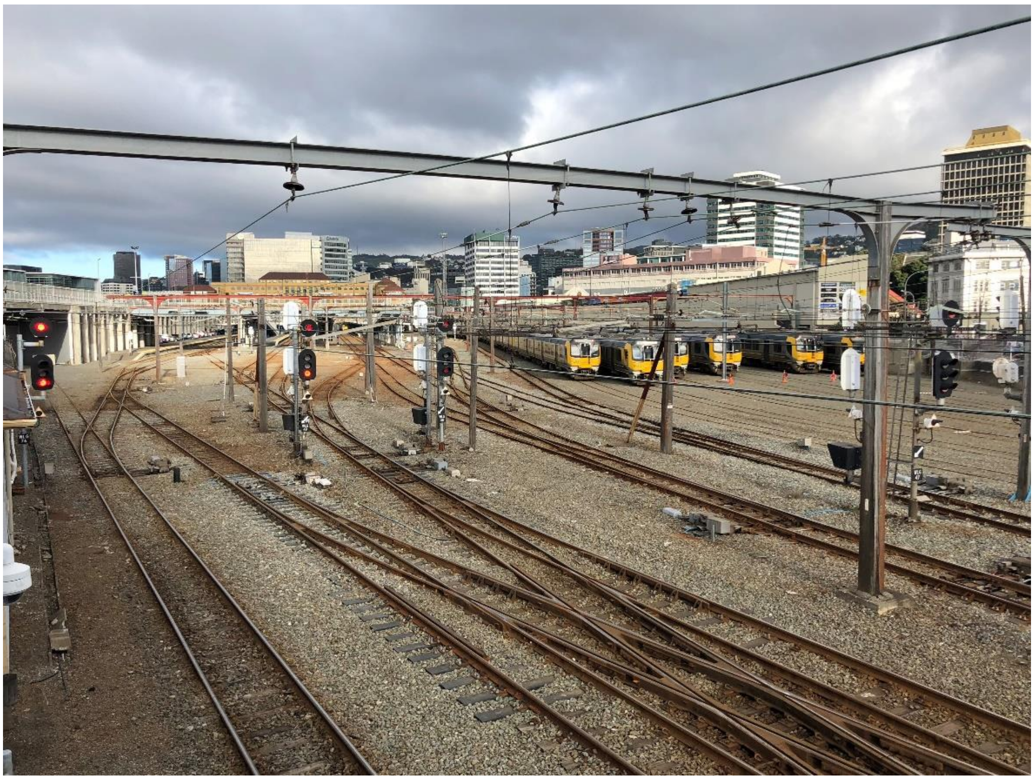
Prepared for KiwiRail

By RICS Rail Infrastructure Consultants (NZ)



Signalling

Route risk assessment of the Wellington ‘A’ Box area

& mitigation strategies

August 2018

Final Issue 1.1

Change History and Approval

Revision Status

REVISION NUMBER:	IMPLEMENTATION DATE:	SUMMARY OF REVISION
0.1	6/7/2018	Working DRAFT
1.0	16/8/2018	First Issue to Client
1.1	27/8/2018	KiwiRail comments addressed

Approvals

ROLE	NAME	ORGANISATION	SIGNATURE	DATE
Prepared By	Rob French & James Clendon	RIC		27/8/2018
Reviewed By	Andy Hillier	RIC		27/8/2018
Approved By	James Clendon	RIC		27/8/2018

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1 Executive Summary

The Wellington station approach (Wellington 'A' Box area) is a complex junction with very tight track and signal space constraints. In addition, the area has a relatively high level of reported operational incidents (such as signals passed at danger - SPADs). KiwiRail required a route risk assessment of the Wellington 'A' Box area including all track and signals south of 38, 39 and 56 Signals, which is from the 0km to the 0+750km (the 'review area').

For the Wellington Electrified Area (WEA), 67 signals have been passed at danger (SPAD) between Jan 2011 and Nov 2015. The review area had 14 out of the 67 SPADs which equates to 21% of the SPADs. In relation to the number of signals in the WEA versus the review area this represents a higher SPAD frequency of approximately 300%.

Four serious near miss incidents within the review area have occurred since 2011. These incidents have been investigated by Transport Accident and Investigation Commission (TAIC) and mitigations have been implemented to reduce the risk of a collision occurring. The primary mitigation within the review area is a reduced speed, which is posted as 20km/hr from the 0km to the 0.632km. Train Stops have been installed on the station entry signals 38, 39 and 56 which are higher speed approaches to the station (60km/h).

It is important to note that because of the above mitigations, the area controlled by 'A' Box has operated safely for a long time due to the low speed, robust right of way process, highly skilled and experienced signalling operators. However, there is a desire to increase the number of trains through the area with the proposed RS1 train plan and the new H&S Legislation requires KiwiRail to look at implementing safety enhancements so far as is reasonably practicable (SFAIRP) rather than as low as reasonably practicable (ALARP) which is, arguably, a more stringent criterion[1].

The assessment of the Risk Profile for the review area identified that the main risk that requires mitigation is the risk of a train on train collision. This risk is currently assessed as an "Unlikely" probability of occurring and a consequence of "Major" if it occurred in the peak times. Based on this assessment the Risk is determined to be classified as **High**[2] – treatment for risks under the Health and Safety at Work Act (HSWA) 2015 need to be controlled "so far as is reasonably practicable" (SFAIRP).

The review has identified that the risk is likely to be most significant on the outbound directing signals (99, 100, 101 and 102) due to the chance of the route being conflicted by another service movement and the short safety margin provided in the event of a SPAD. The inbound directing signals (46, 47, 48 and 49) also have a risk profile significantly worse than most signals in the WEA making the likelihood of a collision disproportionality high despite the very low operating speed.

The assessment has also considered the safety margin provided at each signal and although there is generally not enough room/distance for 'proper' signaling safety overlap it is possible to further mitigate the risk as often enough distance is available to safely stop a train. However, in some cases (e.g. the directing signals) it may be impossible to install a train stop due to the proximity of turnouts and this needs further detailed design assessment and trialing.

The review has identified short, medium and long-term mitigation strategies to reduce the collision risk-based on a SFAIRP approach. It is important to understand the long-term final solution that will be implemented in the future within the review area, this will enable the short and medium-term decisions to be made that head towards the final solution. This will ensure that value for money

[1] ALARP asks what is the risk associated with the hazard and then can that risk be made as low as reasonable practicable. SFAIRP asks what are the available practicable precautions to deal with the identified issue and then tests which precautions are reasonable based on the common law balance (of the significance of the risk vs the effort required to reduce it). CORE 2014, SFAIRP vs ALARP, R. Robinson and G. Francis.

[2] In line with the KiwiRail Enterprise Risk Management Manual July 2017 - Risk Rating Matrix

solutions are implemented that are part of the final solution rather than spending money on solutions that are not part of the end state layout.

All the short-term mitigations are based on no change to the existing lever frame system and include:

- Signaller process reinforcement
- Speed review
- Trial of a train stop on one of the tightly constrained directing signals
- Additional train stops at other signals where practical, including relocation of some platform starting signals (104, 108 and 110 signals) – if the train stop standard is going to be substantially altered it will be preferable to add additional train stops after the trial to ensure reliable operation.

The following medium-term mitigations are proposed which would result in a comprehensive minimisation of collision risk in the ‘A’ Box area:

- Additional train stops on remaining signals.
- Route locking 49 and 99 signals for the very short conflict but allow the locking to release on time. Note this will leave some residual risk of a train starting against a red signal with insufficient safety margin and would require the re-lock of ‘A’ Box Area prior to implementation.
- Swinging of the points beyond the signal for 99, 100 and 101 signals to maximise the safety margin – note this would require the re-lock of ‘A’ Box Area prior to implementation.

It must be acknowledged that train stops may have a poor return on investment due to a short life span. If implementation ends up being close to the Matangi mid-life over haul (starting in approximately 2025), moving directly to ETCS may be a more cost-effective strategy.

The long-term solutions that have been previously identified through the Interfleet assessment of the WEA and would provide the most effective reduction of risk of collision would be the implementation of ETCS Level 2.

ETCS Level 1, whilst reducing the risks of SPADs and collisions could impact on the timetable, as initial assessment of the junction layout has identified that several signals would have to be removed. Alternatively, significant junction layout changes would need to be made to be able to install ETCS Level 1 infrastructure without significant loss of headway and this will likely prove less cost effective than implementing ETCS Level 2.

There are a number of next steps recommended, the most critical of which are:

- Undertake ETCS Level 2 layout assessment for the Wellington Station area to understand what track and signalling layout changes would be preferred in the long term and assess the residual risk of that layout.
- Confirm the RS1 infrastructure changes and timing with consideration to resource levelling and the likely impact on the timing of the re-lock of the ‘A’ Box area.
- Develop a Wellington ‘A’ Box migration strategy and integrate it with the overall WEA signalling strategy

2 Background

The Wellington station approach (Wellington 'A' Box area) is a complex junction with very tight track and signal space constraints and a relatively high level of reported operational incidents (such as signals passed at danger - SPADs) resulting in several TAIC investigations.

KiwiRail required a route risk assessment of the Wellington 'A' Box area involving:

1. an assessment of likelihood and consequence of a train collision resulting from a SPAD under the existing signalling and timetable at Wellington Station for all track and signals South 38, 39 and 56 Signals.
2. identification of potential changes to signalling, track infrastructure, or operating parameters that can further reduce collision risk so far as is reasonably practicable in the same area.

2.1 Document Purpose

The purpose of the report is to provide an assessment of the potential route conflicts in the Wellington 'A' Box area and categorise the hazards such that they can be benchmarked against the historical SPAD data and appropriately risk assessed. The requirements for each of the routes is also assessed such that appropriate mitigations can be applied that do not unduly impact the operational capacity of Wellington Station.

This report is split into two parts:

i. The first part of the report will document the reasons why the work is being undertaken and the approach to undertaking the work. It will include the findings of the analysis undertaken of historical SPADs and risks of each of the routes that trains can take within the Wellington Station area and explain the analysis that has been undertaken to determine the safety margin of a train on train collision based on the layout of the signalling and track work within the Wellington Station area.
ii. The second part of the report uses the findings from analysis undertaken and identifies and assesses risk mitigations to reduce the chance of a train on train collision occurring. The possible mitigation options are described their effectiveness assessed. This involved the identification of potential changes to signalling, track infrastructure, or operating parameters that can further reduce collision risk so far as is reasonably practicable in the same area.

The findings of this assessment were used to discuss and agree the mitigations with the KiwiRail team including representatives from Transdev (the passenger service operator). This covered the ability to undertake the mitigations, the risk of a collision occurring post implementation of the respective mitigations and the possible timing of the works if they were to be progressed. The timings are categorised as 'Short', 'Medium', and 'Long' term as the exact timing is less important than the proposed sequence of the improvements.

2.2 Wellington Junction

Wellington Junction is a complex track arrangement that is the confluence of the four main passenger lines (Johnsonville, Kapiti, Wairarapa, Hutt Valley and Melling) connecting into Wellington Central Rail Station see **Figure 1:** Wellington S&I Diagram below.

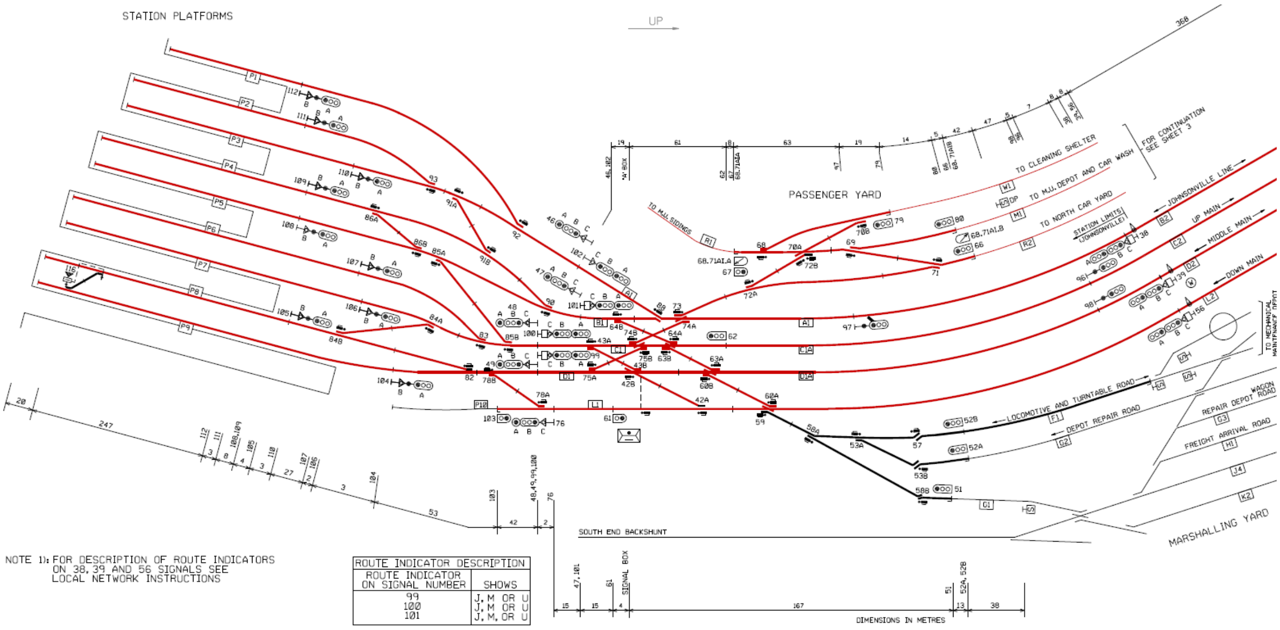


Figure 1: Wellington S&I Diagram

The station has 9 platform faces that are used for inbound and outbound journeys into and out of Wellington. The junction area, as well as being connected to the main lines, has connections into and out of EMU maintenance and stabling facilities, and Diesel shunting operations.

Four main lines (Johnsonville, Up, Middle and Down Mains) enter Wellington and then split into the 9 Platform faces. The layout of the junction allows for access off the mains onto the majority of the platform faces. The layout has a high number of turnouts and crossovers to allow for this ability to enter and exit off the four mainlines into the 9 platform faces and get into and out of the maintenance/stabling facilities.

The Wellington Station area is controlled out of 'A' Box within station limits. 'A' Box was opened on 19th May 1937 when Wellington station opened and provides signalling control to the Wellington Yard via a 127 lever Westinghouse Brake & Signal Co. Ltd. Style 'L' Power Lever Frame (**Figure 2** below). This signalling system is a manual system that is manned 24/7 within 'A' Box. Once trains depart the station they enter the Automatic Signalling Rules (ASR) area controlled by the centralised control centre based in Wellington Station building.

