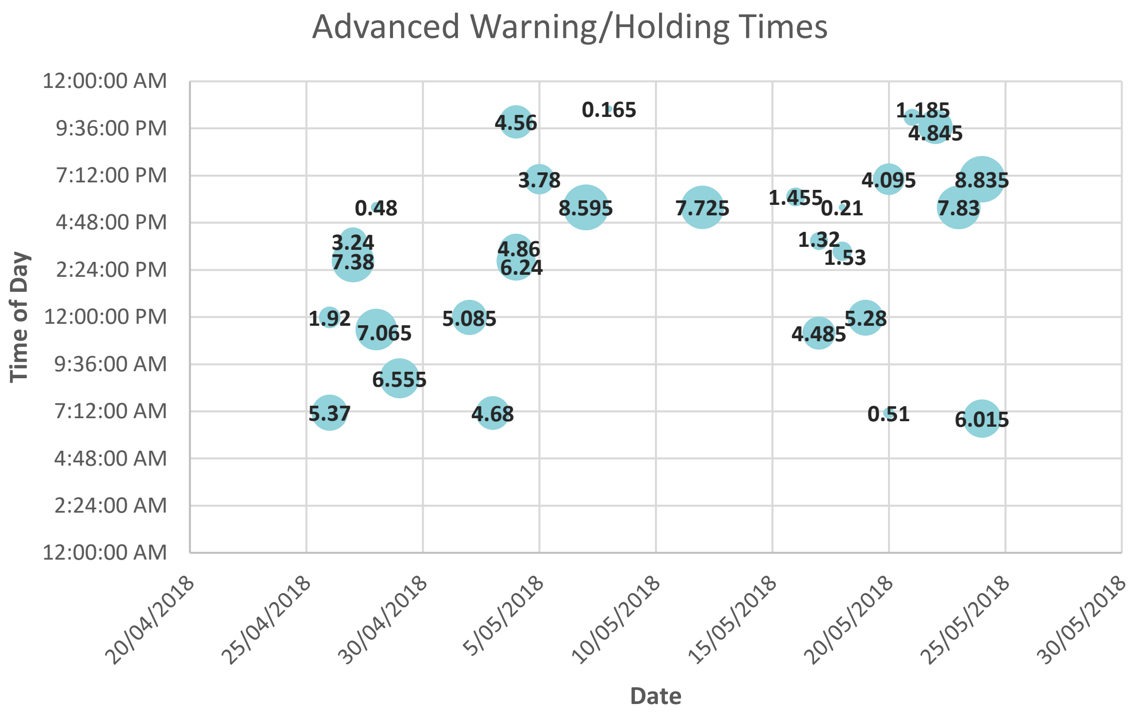

Figure 14 - Advanced Warning/Holding Times

NB: For the trial site the speed proving sections were used as the only Advanced Warning/Holding sections, which are shorter than would be typically provided. If other dedicated sections were provided for the Advanced Warning/Holding function, as is typically provided for production systems, additional Advance Warning/Holding events would be achieved.

3.4.3 Other Detected Events

a) On the night of 2 May 2018, at approximately 0:44am there appears to have been maintenance work undertaken. On the west line, a train was recorded as providing 302.5 seconds warning time for the Frauscher/RCS Level Crossing system, which included a 14 second delay based on the speed of the vehicle, and only 19.5 seconds warning time for the existing level crossing system. As this appears to be a maintenance activity, this event has been removed from the summary results.

b) On the night of 8 May 2018, at approximately 0:44am there appears to have been maintenance works on the Down end of the line. At this time the Frauscher/RCS Level Crossing was activated for approximately 7 minutes. During this time, the existing level crossing did not activate, and therefore it is assumed that there were maintenance works, where either insulated vehicles were used, or the level crossing was disabled. It was also noticed that at around the time of this event the maximum speed for south-bound trains increased from a typical 80km/h to 100km/h. It is assumed that this event was the commissioning of the new bridge on the Changua side of the crossing.

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4 Overall Performance

The Frauscher/RCS Level Crossing system provides a very significant performance increase due to its speed proving capability. On average the Frauscher/RCS Level Crossing reduced the warning time by 23 seconds per train when compared to a typical level crossing.

The existing level crossing system takes a several seconds to determine when the train has exited the crossing and for the level crossing system to recover. While the level crossing system is determining this, the crossing continues to operate, and the boom barriers are prevented from rising, delaying road traffic from proceeding. Due to the high performance of the RCS Level Crossing System and the Frauscher FAdC axle counter system, the Frauscher/RCS Level Crossing System was on average able to recover 4.8 seconds quicker than the existing level crossing after the train had exited the crossing.

Table 1 below shows the overall performance savings of the level crossing during the trial period. It shows that on average the Frauscher/RCS Level Crossing System would have reduced the road closed time for over 73 minutes per day. On average this would translate to 445 hours (18.6 days) per year of reduced warning time leading to significant benefits to road users and a likely increase in overall level crossing safety.

Table 1 - Overall Performance Savings

	Average Saved Per Day (Minutes)	Estimated Annual Time Saved (Hours)	Estimated Annual Time Saved (Days)
Warning Time:	61	374	15.6
Recovery Time:	12	72	3.0
Totals:	**73**	**446**	**18.6**
		East Line:	*2.9*
		West Line:	*15.6*

5 Conclusion

The Frauscher/RCS Level Crossing System trial can be shown to be fully successful. It has shown to:

a) Reliably and safely detect trains and their speeds.
b) Significantly increases the performance of the level crossing, through the use of speed proving and reduced recovery times. At this level crossing speed proving saved on average 23 seconds per train, and the reduced recovery times saved on average an additional 4.8 seconds per train, which can be extrapolated to approximately 445 hours per year less crossing operation time.
c) The ability for the system to distinguish between stopping and express trains based on their speed reduced the warning time for stopping trains by 1 to 2 minutes per stopping train, which would significant increasing traffic flow.
d) The enhanced fault monitoring and degraded mode operation improves the reliability and availability of the level crossing, by enabling it to automatically recover and/or enter degraded modes of operation for disturbances or failures that occur without compromising safety.
e) The advanced warning/barrier holding feature prevents the level crossing boom barrier equipment from opening while a second train is very nearly approaching the crossing. The existing level crossing system does not have this feature.

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