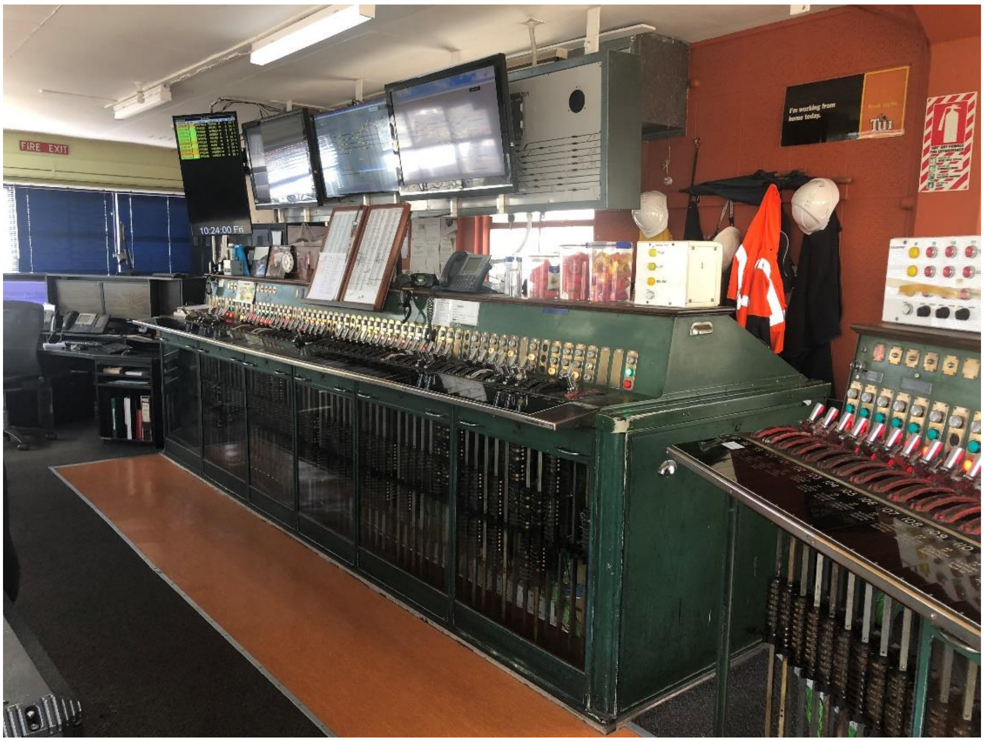


Figure 2: 'A' Box lever frame

Due to the complexity of the junction and as a primary safety mitigation, the speed throughout the area is limited to 20km/h from the end of line (buffer stops) to the 0.632km.

2.3 Study Approach

The approach to this study was broken down into three main steps.

- Investigation – where research was undertaken to review previous work and available SPAD data. This was used to categorise the key train collision hazards in the Wellington area.
- Assessment – where the risks associated with each hazard were assessed along with the operation requirements.
- Mitigation – where mitigation options were reviewed and the applicability to specific hazards are considered.

The overall approach to the study is summarised in **Figure 3** below. Note that the SPAD hazard categorisation was based on earlier work done for Auckland during the transition to ETCS as part of the AEP project. This work categorised Hazards as part of the signalling risk assessments. The categories can overlap and do not consider the specifics of each signal but are a useful tool for comparing relative SPAD risk which can then be applied to Wellington Area.

Based on these Hazards we can identify if they are relevant to each specific route in the Wellington area and assess the risk. Once we understand the risk, we can look at specific locations where it may occur, the need for the associated routes and identify appropriate targeted mitigations.

It has been indicated that KiwiRail's long term mitigation strategy is to implement some form of Automatic Train Protection (ATP) such as ETCS. We know that relocking the yard and implementing a modern signalling system will allow us to solve many issues, however this will likely be several years away. In the short term we can identify mitigations at targeted areas that specifically support the relocking and future provision of ATP until this work can be completed.

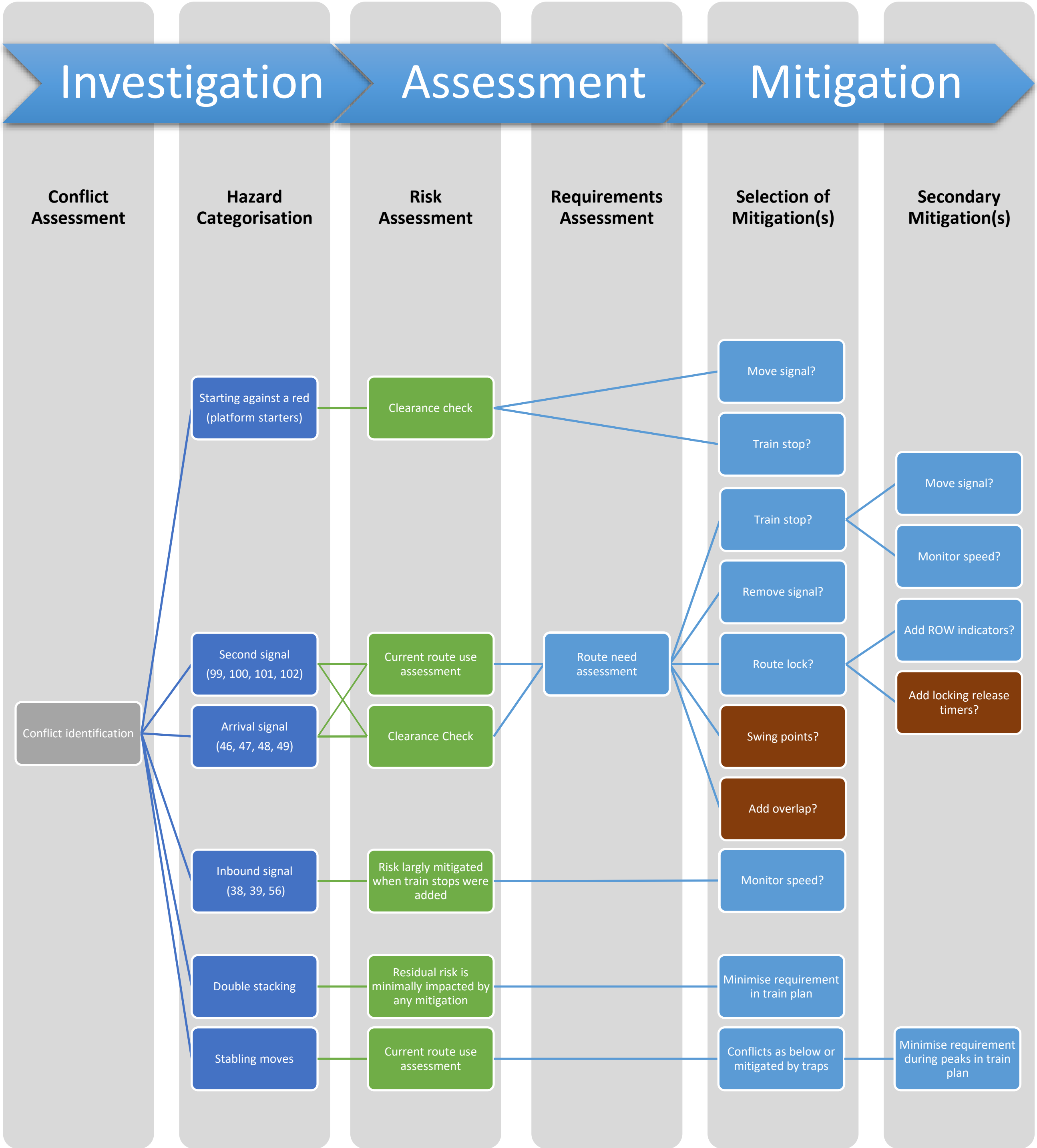


Figure 3: Approach summary

Note: The mitigations in the brown boxes require re-locking of the Wellington Station area as they could not be implemented on the current mechanical interlocking.

3 Investigation

3.1 Historic Data Comparison

For the Wellington Electrified Area, sixty-seven SPADs have occurred between Jan 2011 and Nov 2015. The review area which is from the 0km to the 0+750km had 14 out of the 67 SPADs which equates to 21% of the reported SPADs. In relation to the number of signals in the WEA (~300 signals) versus the review area (21 signals or approximately 7% of WEA signals) this represents a significantly higher frequency of SPAD risk (~300%).

In addition, four serious near miss incidents in the review area have been deemed serious enough for TAIC to undertake a full investigation. These investigations are listed below and can be found on the TAIC website:

RO-2013-108 – 38 Signal Passed at Danger

RO 2016-101 – 100 Signal Passed at Danger

RO-2017-102 – Panel Indication Irregularity

RO-2017-103 – Investigation Pending

Note: only RO-2013-108 is included in the 14 SPADs identified in the study area due to the data available.

3.2 SPAD Assessment

To be able to assess the likelihood of a collision based on the number of conflict moves where the trains were held at stop at a signal whilst and inbound or out bound trains was arriving/departing an assessment of the SPAD Data in Wellington and Auckland was undertaken. This was used to develop the likelihood of a collision due to a SPAD.

The SPAD data for Auckland and Wellington in the period from Jan 2011 through to late 2015 and early 2018 for WEA and AEA respectively was used as a comparison to ascertain the likelihood of a SPAD occurring for different operating movements as listed below:

The key SPAD categories were identified include the following:

- **ATSB** – passing an All Trains Stop Board without authority (not relevant to study area)
- **CSB** – passing a Conditional Stop Board without authority (not relevant to the study)
- **Shunt** – passing a shunt signal in a yard area without authority (protection provided by
- **Directing/Intermediate Overrun**– passing a directing or intermediate 'running' signal without authority – this excludes the signals in the categories below
- **Platform Arrival** – passing the last signal before arriving at a platform without authority – this type of SPAD can be associated with complacency due to consistently driving from station to station unimpeded
- **Second Signal** – passing the second signal after dispatching from a platform without authority – this type of SPAD can be associated with complacency due to consistently driving from station to station unimpeded. This may be exacerbated by the driver consistently being presented with a restrictive aspect (e.g. caution) and expecting the second signal to 'step up'. Where a signal is both a 'Second Signal' and 'Platform Arrival' it has been categorised as 'Platform Arrival'.
- **Platform Starter (Starting against a red)** - passing a platform starting signal without authority after the train has been stationary – this type of SPAD is often referred to as a 'ding-ding-and-away' SPAD where right of way may have been indicated to the driver but the signal was not at proceed.
- **Platform Starter (overshoot)** – passing a platform starting signal without authority where the train failed to stop on arrival – this type of SPAD is typically caused by a driver misjudging the train handling and braking distance required.

- **Platform Starter (undefined)** – passing a platform starting signal without authority – this is one of the above two SPADs but where the data is not clear – for the Wellington SPAD data it is often implied that the train started against the red but was not explicit in the notes.

The date ranges were selected to start once the AEP project had implemented a significant portion of new signalling through to the latest data available for Wellington and Auckland. Only AEA and WEA signals were included. It is important to note that the Auckland SPAD rate initially increased as reporting improved and then decreased with the rollout of ETCS but as we are mainly looking at the proportionality of different types of SPAD all data was included as pre ETCS data is more relevant to Wellington application.

It should be noted that there is significant difference in the operating environment between Wellington and Auckland Metros. Auckland's signalling system was completely replaced as part of the Auckland Electrification Project. This altered the signalling placement to be more aligned with a metro operation. This included the following significant changes:

- The provision of platform starting signals at all stations – this would likely have slightly increased the probability of a minor platform overshoot resulting in a SPAD
- The implementation of ETCS Level 1 – this reduced the chance of a SPAD on a 'running' Directing of Intermediate signal as the driver is given a warning to reduce speed
- Continuous monitoring of the entire Auckland network was provided and SPAD alarms were added to the control system – this significantly increased the reporting rate of SPADs

Many platforms in Wellington do not have platform starting signals and the categorisation is therefore a little more subjective than for Auckland as a decision needs to be taken whether a signal is close enough to the platform to be considered a 'platform starter'.

For the two categories **Platform Starter (starting against a Red)** and **Platform Starter (Overshoot)** there is only data for these types of SPAD in the AEA. With the data available it was not possible to categorise the SPADs at platform starting signals in the WEA and hence are shown as a 0% in the tables below.

The information is shown in the **Table 1** and

Table 2 below with the respective graphs (**Figure 4** and **Figure 5**) showing the outcome of the analysis:

Table 1: SPADS in AEA (Jan 2011 - May 2018)

<table>
<tr><th>Category</th><th>Number of SPADS in AEA (Jan 2011 - May 2018)</th><th>% of SPADA</th><th>% of Signals in AEA</th></tr>
<tr><td>ATSB</td><td>1</td><td>1%</td><td>N/A</td></tr>
<tr><td>CSB</td><td>3</td><td>3%</td><td>N/A</td></tr>
<tr><td>Shunt</td><td>8</td><td>8%</td><td>21%</td></tr>
<tr><td>Directing/Intermediate Overrun</td><td>11</td><td>12%</td><td>39%</td></tr>
<tr><td>Platform Arrival</td><td>31</td><td>33%</td><td>14%</td></tr>
<tr><td>Second Signal</td><td>11</td><td>12%</td><td>6%</td></tr>
<tr><td>Platform Starter (undefined)</td><td>6</td><td>6%</td><td rowspan="3">20%</td></tr>
<tr><td>Platform Starter (Starting against a red)</td><td>13</td><td>14%</td></tr>
<tr><td>Platform Starter (overshoot)</td><td>11</td><td>12%</td></tr>
</table>

Figure 4: SPADS in AEA (Jan 2011 - May 2018)

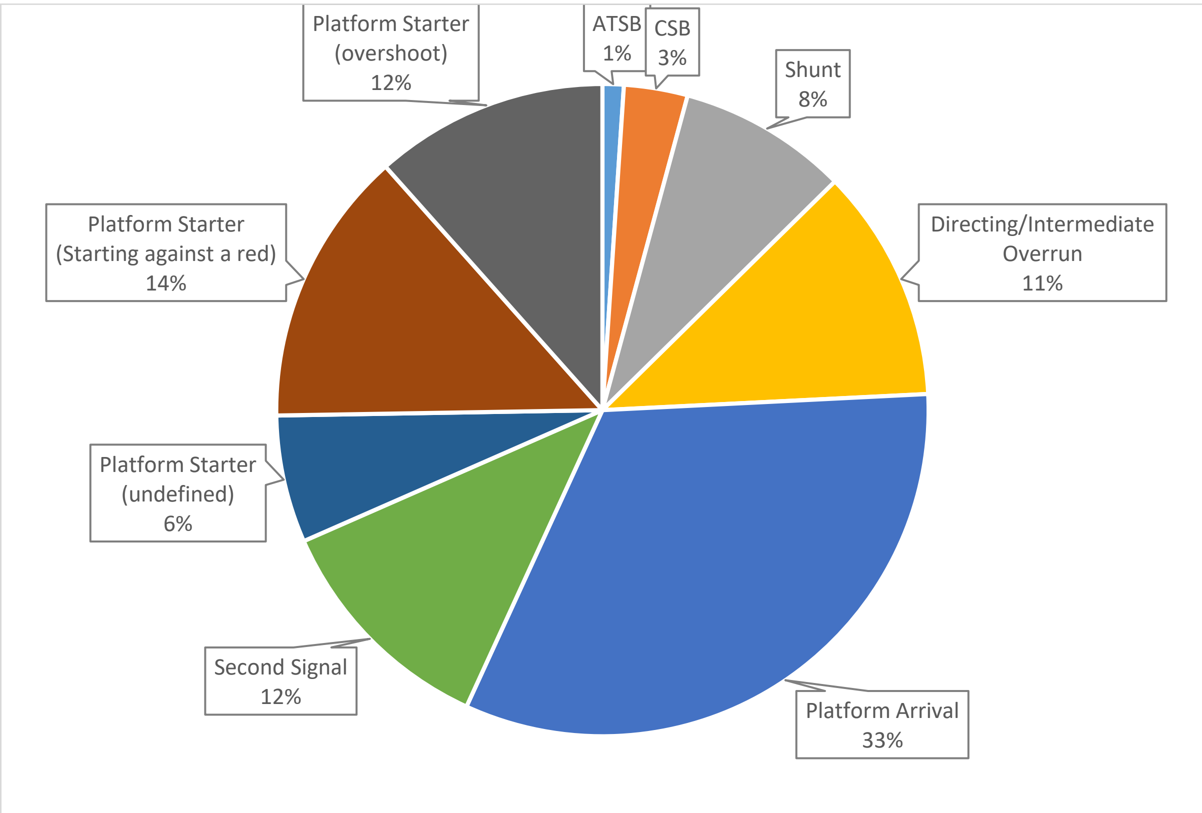
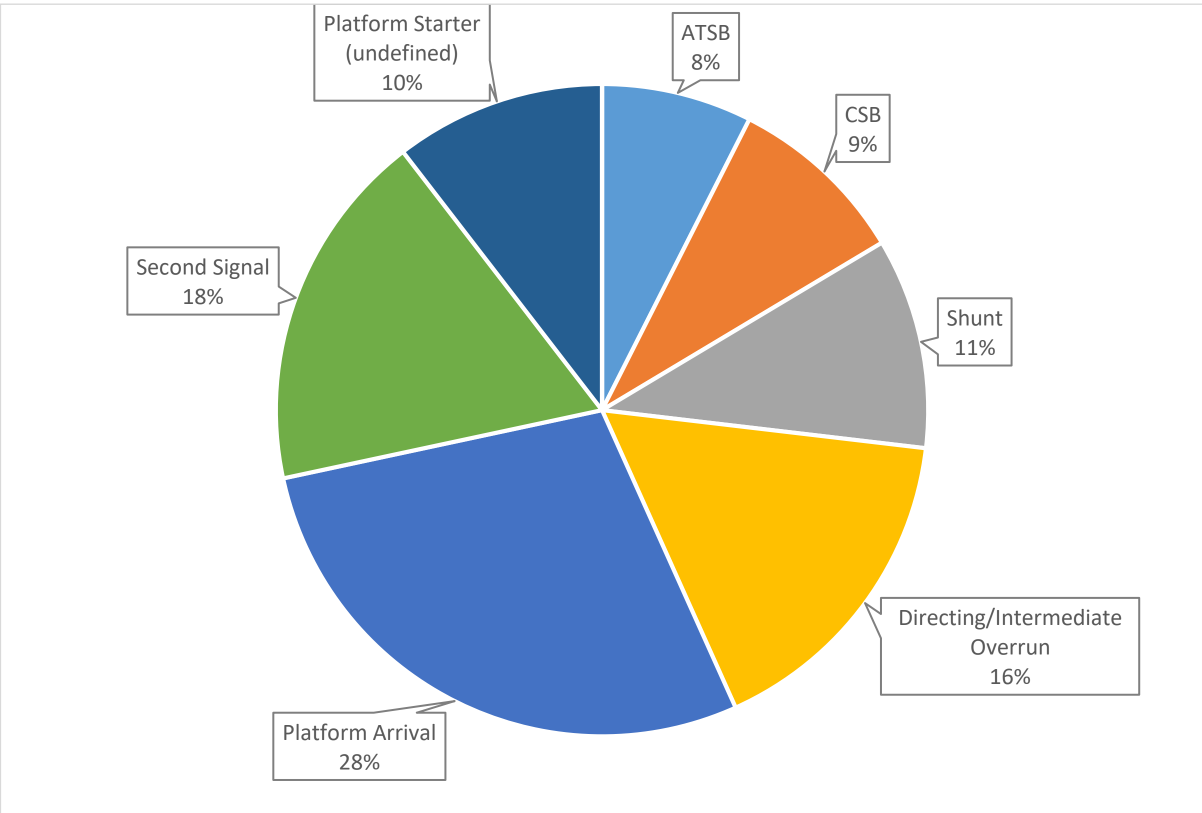


Table 2: SPADS in WEA (Jan 2011 - Nov 2015)

Category	Number of SPADS in WEA (Jan 2011 - Nov 2015)	% of SPADA	% of Signals in WEA
ATSB	5	7%	N/A
CSB	6	9%	N/A
Shunt	7	10%	14%
Directing/Intermediate Overrun	11	16%	34%
Platform Arrival	19	28%	22%
Second Signal	12	18%	9%
Platform Starter (undefined)	7	10%	
Platform Starter (Starting against a red)	0	0%	21%
Platform Starter (overshoot)	0	0%	

Figure 5: SPADS in WEA (Jan 2011 - Nov 2015)



Looking at SPAD data from both Auckland (pre ETCS) and Wellington there are three stand out SPAD risk categories that pose the greatest risk of collision in the Wellington area. These are:

- Starting against a red (ding-ding and away SPAD)
- SPAD on second signal on departing a platform (directing signal SPAD)
- SPAD on the station arrival signal (arrival SPAD)

Although a head on risk is possible if for example double stacking was planned (using the low speed signals) and a train departed from a station platform into the inbound train. The consequence of such an event would be similar to a sideswipe or flank collision due to the low operating speed in the area.

For the Wellington Station area, the critical risks based on the SPAD Data are:

- Platform Arrival – approximately 33% of AEA and 28% of WEA SPADs
- Second Signal – approximately 12% of AEA and 18% of WEA SPADs
- Platform Starter (Starting against a red) – approximately 14% of AEA and possibly 10% of WEA SPADs[3]

The other high percentage of WEA SPADs recorded was Directing/Intermediate Overrun signals at 16%, but these signals in the review area are signals that have a good safety distance and have already been fitted with Train Stops as a mitigation.

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[3] This may be significantly less than 10% as many of the platform starting signal SPADs were not adequately described in the data available and some may in fact be platform overshoot SPADs although this is less likely in Wellington as the signals are generally further from the platform.

There are a number of human factors that are significant contributors to SPAD risk and in Metro environments one of these is the regularity of the operation. Drivers may become very used to being signalled from station to station and can be caught out when the full route to the next platform is not available (e.g. due to a train ahead being held up or a shunt operation). This a likely reason why such a portion of SPADs occur at the second signal from a station or on the arrival signal to a station. In both Wellington and Auckland these make up almost half of the SPADs. The SPAD rate for these signals is also highly disproportionate to the number of signals in those categories as highlighted in Table 1 and Table 2 above.

The significance of this in the context of this study is that the outbound directing signals including 99, 100, 101 and 102 signals (“Second Signals”) and the inbound directing signals including 46, 47, 48 and 49 signals (“Platform Arrival Signals”) likely carry a higher probability of a SPAD than many other signals in the WEA.

3.3 Existing Risk Models WEA

A list of key risks that could occur within the Wellington Station area are listed below based on a previous risk assessment undertaken by KiwiRail specifically when assessing the risks associated with the changes due to the introduction of the Middle Main:

- Driver of down train misreads adjacent signal
- Driver of down train SPADs home signal due to distraction or inattention.
- Driver of up train misreads adjacent signal
- Driver of up train SPADs starting signal due to distraction or inattention.
- Driver of up train SPADs 97 departure signal starting signal due to distraction or inattention.

A KiwiRail risk assessment undertaken in May 2006[4] identified the following specific risks for operations into and out of the Wellington Station area which identified the high-risk signals as the Home and Starter signals. The mitigations that were put in place to mitigate these risks were:

- Arrow indicators on the signals to indicate line.
- 20km/h speed restriction from the 0.632km into the Station[5]
- Overrun protection >150m to collision point from these signals

As a result of this Risk assessment KiwiRail installed train stops on 39 and 56 signals as part of the Middle Main project in 2010. As no change was made to 38 signal, a train stop was not added as part of the works. The TAIC report RO-2013-108 proposed as further mitigation a train stop on 38 signal to fully mitigate the risk of a SPAD and train collision for trains entering the Wellington Station Area.

The latest Risk Assessment was undertaken in July 2015 by Interfleet[6]. This report baselined the Wellington metro area and then assessed the risk profile against a range of mitigation measures ranging from additional Train Stops through to the re-signalling of the Wellington Metro using ETCS and fitting out the train fleet for the new system.

The Interfleet Report used the following methodology used to produce the collision risk profile. The collision risk was calculated using the following steps:

1. Establish all potential SPAD collision scenarios on the WRN

2. Calculate consequence for each scenario

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[4] OMF-RM-001 May 2006

[5] Local Network Instructions Section L4 -All lines south of Waikanae and Masterton inclusive limits the speed to 20km/h from the platforms to 0.632km

[6] ITNZLR/TR360/002 Issue 2 – 21/07/2015

3. Calculate likelihood for each scenario

4. Sum consequence level likelihoods for all scenarios to give network risk

The Interfleet risk assessment assessed the likelihood of collisions in the Wellington Station area but the review was limited to the high-speed intermediate and home signals – 38/39/56/8/6/4/2. The recommendation was to fit Train Stops to these signals to mitigate the risk of an SPAD and possible collision occurring. These measures have been undertaken and are in place on these signals.

The Interfleet Report assessed the list of mitigations for the WEA was the following scenarios over time:

- Scenario 0: No train stops – Baseline Risk Profile
- Scenario 1: Baseline - Existing train stop system for EMUs
- Scenario 1a: EMUs with existing and additional train stops as identified in Wellington Metro ATP Report
- Scenario 2: EMUs and ETCS infrastructure areas fitted with ETCS
- Scenario 3: EMU and full metro network fitted with ETCS
- Scenario 4: EMUs, full metro network + captive shunt fleet fitted with ETCS
- Scenario 5: Full metro network and full fleet fit out with ETCS

3.3.1 Probability

The review area has approximately 7% of the WEA signals. Based on the historical SPAD data analysed these signals have accounted for 21% of the total number of SPADs. The probability of a SPAD occurring is implied to then be 300% more likely to occur within the review area than the rest of the WEA.

The probability of a collision occurring if a SPAD occurs then has the following factors that determine whether a collision would happen:

- Speed of SPAD train
- Speed of Oncoming train
- Driver awareness of SPAD and emergency breaking
- Distance from the signals to the train collision point
- Oncoming Train Driver awareness and emergency breaking
- Oncoming train is in a position that a collision occurs

Based on the **Figure 6:** NRSS/4 likelihood table below the likelihood of a collision occurring once a SPAD has occurred based on the factors listed above would be Remote or 2 in the interpeak and a 3 during the peak. This is further justified by the fact that a collision has not occurred in the review area in the past 16 years[7].

[7] Saturday 31st August 2002 collision between two units as a result of a SPAD at 46 signal [RO-2002-120]

STEP 1. Select the likelihood rating of the hazard:

Likelihood

Rating	Description	Return Period (years)	Definition
1	Improbable	40	Unlikely to occur but possible. It can be assumed the hazard may exceptionally occur
2	Remote	20	It can be reasonably expected for the hazard to occur
3	Occasional	5	Highly possible for the hazard to occur
4	Probable	1	(Almost certain) The hazard can be expected to occur frequently
5	Frequent	0.25	Hazard is certain to occur or already has

Figure 6: NRSS/4 likelihood table

Based on the new KiwiRail Risk Matrix (see **Figure 21**: KiwiRail risk rating matrix below in section 3.6 Current Risk) the assessed probability of an event occurring would be rated as Unlikely. The return period has changed between the NRSS/4 matrix and the current KiwiRail matrix.

The Interfleet report[8] assessed the probable reduction of risks by the mitigations listed in **Figure 7**: Interfleet probability table of a collision or derailment below. Unsurprisingly, the mitigations that were the most effective at reducing the probability of the serious incident occurring were where ETCS was fitted to the EMU and the network.

Scenario No.	Scenario Description	NRSS/4 score	Continuous Risk Rating[1]	Percentage risk of Scenario 1
0	No train stops	10	435	110%
1	Baseline - Existing train stop system for EMUs	10	395	100%
1a	EMUs with existing and additional train stops as identified in Wellington Metro ATP Report	5	356	90%
2	EMUs and ETCS infrastructure areas fitted with ETCS	5	328	83%
3	EMU and full metro network fitted with ETCS	5	51	13%
4	EMUs, full metro network + captive shunt fleet fitted with ETCS	5	46	12%
5	Full metro network and full fleet fit out with ETCS	0	0	0%

Figure 7: Interfleet probability table of a collision or derailment

3.3.2 Consequence

The consequence of a train passing a signal at danger and hitting another train is the possibility of causing serious injuries or death to passengers and train staff. The NRSS/4 rating of consequence in table below rates this impact as a Rating 5 - Catastrophic.

[8] ITNZLR/TR360/002 Issue 2 – 21/07/2015

STEP 2. Select the consequence rating of the hazard

Consequence

Rating	Description	Financial Damage	Effect on People
1	Negligible	<$10,000	No medical treatment by professional medical personnel
2	Minor	$10,000-$100,000	Lost time injury
3	Major	$100,000-$1million	Possible fatality, severe injury
4	Critical	$1 million - $10 million	One fatality
5	Catastrophic	>$10 million	More than one fatality (multi-fatality) and/or multiple severe injuries

Figure 8: NRSS/4 consequence rating table

There are two factors that influence this score – the speed of the trains when the collision occurs and the timing during the day due to the number of people on the train. Both of these factors influence the probability of serious injury or death if a collision occurs. The Interfleet report identified that the consequence score changes during the day depending on the number of trains and train loadings. The graph below shows the findings across the WEA had the highest risk occurring during the two peak periods 7-9am and 5-8pm see **Figure 9: Interfleet** Scenario 1 assessment of risk profile during a 24hr period below.

The review area is a low speed area and the speed trains arrive and depart the station area from the 0.632km at 20km/hr.

Due to this mitigation the consequence of a train collision in the review area would be rated under NRSS/4 as a 4 – one fatality. It is unlikely that the consequence of a collision can be reduced below a 4 rating unless the speed of the trains were further reduced.

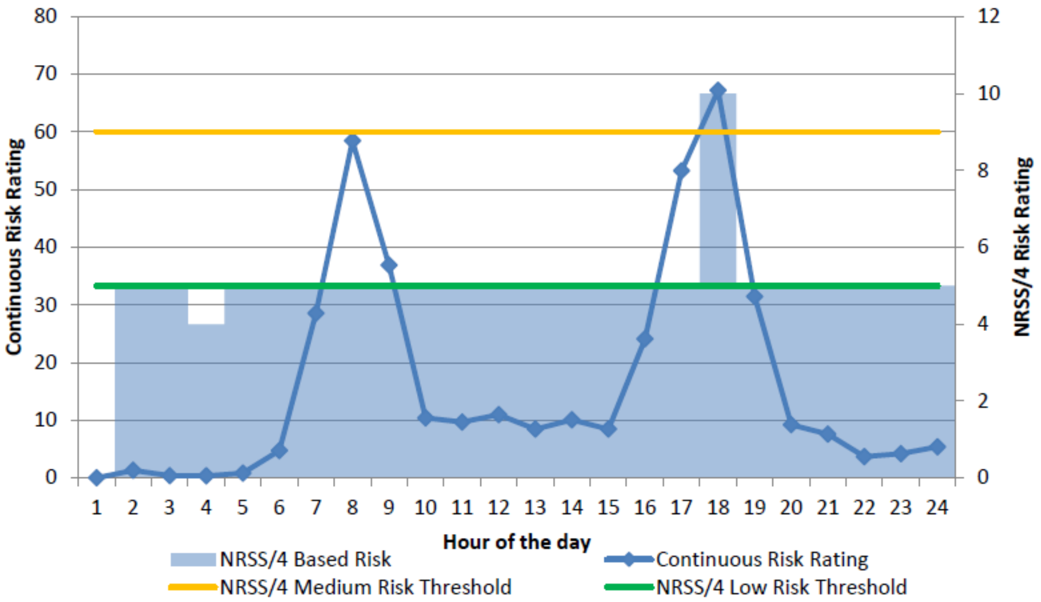

Figure 9: Interfleet Scenario 1 assessment of risk profile during a 24hr period

Based on the new KiwiRail Risk Matrix **Figure 21:** KiwiRail risk rating matrix the consequences would be rated as **Major**. The new Risk Matrix assesses not only the safety consequence but also operational, reputational, customer, regulatory and stakeholder confidence. These additional factors are assessed as Major.

4 Assessment

4.1 Assessment of Collision Risk in the Wellington Station Area

To understand the likelihood of a conflict occurring specifically in the Wellington Station area the following work and assessment has been undertaken to develop an understanding of how many instances of a collision risk there are within the area. There are two components that have been assessed to better understand these risks:

1. First the usage of the routes was assessed based on the current timetables to understand the frequency of train movements and the likelihood of an incident occurring on each route based on the train frequency of opposing movements. As well as the timetable assessment a 24hour period was downloaded from 'A' Box and all movements assessed, and the conflicts documented. This was used as a check to see whether the actual routes and timetabled routes and conflicts varied. The outcome of this assessment is covered in section 2.
2. The second assessment that has been undertaken is each of the routes has been modelled using a Matangi unit layout to ascertain the safety distance between the signal and where a collision would occur on the opposing route. These distances have been used to evaluate the risk profile for the route. The longer the distance between the signal and the opposing route the less chance of a collision occurring. The outcome of this assessment is covered in section 4.2.3.

4.2 Route Usage Assessment and Conflict Frequency

The results of the 24hour analysis has provided information to assist in determining that although the timetable does not allow for conflict moves the way that the trains are being controlled does mean that trains are being routed and held at red signals. This means that the probability of a collision does exist during normal day operations within Wellington Station area.

4.2.1 Route Usage

Table 3: Summary of route usage during a 24-Hour review period for departing trains shows what routes were used and when. From this analysis it can be seen that not all the routes were used during the 24-hour period. 112B, 107B and 106B were not used. One route was used only once during period 110A and two other routes were used < 5 times so were very low usage 109C and 105A. All other routes were used >5 times per 24hour period with the highest use route 112A. The summary table below shows the routes and the total number of services during the review period.

Table 3: Summary of route usage during a 24-Hour review period for departing trains

Platform	**P1**		**P2**		**P3**		**P4**	
Route	**112A**	**111A**	**111B**	**110A**	**110B**	**109A**	**109B**	**109C**
Usage	**37**	**8**	**11**	**1**	**20**	**7**	**18**	**4**

Platform	**P5**		**P6**	**P7**	**P8**			**P9**	
Route	**108 A**	**108B**	**107A**	**106A**	**105A**	**105B**	**105C**	**104A**	**104B**
Usage	**13**	**19**	**23**	**23**	**4**	**12**	**8**	**16**	**7**

Key

37	High Usage - Critical Route
19	Medium Usage – High Importance
8	Low Usage – Non-Critical
4	Assess Route Closure – Route Lock

Figure 11: Total no. of arrivals into the platforms shows that in general the platform usage is well spread with the lowest usage for the day on platform P2 -19 and the highest usage on platform P1 – 36. The signals controlling the route into and out of P1 are 112 Departure Signal and 102 and 46 Throat Directing Signals.

Figure 12: Number of conflicts per route show the outcome of the analysis of the 24-hour period with regard to the possibility of a conflict arising due a train departing the platform and then being held at stop at the Throat Directing signals. The assumption is that due to the train being held at stop then if the train SPAD the Throat Directing signal then there is a possibility of a conflict and train on train collision. From this data it can be seen that the highest number of possible conflicts are trains departing Platform 8 (105b) and being held at 99 Throat Directing Signal with a count of 6 conflicting moves during the 24hr period. The next highest was trains departing Platform 5 (108A (4) and 108B (5)) and being held at 100 and 101 Throat Directing Signals. It can be seen from the graph that the only platform that does not have a conflicting move during the 24hours was platform 1.

The highest grouping of conflict moves was found to be on platforms 5-9 with an average of 5 conflict moves in the 24hour period from these 5 platforms.

The lowest grouping of conflicts was on platforms 1-4 with an average of 2.75 number of conflict moves within the 24hour period from thee four platforms.

The average train frequency for platform 1-4 and for 5-9 is the nearly the same with 25 and 26 average incoming trains into each group of platforms. So, there is a higher risk and probability of train collision occurring on platforms 5-9.

Count of File ref	Colum																	
	P1	P2		P3		P4			P5		P6	P7	P8			P9		Grand Total
Row Labels	112a	111a	111b	110b	110a	109a	109b	109c	108a	108b	107a	106a	105a	105b	105c	104a	104b	
No																		
4 AM							1											1
5 AM		1		1			1				1	1						5
6 AM	4	1		1			2			2	2	1	1			2	1	17
7 AM	4		1	2			1			1	2	3			2		1	17
8 AM	3	2		2			1			2	2	2					1	15
9 AM	1	1		1			1		1	1	2				1		1	10
10 AM	2		1	1			1						1			2		8
11 AM	2		1	2										1				6
12 PM	2		1	2			1			1			1		1		2	11
1 PM	2				1		1		1		1	1		1		1		9
2 PM	1			1					1	1	1					1	1	7
3 PM	3		2	1				1	2		2	1		1	1	2		16
4 PM	4		1	2			3		1	2	3	3			1	1		21
5 PM	4		2	1				2	1			2	1	1	2	2		18
6 PM	3	1					2		2		1	2				1		12
7 PM	2			1		1					1					1		6
8 PM						2				1	1	1		2				7
9 PM						1				1		1						3
10 PM						1				1		1						3
11 PM						1				1		1						3
No Total	**37**	**6**	**9**	**18**	**1**	**6**	**15**	**3**	**9**	**14**	**19**	**20**	**4**	**6**	**8**	**13**	**7**	**195**
Yes																		
7 AM			1				1			1				1				4
8 AM		1					2		1	1	1	1		1		1		9
9 AM									1									1
10 AM									1									1
11 AM										1								1
1 PM											1	1						2
2 PM		1																1
3 PM				1														1
4 PM														1				1
5 PM									1		1	1				1		4
6 PM			1	1		1		1			1			1		1		7
7 PM										2				1				3
8 PM														1				1
Yes Total		**2**	**2**	**2**		**1**	**3**	**1**	**4**	**5**	**4**	**3**		**6**		**3**		**36**
Grand Total	**37**	**8**	**11**	**20**	**1**	**7**	**18**	**4**	**13**	**19**	**23**	**23**	**4**	**12**	**8**	**16**	**7**	**231**

Figure 10: Route usage and conflicts during a 24hr period

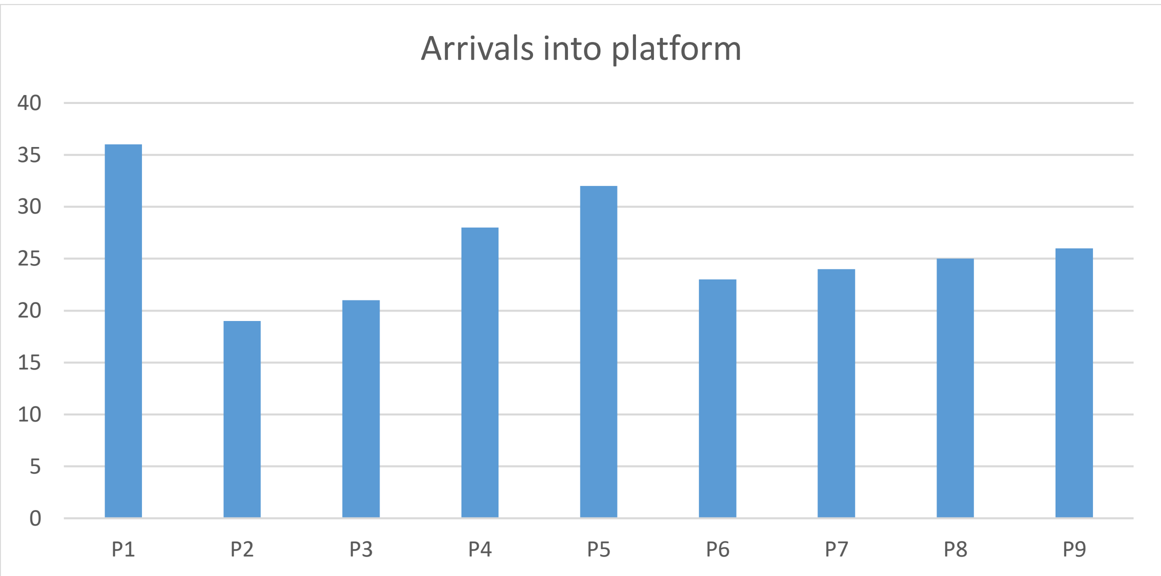

Figure 11: Total no. of arrivals into the platforms

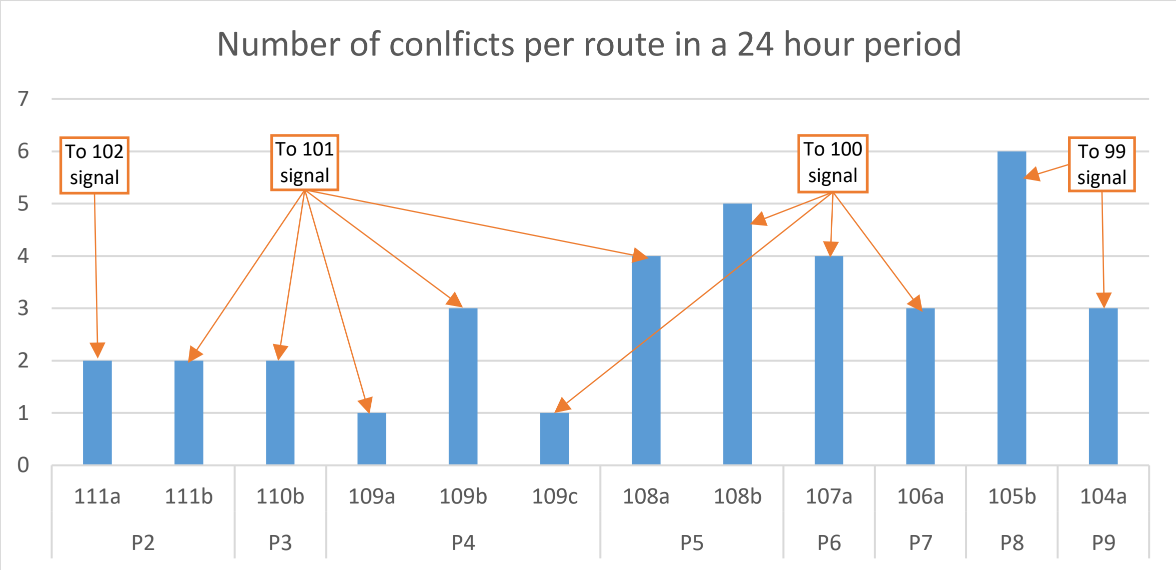

Figure 12: Number of conflicts per route

From the analysis, the time of day when the highest numbers of conflicting moves occur is towards the end of the morning peak 8am and toward the end of the evening peak 6pm. The assumption that could be formed from this analysis is that over the period of the two peaks to ensure that the on-time performance is maintained there is a requirement for more non-timetabled movements from the platforms and trains being held at stop at the Throat directing signal so that the inbound service can be brought into the platform.

For the rest of the period the frequency of the conflict moves remains around 1-2/hour outside of the morning and evening peaks. The risk is that during the peak times is when the trains are at their fullest and so the consequence of a collision during the peak or the peak shoulder would have a higher impact due to the loading of the trains that collide.

4.2.2 Timetable, Train Plan and Critical Routes

To be able to further refine the risk of a collision the usage of the route combined with amount of times the routes are used will determine the probability of a SPAD occurring on that route.

In general, the analysis of the timetable has shown that the timetabled movements into and out of the platforms are scheduled movements that do not create a conflict. This is a very effective mitigation from a timetabling and train plan perspective.

The analysis that was undertaken based on the 24hour period was used as a check to see whether a "normal day"[9] was any different from the timetabled service. The day that was analysed was the 27th March 2018 and the recordings from train control were downloaded. Every train path was documented and recorded and the route that the train took was recorded. Any conflict movements were recorded and where trains were held at a red signal at the Throat Directing Signals see **Figure 13:** Wellington Station signals layout, were assumed to be waiting for another train and were recorded as conflicts.

[9] The 24hour period that was analysed was Tuesday the 27th March 2018 and through discussion with the Network Control staff was deemed a typical normal day.

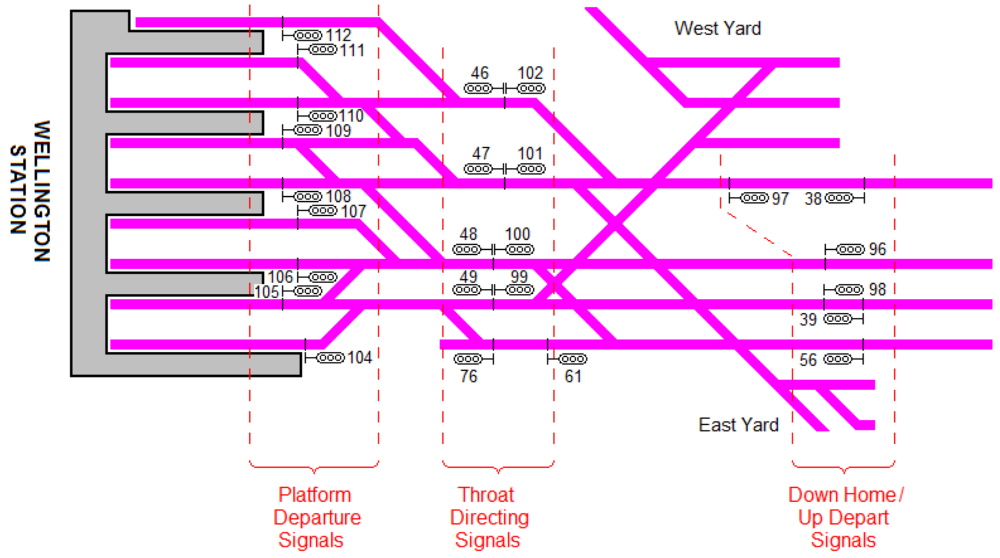

Figure 13: Wellington Station signals layout

4.2.3 Needs Assessment

A thorough assessment of the impact of removing the directing signals was carried out by KiwiRail[10]. This assessment identified the time cost for the four main scenarios:

1. One train following another inbound, at minimum headway.
2. One train following another outbound, at minimum headway.
3. One train following another inbound at min headway, just as an outbound train crosses its path.
4. One train following another outbound at min headway, just as an inbound train crosses its path.

In these scenarios a 30s platform-depart routine was applied in all cases. If ROW indicators were applied the ROW process could commence before the platform starting signal clears to green (with the directing signals effectively locked out) this would reduce the impact of 'removing' the directing signals.

Table 4 shows the summary of the time cost due to loss of directing signals. As can be seen, even with the provision of ROW indicators the loss of the headway provided by the directing signals is significant. With plans to further increase the service levels this loss of headway would need to be carefully considered on a case by case basis.

[10] Wellington Station Director Signal Capacity Investigation Issue 1.0 Dated 17 May 2017

Table 4: Time cost due to loss of directing signals

	Train Consist	Scenario 1 Inbound following [m:ss]	Scenario 2 Outbound following [m:ss]	Scenario 3 Inbound crossing [m:ss]	Scenario 4 Outbound crossing [m:ss]
Headway w/ directing signals active	2-car	1:32	1:55	1:17	1:53
Headway w/ directing signals inactive		1:32	2:48	1:32	2:49
Time cost without directing signals		Nil	0:53	1:05 + 1:20 *	1:06 + 2:02 *
Headway w/ directing signals active	6-car	1:48	1:53	1:23	1:50
Headway w/ directing signals inactive		1:48	2:46	1:48	2:47
Time cost without directing signals		Negligible	0:53	1:05 + 1:30 *	1:19 + 2:16 *

* 1st figure = Time-cost to first train held due crossing movement

2nd figure = Time-cost to 2nd train following at minimum headway

Lost time outbound can be significantly reduce by providing ROW indicators

4.3 Conflict Worst Case Assessment

The purpose of the conflict worse case assessment was to understand the likely effectiveness of a train stop or ATP mitigation. The distance between the signal and the conflict point (fouling point) is very dependent on the specifics of the geometry and train profile. The ability of the train to stop before the conflict point is obviously determined by the speed and the performance of the braking system.

Each SPAD conflict was assessed to understand how much 'safety margin' there was in the event of a SPAD. The 'safety margin' is not the same as a traditional signalling 'overlap' as it is not proven clear before allowing a train to approach the signal. It is theoretically possible for the rear of a preceding train to occupy this 'safety margin' however it is very unlikely and therefor provides some significant mitigation against a collision, provided the brakes have been applied – either by the driver, a train stop or ATP system.

Similar assessments were conducted for Britomart and Newmarket[11] as part of the AEP project. This was primarily to understand and minimise the residual risk associated with a SPAD when starting off against a red signal (e.g. departing Britomart) when in Staff Responsible mode. This is the mode a train is in when starting and the speed limit is set to a specific speed (in the case of Britomart – 20km/h) and brakes only applied as the train reads the balise at the signal. In this situation there is a no traditional signalling 'overlap' and just a 'safety margin' very much like the situation in the Wellington 'A' Box area.

[11] Siemens AMRP ETCS Risk Assessment SP1B and SP1C Version: 2.1 Date Issued: 31.3.2015

The collision point could be aligned with the ‘Danger Point’ when implementing ATP (e.g. ETCS) in the future but ideally some proven ‘overlap’ should also be provided to minimise residual risk.

See **Figure 14:** Example collision point assessment diagram for example of analysis.

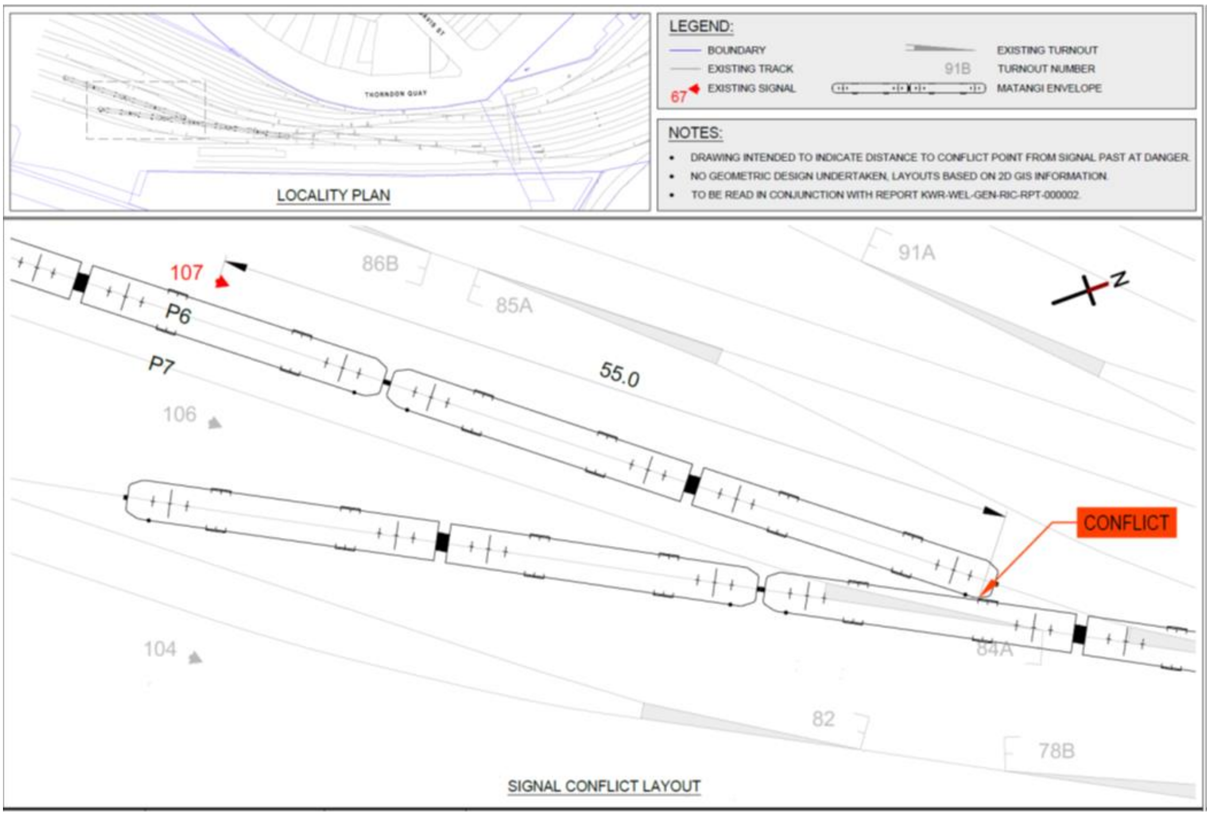

Figure 14: Example collision point assessment diagram

4.3.1 Matangi Stopping Distance

The assessment of the Matangi Braking performance and the profile in emergency braking mode has been undertaken to ascertain how far the unit will travel once the emergency brakes are applied or in the case of the Train Stop or ATP mitigation. The two graphs shown below are the braking performance graphs of the Matangi units - **Figure 15**: Matangi Trip Stop Braking Test and **Figure 16**: Matangi Emergency Braking Performance.

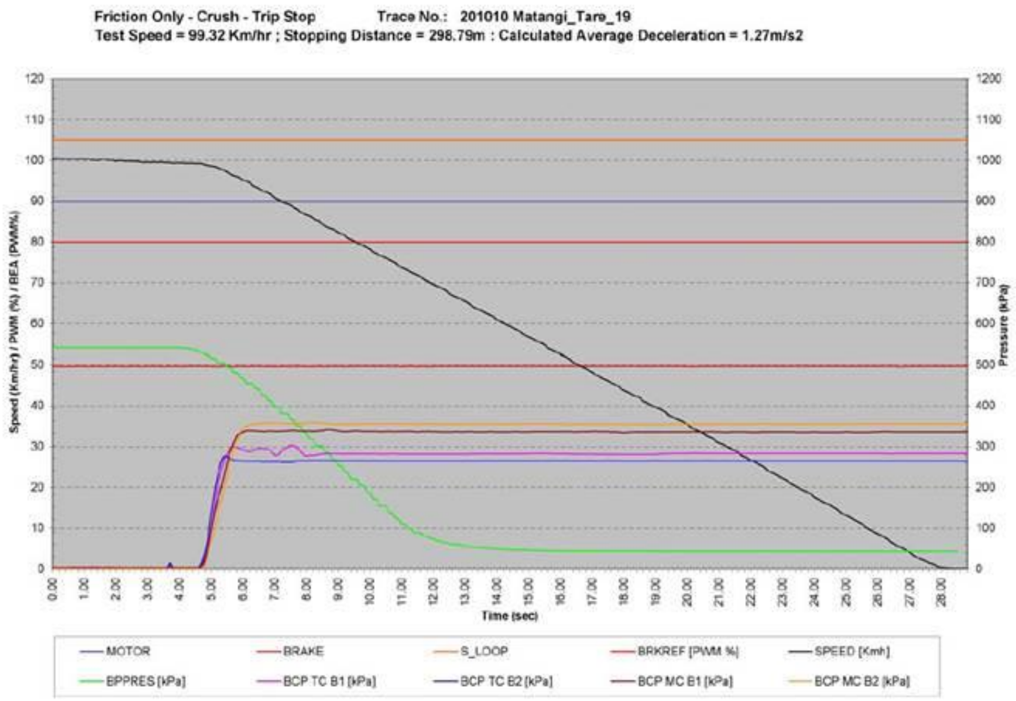

Figure 15: Matangi Trip Stop Braking Test

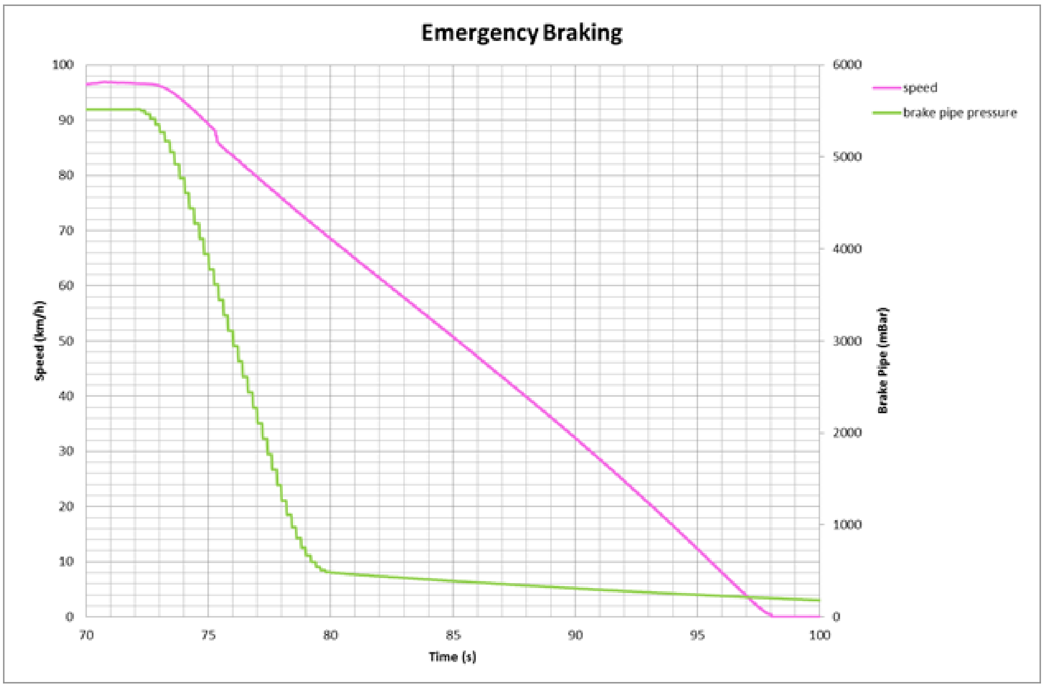

Figure 16: Matangi Emergency Braking Performance

Based on the train stopping performance the following assessment has been undertaken:

- The trip cock drops the brake pipe at a rapid rate comparable to an Emergency brake application.
- Assume that from trip cock activation to fill brake cylinders to EM brake pressures would take 1 second.
- Once the emergency brake system is then working to full capacity based on the braking performance graphs above it would take 5 seconds to stop from 20km/h in EM brake.

So assuming constant deceleration stopping distance is approx. 20/3.6*1 +((20/3.6 – 0)/2)*5s = **19.4m.**

Other factors will come into play that would mean that a further allowance for safe stopping may need to be applied in the case of factors that affect the wheel to rail adhesion – rain, oil, grease rail wear, isolated brakes etc. It can be argued that a significant factor should be applied to mitigate for anything less than ideal adhesion. For the purposes of this study a further 25% was allowed for, making the minimum stopping distance 25m. Note: this would likely not be sufficient to stop the train in all possible adverse adhesion conditions.

Train speeds without ETCS are not controlled and are the trains speed is manually controlled through the review area, so there is a risk that the train driver is going faster than the allowable speeds. For every km/h over the speed limit additional stopping distance is required.

It should also be noted that where there is not 25m of safe stopping distance the Train Stop option is still a mitigation tool as the consequences of a collision are influenced by speed as one of the key factors in determining the outcome. So, any reduction in speed will reduce the rating of the consequence.

Note this is also consistent with the AM class EMU's in Auckland stopping from Staff Responsible speed at Britomart (20km/h) which is deemed a safe speed to mitigate train collision.[12]

4.3.2 Matangi Envelope

The Matangi unit's dimensions and clearance envelope have been used to determine where the collision point will be in the review area based on the different routes. This is then used to determine the distance between the signal and the collision point which is what has been used to determine the safety distance on the routes. **Figure 17**: Matangi Unit Clearance Envelope and **Figure 18**: Matangi Unit Dimensions have been used to generate a Matangi unit dimension modelled on the track geometry to determine the collision point.

An example of this is shown in **Figure 14**: Example collision point assessment diagram which is the collision point based on a train SPAD occurring past 107 signal, which then has a safety distance of 55.0m before a colliding with an oncoming service. The full suite of drawings assessing each route is found in **Appendix C**.

[12] AMRP ETCS Risk Assessment SP1B and SP1C – Siemens 2015

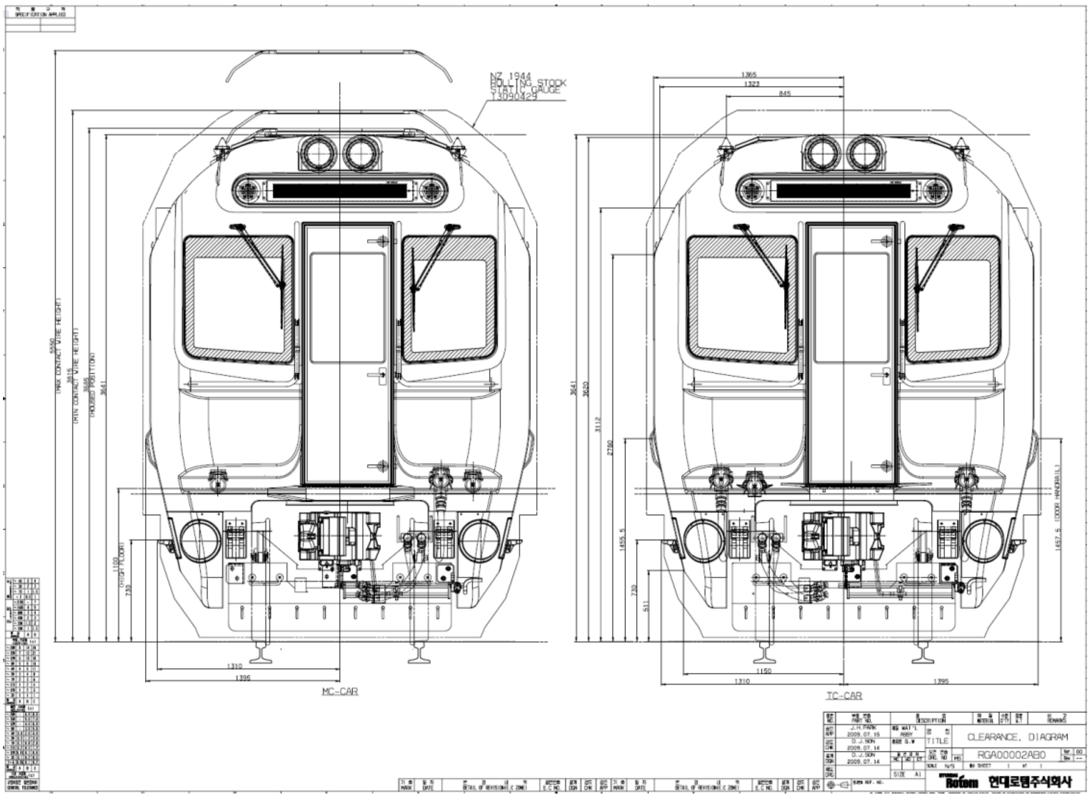

Figure 17: Matangi Unit Clearance Envelope

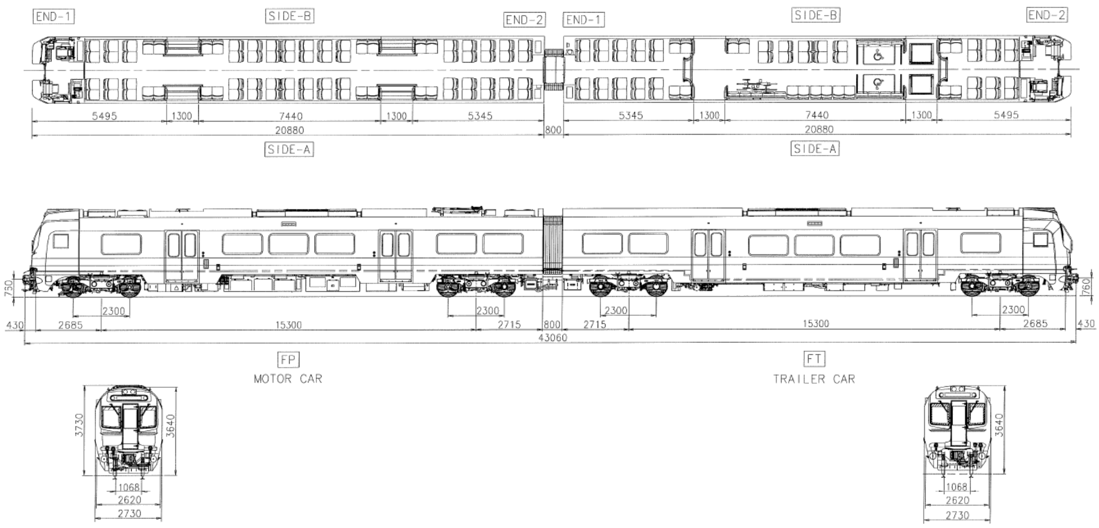

Figure 18: Matangi Unit Dimensions

4.3.3Track Layout Assessment

The track layout assessment was undertaken and the Summary of the key (worst case) flank conflicts are listed below see **Figure 19**: Distance from signal to collision point assessment. These have been assessed with the track layout drawings in **Appendix C**. The table shows the routes in the 20km/hr area and has been used to identify opportunities for installing a train stop solution based on the safety margin/distance.

The colour coding on the table is relating to the Safety Distance assessment.

Red = <20m – Collision **would not** be avoided with Train Stop emergency braking applied

Orange = 20-30m – Collision could be mitigated by Train Stop but is on the limit of factor of safety of 50% consequence of a collision would be reduced.

Green = >30m – Collision could be mitigated by installing a Train Stop.

Route Description	SPAD Signal	Distance To Conflict (m)	SPAD Type (primary risk)
Platform 1 Exit Conflict	112	126.0	Starting against a red
Platform 2 Exit Conflict	111	33.2	Starting against a red
Platform 3 Exit Conflict	110	14.9	Starting against a red
Platform 4 Exit Conflict	109	117.4	Starting against a red
Platform 5 Exit Conflict	108	17.7	Starting against a red
Platform 6 Exit Conflict	107	55.0	Starting against a red
Platform 7 Exit Conflict	106	31.9	Starting against a red
Platform 8 Exit Conflict	105	55.4	Starting against a red
Platform 9 Exit Conflict	104	16.7	Starting against a red
Train Stop Signal 38 Conflict	38	211.5	Directing/intermediate overrun
Train Stop Signal 39 Conflict	39	206.7	Directing/intermediate overrun
Train Stop Signal 56 Conflict	56	183.5	Directing/intermediate overrun
Arrival Signal 46 Conflict	46	38.8	Platform arrival
Arrival Signal 47 Conflict	47	69.4	Platform arrival
Arrival Signal 49 Conflict	49	13.9	Platform arrival
Directing Signal 99 (#1) Conflict	99	17.3	Second signal off platform
Directing Signal 99 (#2) Conflict	99	72.5	Second signal off platform
Directing Signal 100 Conflict	100	42.3	Second signal off platform
Directing Signal 101 (#1) Conflict	101	19.0	Second signal off platform
Directing Signal 101 (#2) Conflict	101	27.7	Second signal off platform
Directing Signal 101 (#3) Conflict	101	25.1	Second signal off platform
Directing Signal 101 (#4) Conflict	101	36.0	Second signal off platform
Directing Signal 102 Conflict	102	38.9	Second signal off platform

Figure 19: Distance from signal to collision point assessment

Note 1: 48 signal has all diverging routes and no flank conflict risk.

Note 2: 76 signal effectively has a run-off so no conflict risk.

4.4 Double Stacking, Stabling and Relay Moves Risk

The way that the Wellington Station area operates adds additional movements and probability of SPAD and hence collision by making and breaking of units on the Platforms. The main stabling facility is situated on the Western side of the station so any units that are being brought into and out of stabling must cross the throat to get into and out of stabling. Depending on where the units start or end their journey out stabling depends on how many tracks they are crossing and hence the number of possible opposing movements.

There is also the risk of a wrong routing increasing the chance of an error resulting in a collision when undertaking the double stacking movements.

Whilst this practice is not uncommon internationally and the drivers are presented with a different signal (Low Speed Aspect) the relay movements and double stacking increases the risks.

Analysis shows double stacking on P8 (10) and P9 (8), there is also on P6 (6) (times occurred in 24-hour period form 'A' Box playback). A total of 36 double stacking movements occurred in the 24-hour period.

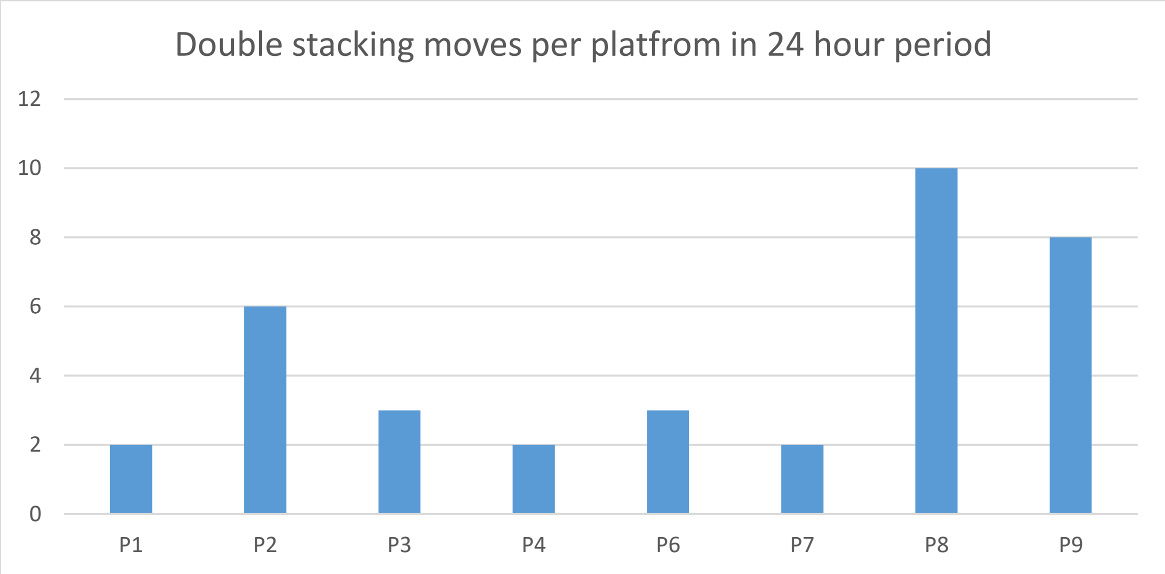

Figure 20: Double Stacking moves within a 24hour period per platform

Given the location of the stabling and the need to scale train consists to suit demand the most practical way to manage this risk is to try and minimise both the frequency of make/break movements and the timing the movements into and out of stabling to minimise conflict. This should be one of the assessment criteria when considering a new train plan/timetable. Note that an additional entry to the EMU stabling to/from the north to facilitate direct access for empty movements without entering the station platforms would also reduce this conflict risk.

4.5 Existing Controls

The existing controls in place currently within the review area are the following:

- The area from the 0.0km – 0.632km[13] is low speed 20km/hr which is a very effective measure to mitigate the probability of a collision occurring and the consequence.
- Route indicators on 38, 39 and 56 Signals to assist drivers with location of next signal.
- Timetable has been developed to avoid conflicting movements and reduce the risk of collision.
- Train stops have been provided for the higher speed movements (60km/hr beyond 0.623km) on signals 38, 39 and 56.
- Arrows placed on all running signals to indicate the track to which the signal applies.
- High level of competence of operations staff.

[13] Local Network Instructions Section L4 Maximum Speeds Section 1.5

4.5.1 Speed Risk

As previously mentioned one of key factors in determining the consequence of a collision is the speed of the units. The analysis undertaken in section 4.3.1 has shown that the minimum safety distance required for a Matangi travelling at 20km/hr in ideal conditions to be 20m.

The actual speed of the units and how they are driven will impact on the chance of a collision being mitigated if there is a SPAD by the driver. Even small speed increments above the 20km/h will add distance into the ability to stop the units before a collision occurs and impacts on the success of Train Stops if they are installed.

A system which ensured that the trains only travelled at 20km/hr and did not speed would reduce the consequences of a collision if it occurred or could avoid a collision happening. Although a practical way of doing this short of installing ATP (e.g. ETCS) may not be possible. In lieu of speed control a review of speeds of the units within the throat area could be a valuable exercise to help understand and quantify the actual risk

4.6 Current Risk

The NRSS/4 Risk Standard at the time of writing is in the process of being updated. The KiwiRail risk rating matrix, which is slightly more stringent than NRSS/4 is attached below **Figure 21:** KiwiRail risk rating matrix**.** In lieu of NRSS/4 being updated the KiwiRail risk rating matrix has been used as the main assessment tool for this study. Based on this matrix the assessed risk would be ranked as **High**, as the likelihood of a collision occurring would be **Unlikely** and the Consequence during the Peak would be **Major**.

The new Health and Safety Legislation[14] determines that the approach to dealing with risks of this nature would be “so far as is reasonably practicable” (SFAIRP). Although ALARP (As low as reasonably practicable) and SFAIRP are very similar, the approach needs to be based on the new legislation. Mitigations as described later in the document based on the short medium and long-term solutions. Discussion about the assessment and of the definition of SFAIRP is required with KiwiRail. The recommendation would be to commence on the journey towards the Long-Term Solution and put a programme in place that works towards this solution at reasonable cost. The programme would show the approach to the short and medium-term mitigations that are heading towards the final Long-Term goal.

Based on the NRSS/4 Standard the Probability and Consequence the risk profile is determined for the Wellington Station area of a collision occurring would be ranked as an 8 in the off-peak and a 12 in the peak, see **Figure 22:** NRSS/4 risk screening matrix. This means that the overall the treatment of the risk of a collision in the Wellington Station area would be to reduce the risk at reasonable cost. (Apply ALARP principle – reduce the risk as low as reasonably practicable).

[14] Health and Safety at Work Act 2015 (HSWA)

LIKELIHOOD: Frequency Description	Qualitative Description	Rating	Negligible	Minor	Moderate	Major	Catastrophic
> 3 times in 12 months	Always occurs in Industry	*Almost certain*	MEDIUM	HIGH	VERY HIGH	EXTREME	EXTREME
Once a year	Periodically occurs in Industry	*Likely*	MEDIUM	HIGH	VERY HIGH	VERY HIGH	EXTREME
Once in 3 years	Occasionally occurs in Industry	*Possible*	LOW	MEDIUM	HIGH	VERY HIGH	VERY HIGH
Once in 10 years	Infrequently occurs in Industry	*Unlikely*	LOW	LOW	MEDIUM	HIGH	VERY HIGH
Less than once every 10 years	Almost never occurs in Industry	*Rare*	LOW	LOW	LOW	MEDIUM	HIGH

IMPACT / CONSEQUENCE

	Negligible	*Minor*	*Moderate*	*Major*	*Catastrophic*
Safety (passengers, public and staff)	• Injury/illness not requiring treatment by medical professional	• Minor incident, illness or injury requiring medical treatment	• Multiple medical treatment incidents, injuries or illness • Injury or illness resulting in a lost time injury	• One fatality; or • Multiple incidents, injuries or illness resulting in lost time injury	• Multiple fatalities; and/or • >10 incidents, injuries or illness resulting in lost time injuries
Service Delivery	• Inability to provide service: o Premier Freight OTP <95% o Interislander sailed vs planned <95% o Metro services <15mins (in peak or events) o Scenic 2 hours	• Inability to provide service: o Premier Freight OTP <90% o Interislander sailed vs planned <90% o Metro services 15-30mins (in peak or events) o Scenic 2-24 hours	• Inability to provide service: o Premier Freight OTP <80% o Interislander sailed vs planned <80% o Metro services 30mins-2 hours (in peak or events) o Scenic 1-7 days	• Inability to provide service: o Premier Freight OTP <75% o Interislander sailed vs planned <75% o Metro services 2 -24 hours o Scenic 8-30 days	• Inability to provide service: o Premier Freight OTP <70% o Interislander sailed vs planned <70% o Metro services >1 day o Scenic >30 days
People	• Localised employee disengagement	• Minor employee disengagement • Unplanned loss of staff resulting in reprioritisation of projects	• Significant employee disengagement • Threat of industrial action • Resistance to business improvement by employee representatives • Unavailability of key capability for key projects	• Industrial action significantly affecting delivery of one or more major services for a significant period • Annual staff turnover of between 10% and 25% in critical technical areas	• Prolonged industrial action which prevents the ability to deliver critical services for a prolonged period • Annual staff turnover of greater than 25% in critical technical and customer serving areas
Customer	• Insignificant localised customer dissatisfaction	• Minor localised customer dissatisfaction	• Significant localised customer dissatisfaction	• Considerable widespread customer dissatisfaction	• Significant nationwide customer dissatisfaction
Stakeholder Confidence / Reputation	• Reports / events requiring no company response	• Customer concerns are contained at business unit level • Local community complaint satisfactorily resolved	• Dissatisfaction resulting in action by a group of stakeholders • Community complaint, reputation damage or exposure to a regional audience	• Shareholding Minister may express concern to the Board • Community complaint, reputation damage or exposure to a nationwide audience	• Public / government criticism or inquiry of KiwiRail resulting in loss of confidence • Ministerial intervention due to poor performance
Commercial / Financial Sustainability	• Shortfall of up to 2% in EBITDA against agreed budget • Cash shortfall of up to $3m	• Shortfall of between 2% and 5% in EBITDA against agreed budget • Cash shortfall of between $3-10m	• Shortfall of between 5% and 10% in EBITDA against agreed budget • Cash shortfall of between $10-20m	• Shortfall of between 10% and 25% in EBITDA against agreed budget • Cash shortfall of between $20-50m	• Shortfall of greater than 25% in EBITDA against agreed budget • Cash shortfall greater than $50m
Regulatory	• Potential breach of requirements managed at a regional level.	• Regulator issues formal warning or enforceable undertaking requiring action. • Fine of <$100,000 for failure to comply with legal, regulatory or contractual requirements	• Fines of $100,000 - $500,000 for failure to comply with legal, regulatory or contractual requirements • Criminal prosecution punishable by fine	• Restriction on rail or maritime operations • Criminal prosecution punishable by suspended sentence • Fines > $500,000 for failure to comply with legal, regulatory or contractual requirements	• Suspension or cancellation of rail or maritime operation licenses • Criminal prosecution punishable by imprisonment
Environmental	• Negligible environmental impact requiring no clean-up or minimal restoration.	• Minor reversible environmental impact that can be cleaned up immediately with minimal environmental impact	• Moderate short term environmental impact that may take 1-2 months to restore.	• Significant environmental impact that may take up to 1 year to restore and/or is of national importance.	• Catastrophic environmental impact that may take longer than 1 year to restore and/or is permanent.
Technology	• Insignificant impact on system integrity or information availability that is dealt with by routine	• Loss of system integrity or information availability which could have a minor adverse effect on operations, assets or individuals.	• Loss of system integrity or information availability which could have a serious adverse effect on operations, assets or individuals.	• Loss of system integrity or information availability which could have a major adverse effect on operations, assets or individuals.	• Loss of system integrity or information availability which could have a catastrophic adverse effect on operations, assets or individuals.

Figure 21: KiwiRail risk rating matrix

STEP 3. Assess risk from the 5x5 matrix below which multiplies the likelihood rating and the consequence rating:

Consequence

	RISK		Negligible 1	Minor 2	Major 3	Critical 4	Catastrophic 5
Likelihood	Improbable	1	1	2	3	4	5
	Remote	2	2	4	6	8	**10**
	Occasional	3	3	6	9	**12**	**15**
	Probable	4	4	8	**12**	**16**	**20**
	Frequent	5	5	**10**	**15**	**20**	**25**

Key	**Pattern**	**Risk Rating**	**Action**
Low		1-9	Risk can be monitored or accepted.
Medium		10-16	Risk should be reduced at reasonable cost. (Apply ALARP principle - reduce the risk As Low As Reasonably Practicable)
High		20-25	Immediate action required to reduce risk.

Figure 22: NRSS/4 risk screening matrix

5 Mitigations

There are a number of potential controls that can be applied to mitigate collision risk. And these are summarised in **Table 5:** Potential Mitigations to reduce SPAD and/or collision risk. These can be broadly categorised into procedural, restriction, or train protection as described below.

5.1 Procedural Controls

Procedural controls can be very effective but if they rely on a person to carry out a specific task repeatedly their effeteness can vary over time. The current 20km/h speed limit is an example of a procedural control that has been effective at making the Wellington 'A' Box area relatively safe since it was implemented.

One idea proposed is encouraging the signallers to prioritise setting the directing signals before the platform starter if possible to reduce the driver complacency of always seeing a caution aspect when starting. However, observations at A-Box on 6th July 2018 indicate that it would be very difficult to consistently apply this process. Although all the levers (directing and platform starters signal levers) are located together and with the addition of a separate ROW indicator system it may be possible to more frequently clear the directing signal before the platform starting signal there will be significant loss of flexibility and it would be challenging for this to be consistently applied.

5.2 Restriction Controls

Restriction controls really consist of two options route locking or signal removal:

- Route locking means that when a route is set the other routes that could conflict with that route in the event of a SPAD are blocked. This blocking is usually only applied when there is not a signalling 'overlap' providing a safety margin. The locking of the route can be set to release on time. This means that the locking is released when the train has occupied the same section of track (the berth track for the signal) for a specified time which indicates that it is very likely to be stationary and therefore very unlikely to SPAD.
- Signal removal obviously reduces the chance of a SPAD as the signal can no longer be approached at stop. Although this might eliminate a particularly high-risk signal or group of signals this has a very high impact on the capacity of infrastructure as trains are required to wait for a much longer time for the train ahead to clear the longer section.

5.2.1 Right of Way Procedure and Implications on Route Locking

As has been noted in section 4.2.3 the consequence to the Wellington Station capacity of removing or 'locking out' the directing signals is significant. This could be partially mitigated by providing Right-Of-Way (ROW) indicators. A possible mitigation would be to remove the caution aspect from the platform starting signals and replace these with ROW indicators on the platform. These are often in the form of a blue light to indicate to the Train Manager to commence the departure process. In the scenario presented in **Figure 23** the 'lost time' is reduced from 53s to 23s as the second train (train #4) would be ready to dispatch as soon as the first train (train #2) clears the full section. Note that a 30s platform departure routine time is applied in the modelling, but the train is unable to depart until 53 seconds after the ROW indicator is illuminated in the case below.

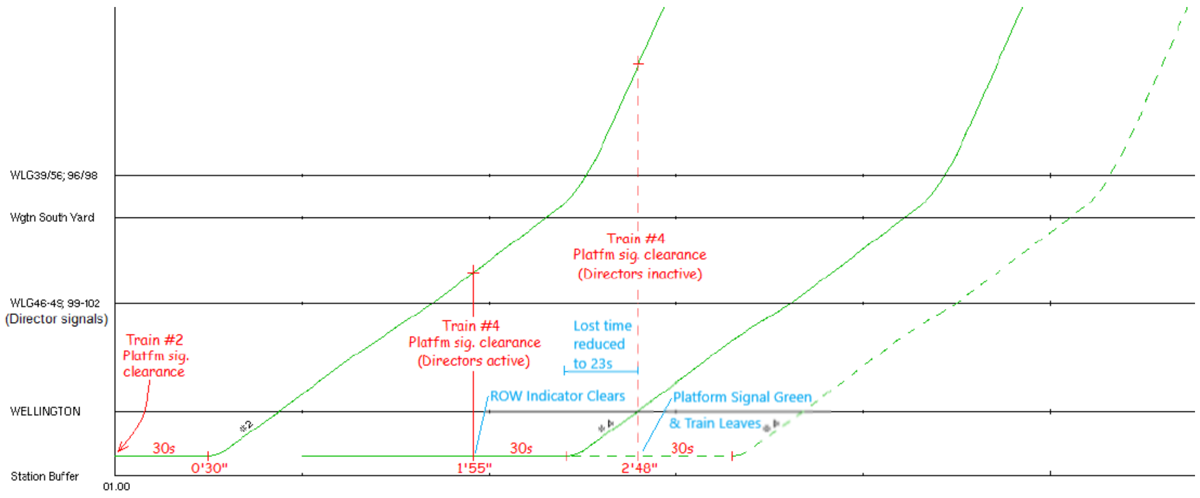

Figure 23: Impact of ROW indicators on lost time

5.3 Train Protection Controls

There are three type of train protection used on the New Zealand rail network:

1. Stop block, trap switch or safety points – these are generally used to prevent movements in sidings and yards from entering or fouling the main lines, however, safety points are sometimes used to provide protection at converging junctions.
2. Train Stop – these are generally utilised on high risk junction signals in the Wellington electrified area for EMUs.
3. ETCS – this is used to provide comprehensive train protection in the Auckland electrified area for fitted trains.

It is generally not possible to add trap switches and safety points to the Wellington layout without significant track configuration changes and replacement of the 'A' Box lever frame.

However, one of the mitigations that can be used to avoid a SPAD collision is the addition of more train stops. This is a simple mechanical system fitted adjacent to the signal that trips the emergency braking system on the Matangi unit if one passes a signal at stop.

ETCS Level 1 or Level 2 if deployed in Wellington would provide comprehensive Automatic Train Protection (ATP) virtually eliminating collision risk.

5.3.1 Requirements for train-stops

The directing signals in the throat including 46, 47, 48 and 49 'Arrival signals' and 99, 100, 101 and 102 'Second signals' are very constrained due to the track layout.

The KiwiRail standards require a train stop to be located at the signal with the train stop track boundary located 8m in advance of the signal[15]. This is depicted in **Figure 24:** Train stop positioning. The reason the signal and train stop need to be placed 8m before the track circuit joint is to ensure that the train stop will not rise before the train has completely passed. A train stop will stay down as long as the track preceding the signal (known as the "trainstop track") is occupied. Once most of the train has passed and there is only one bogie left on the track circuit it could pick up causing the train stop to rise – thereby potentially making the train stop foul of the remaining train that is passing (in particular low hanging equipment such as battery boxes), resulting in damage to the train stop.

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[15] S-PR-TP-2014 Train Protection Principles – Section 8.2

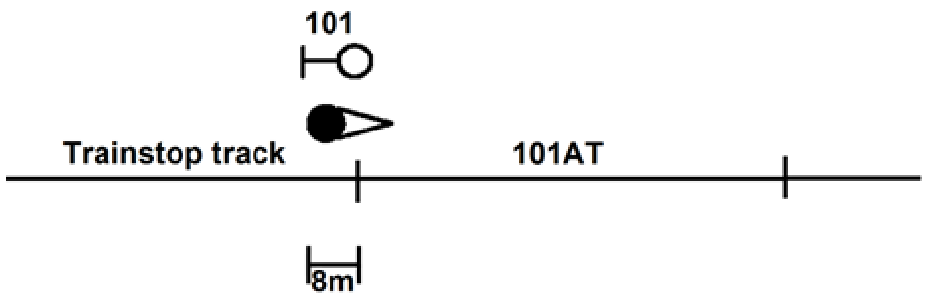

Figure 24: Train stop positioning

Due to the proximity of the turnouts this standard cannot be achieved for most of the throat directing signals. Only 46 and possibly 99 signals could be adjusted to meet the requirement. Note as 48 signal only has facing points in-route it was seen is less critical to provide a train stop at this signal.

It may be viable to reduce the train stop space requirements. The trip cock is on the leading axle of the Matangi units and it may be possible to reduce the 8m to a distance that would work in the space available. The space requirement in Sydney is significantly less as can be seen in **Figure 25** below.

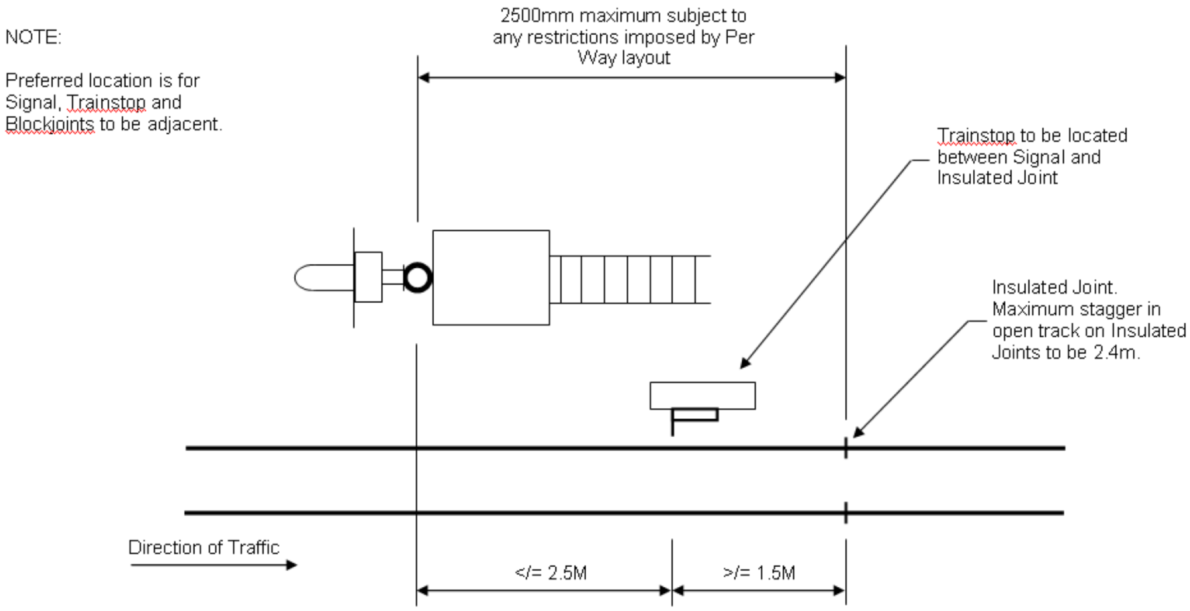

Figure 25: Drawing 0706/003 from Transport for NSW Engineering Specification SPG0706 Installation of Trackside Equipment Version 2.3 Issued 4 Dec 2012

In order to install train stops at the directing signals the train stop and signal will need to be placed adjacent to the preceding turnout. This is prior to the convergence of the track and has not been implemented before in NZ. The KiwiRail standard for Trains Stops could not be achieved but it may be possible by reducing the 8m requirement (e.g. like Sydney). Using axle counters rather than track circuits may help facilitate reducing the 8m requirement as the chance of the track circuit picking prior to the last axle clearing the section is eliminated.

5.3.2 Requirements for ETCS Level 1

For ETCS Level 1 balises are required to be placed 14m (nominally) in advance of a signal. This also means that for the directing signals it is not possible to install ETCS level 1.

The above dimensions are illustrated in **Figure 26** below. The directing signal will need to be removed for ETCS Level 1 to be installed.

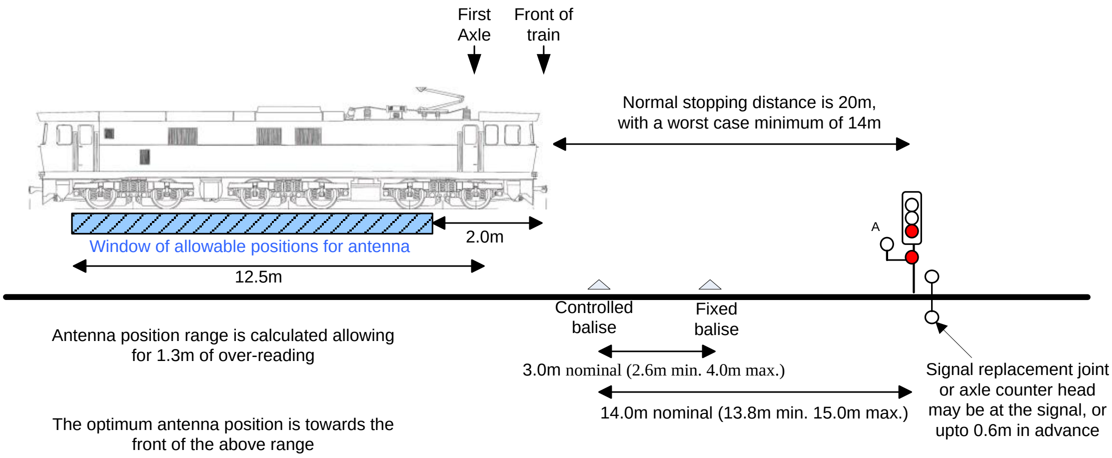

Figure 26: Balise group positioning

5.3.3 Requirements for ETCS Level 2

For ETCS Level 2 (without signals) the directing signals could be removed and replaced by Block Marker Boards creating 'virtual signals' in the same location. Headway would be retained as these positions would still act as a signalling section. As there is no requirement for controlled balises that issues movement authorities in Level 2 the position of any fixed balise associated with the ETCS Marker Board could be reduced to a minimum distance and possibly placed between the turnouts in the current signal positions preserving the current headway.

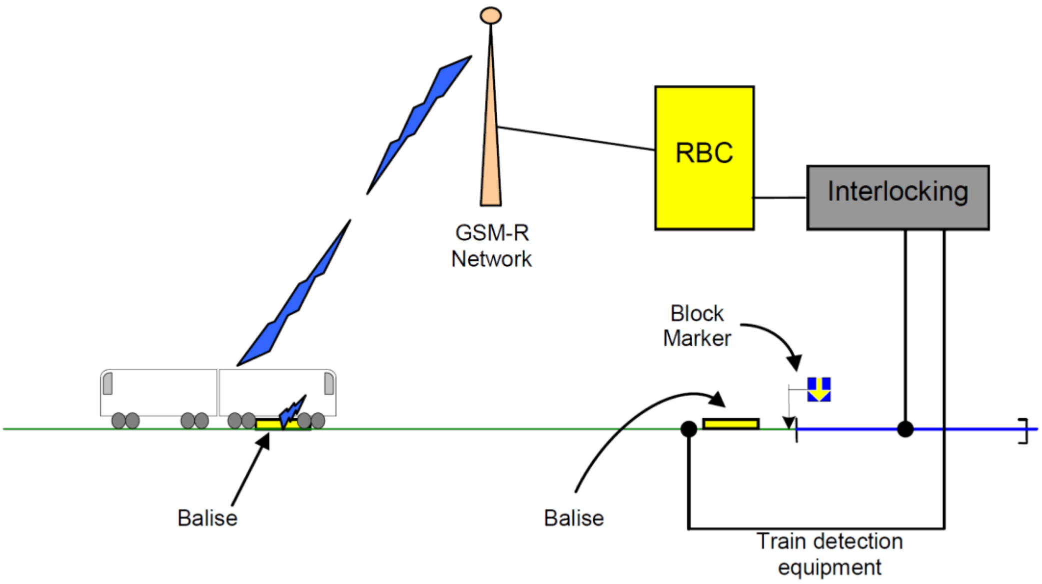

Figure 27: ETCS Level 2 without lineside signals

5.4 Proposed / Potential Controls

The options that have been identified and assessed as potential controls are listed below. The mitigations have been assessed at how effective these measures would be at mitigating a SPAD and possible collision risk. The table lists the possible mitigations and assesses whether they will reduce the probability of a SPAD at specific signals, and/or decrease the risk of a collision occurring. The Issues comments also captures the feedback from the study risk workshop.[16]

Mitigation	SPAD Risk Removal	Collision Risk Removal	Issues /Comments
Signallers process to clear directing signal prior to platform starters such that most departing trains get a green aspect (improving human factors of regularly departing on a caution).	No (would reduce the likelihood of a SPAD due to improved human factors)	No (would reduce likelihood)	It is generally agreed that this is good signalling practice and is done when practical, however, due to the timetabling often the directing signal cannot be pre-set before the platform starter as it could delay services. The ROW process takes time so getting this underway as soon as possible is critical to timely departure and the process does not start until the platform starter is at proceed. Means that the ability to mitigate lost time in the timetable cannot be mitigated and on time performance could be impacted if strictly implemented (similar to route locking).
Speed review of current operations and enforcement if drivers are over speeding.	No	No	Because this is the primary risk mitigation in place today it is important to understand that it is working effectively and that the 20km/h restriction is being complied to. No change to risk profile but ensures that the current speed mitigation is effective and shows management of the risk.
Route lock with Right-Of-Way indicators for platform starting signals.	No (would reduce the likelihood of a SPAD but not eliminate)	Yes (at the directing signals)	Significant concerns have been raised regarding the use of the ROW indicators with route locking of the directing signals. The impact to the service headway and timetable would be significant and ROW indicators will only mitigate a portion of the impact. Transdev also raised a concern that requiring a train to pull up to the red signal off the platform end goes against the culture/driver training and would negatively impact HF.
Additional train stops at the directing signals	No	Yes (at the directing signals)	Train stop 99, 100, 101, and 102 – these would largely be effective. One conflict on 101 signal has less than 20m safety margin but could be further mitigated with 64B points reverse providing flank protection (implemented with relock). 99 signal also has one conflict route below 20m which may be improved slightly by adjusting the signal position but it will not fully mitigate the risk. Technical feasibility of installing train stops between the back to back turnouts needs further investigation [not possible with current standards]. Train stop 46 and 76 – These provide little protection as 76 runs to a backshunt and 46 to facing points so with auto-normalization of the points (which could be provided with the re-lock) the risk would be significantly reduced.

[16] A risk workshop was held on the 6th July 2018 with representatives from KiwiRail Signalling, KiwiRail Network Control, and Transdev

Additional train stops at the platform starting signals (with some relocation)	No	Yes (at the platform starting signals)	Train stop 105, 106, 107, 109, and 111 – These would be very effective at eliminating the 'ding-ding and away' SPAD risk, however, based on the SPAD data this risk appears to be fairly low in Wellington, indicating the current ROW procedures are working well. Fitting these signals with trains stops would be fairly simple but lower priority than the directing signals. Train stop 104, 108 and 110 (with signal relocation) – These signals are located too close to the collision point and should be relocated back toward the platforms to increase the safety margin. This would need to be done for ETCS fitment anyway and would not have a significant operational impact.
Locking out of the directing signals	Yes	Yes (at the directing signals)	Route lock 99, 100, 101, and 102 – This would provide significant mitigation but would not be viable unless it was implemented with time release and even then, the timetable impact would be 'High'. It may be that the one 99 signal conflict is route locked for time post re-lock in conjunction with the train stops noted above. Route lock 47 and 49 – As 47 signal has almost 70m of safe overrun distance it is not necessary to route lock if a train stop can be fitted. Even route locking for time would have a medium operation impact. 49 signal has very little distance to the conflict point (13.9m) and cannot be readily relocated so route locking for time may be the only viable mitigation (possibly combined with a train stop) or the residual risk tolerated. As the conflict is only with movements from P8 and P9 to the Down Main or Loco Depot roads route locking for time would be tolerable.
Junction re-lock	No	No	On its own the junction relock would provide no specific safety improvement but is an enabler of many high benefit mitigations would provide options for improving the signalling system resilience and recovery.
Providing standard overlaps for the directing signals (swinging if required) that time off when train is at stop	No	Partial (train could stop then proceed into conflict)	This requires the Junction relock as a precursor and would have a High impact on the timetable/capacity, and resilience as many overlaps would prohibit opposing routes. The impact would not be quite as bad as removing or locking out the signals.
Introduction of swinging overlaps with a re-lock	No	Yes (but only for some routes)	Would provide additional safety margin for some routes. Requires the re-lock to be undertaken before implementation.
Removal of the directing signals	Yes	Yes	Consequence on headway/timetable would be so great that the current service plan would not be possible. Long term additional ETCS L2 'virtual' signals could be provided in the same location as the directing signals so removal may not match future strategy.
Reconfiguration of some of the junction track works (basic)	No	No (would reduce the consequence	Some conflicts could be improved by for example relocating 64 crossover but some movements would no longer be possible losing operational flexibility. This has maintenance benefits of reducing the complexity of the track work but would not greatly reduce risk. Requires a re-lock as a precursor dur to the lever frame restrictions.
Relocation of the directing signals (maybe in conjunction/combination with the above)	No	No (would reduce likelihood)	Would improve safety distance and would be an effective mitigation if train stops could be fitted then the collision Risk could be mitigated

Introduction of minimum standard overlaps - reconfiguration of some of the junction track works and provision of overlaps (more extensive, incl. Re-lock)	No	No (would reduce the consequence	This could only be achieved by significant track reconfiguration (requiring a relock) cost would be high but would be part of the long-term strategy towards an ATP fitment.
New Location Hut	No	No	As with the re-lock, on its own the new location hut would provide no specific safety improvement but is an enabler of many of the items above and would provide options for improving the signalling system resilience and recovery and allow a staged implementation of improvements.
ATP fitment (ETCS Level 1 incl. Re-lock)	Reduces Probability and Consequence	Yes	ETCS level 1 will require significant track and signalling layout changes and will impact on the timetable/headway.
ATP fitment (ETCS Level 2 incl. Re-lock)	Reduces Probability and Consequence	Yes	Has benefits with regard to minimising track reconfiguration works and ability to remove signals but retain functionality/headway.
ATO (Automatic Train Operation	Yes	Yes	Would virtually eliminate human errors but cannot be implemented without an underlying ATP safety system such as ETCS

Table 5: Potential Mitigations to reduce SPAD and/or collision risk

6 Implementation

The ability to deliver certain components of the work has dependencies on other items being delivered first.

The timing of the works and decisions about when to implement activities should consider the end state of the junction and what the final product will be. This would then allow for best value for money decisions to be made that are heading towards the end goal of the junction layout and final signalling solution. The timeline below is an indicative timeline and shows the dependencies of activities and key milestones that would need to be considered when committing to activities. Further work could be undertaken to progress an end state design layout of ETCS Level 1 or 2 to fully understand the costs and programme.

6.1 Short Term Mitigations

The collision hazard can be slightly reduced in the short term through a several actions. This includes:

- Signaller process – human factors setting the route so that services are not regularly held at 99, 100, 101 or 102 signals at red where possible.
- Speed review – validation that the current 20km/h speed limit mitigation is currently effective
- Trial of a train stop on one of the tightly constrained directing signals – this will validate the standards change required to install train stops on the directing signal will not inadvertently introduce problems.
- Additional train stops at other signals where practical, including relocation of some platform starting signals (104, 108 and 110 signals) – if the train stop standard is going to be substantially altered it will be preferable to add additional train stops after the trial to ensure reliable operation.

6.2 Medium Term Mitigations

In building to the eventual, inevitable replacement of the ‘A’ Box interlocking there would be significant benefit in developing an overall ‘final’ design for the ‘A’ Box area that incorporates the proposed infrastructure for the RS1 train plan, ETCS, and all the safety enhancements proposed here. Installing a new Main Location Building and establishing Ducting/Cabling Routes so that any new infrastructure is then cabled to the final location would reduce rework, commissioning risk, and potential delays.

Relocking the Wellington Station area to allow the implementation of swinging overlaps and/or more sophisticated overlaps that release once a train has been timed to a stop would also facilitate the ability for comprehensive collision mitigation to be implemented where all collision risk in the study area is largely eliminated.

On the basis that the train stop standard can be altered substantially enough to make implementation on the directing signals possible (perhaps utilising axle counters for the train detection) the follow steps have been identified to implement comprehensive train protection in the ‘A’ Box area.

- Additional train stops at remaining signals.
- Route locking 49 and 99 signals for the very short conflict but allow the locking to release on time. Note this will leave some residual risk of a train starting against a red signal with insufficient safety margin.
- Swing the points beyond the signal for 99, 100 and 101 signals to maximise the safety margin.

By the end of the short and medium term (which together have been called Stage 0 in the sequencing below – see **Figure 29**) the collision risk should be dramatically reduced. All the key conflicts (by signal) will have been addressed as outlined below in **Figure 28**: Proposed medium term mitigation strategy. This is however contingent on being able to adjust the train stop standard to all comprehensive fitment.

Route Description	SPAD Signal	Distance To Conflict (m)	SPAD Type (primary risk)	Collision Mitigation	Train stop possible with current standards
Platform 1 Exit Conflict	112	126.0	Starting against a red	Train stop	Yes
Platform 2 Exit Conflict	111	33.2	Starting against a red	Train stop	Yes
Platform 3 Exit Conflict	110	14.9	Starting against a red	Relocation of signal and train stop	w/ signal relocation
Platform 4 Exit Conflict	109	117.4	Starting against a red	Train stop	Yes
Platform 5 Exit Conflict	108	17.7	Starting against a red	Relocation of signal and train stop	w/ signal relocation
Platform 6 Exit Conflict	107	55.0	Starting against a red	Train stop	Yes
Platform 7 Exit Conflict	106	31.9	Starting against a red	Train stop	Yes
Platform 8 Exit Conflict	105	55.4	Starting against a red	Train stop	Yes
Platform 9 Exit Conflict	104	16.7	Starting against a red	Relocation of signal and train stop	w/ signal relocation
Train Stop Signal 38 Conflict	38	211.5	Directing/intermediate overrun	Risk largely mitigated	N/A
Train Stop Signal 39 Conflict	39	206.7	Directing/intermediate overrun	Risk largely mitigated	N/A
Train Stop Signal 56 Conflict	56	183.5	Directing/intermediate overrun	Risk largely mitigated	N/A
Arrival Signal 46 Conflict	46	38.8	Platform arrival	Train stop	Yes
Arrival Signal 47 Conflict	47	69.4	Platform arrival	Train stop	No
Arrival Signal 49 Conflict	49	13.9	Platform arrival	Route lock + Train Stop (release on time)	No
Directing Signal 99 (#1) Conflict	99	17.3	Second signal off platform	Route lock + Train Stop (release on time)	No
Directing Signal 99 (#2) Conflict	99	72.5	Second signal off platform	Train stop + swinging overlap (42 reverse)	No
Directing Signal 100 Conflict	100	42.3	Second signal off platform	Train stop + swinging overlap (43 reverse)	No
Directing Signal 101 (#1) Conflict	101	19.0	Second signal off platform	Train stop + swinging overlap (64B reverse)	No
Directing Signal 101 (#2) Conflict	101	27.7	Second signal off platform	Train stop	No
Directing Signal 101 (#3) Conflict	101	25.1	Second signal off platform	Train stop	No
Directing Signal 101 (#4) Conflict	101	36.0	Second signal off platform	Train stop + swinging overlap (64B normal)	No
Directing Signal 102 Conflict	102	38.9	Second signal off platform	Train stop	No

Figure 28: Proposed medium term mitigation strategy

If the overall long-term strategy for ETCS comes forward or the medium-term items above are not delivered as planned due to funding constraints then train stop fitment may be superseded by the implementation of ETCS. This is because the long-term strategy will be to eventually remove all train stops as they become redundant.

Due to the complexity and disruption that modifying the Wellington trackwork would cause and the difficulty of doing this prior to a re-lock of the 'A' Box area it has been assumed that any track layout changes would be implemented later. This has pushed any potential layout changes into the 'long term' phase. The cost of track reconfigurations will always be on top of the signalling re-lock costs so staging the re-lock first is logical. Additionally, it would require very long BOLs to do any significant reconfiguration prior to a re-lock. It has however been assumed that additional connectivity required for RS1 such as the new yard access and 4th main works could be delivered in conjunction with the re-lock.

6.3 Long Term Mitigations

KiwiRail and GWRC have a defined long-term strategy to implement ATP most likely aligned with the mid-life overhaul of the Matangi trains. It is likely (although not certain) that it will be some form of ETCS so that nationally an interoperable train protection system is provided to support freight trains travelling the entire national network.

If ETCS Level 2 is adopted as the strategy without signals it would likely reduce the track reconfiguration work required to maintain the headway. ETCS level 2 still needs traditional signalling overlaps for trains to pull right up to an ETCS Level 2 'block marker'[17] or a low fixed release speed could be used with some residual risk. There is significantly more flexibility in where the block markers can be placed as they do not need controlled balises placed 14m before them as is required with ETCS Level 1.

It is possible to design an ETCS Level 2 (without signals) solution for the Wellington 'A' Box area that would require very little or no reconfiguration depending on the level of residual risk that can be

[17] An ETCS Level 2 Block Marker is a sign that indicates to the driver the limits of the section in lieu of a signal.

tolerated. For some of the 'straight' routes ETCS would also enable the speed to be increased further improving clearance times and capacity.

For this reason, the scope of any further track work reconfiguration in the long term to provide 'proper' signalling overlaps will depend on the specifics of the ETCS implementation and the residual risk tolerance it may be that maintainability may be a more significant driver for any reconfiguration to simplify the trackwork and improve reliability.

As it has been identified that the Right-Of-Way (ROW) process does have a significant impact on Wellington Station capacity there may be some merit in introducing some additional indicators in conjunction with, or soon after the re-lock to facilitate a faster dispatch process. This may be the instruction of blue light "get ready to start" indicators to inform the Train Manager to start door closure and ROW process.

6.4 Summary of the Proposed Implementation Sequence

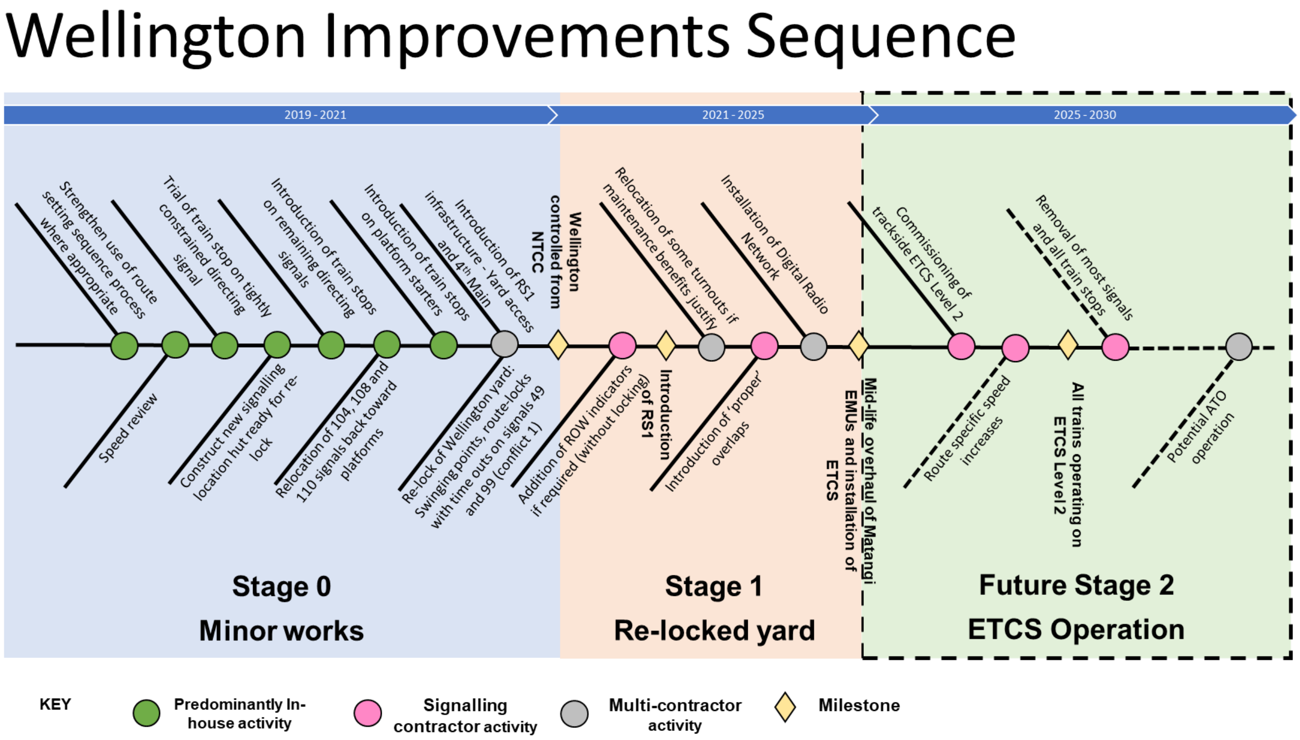

Figure 29: Implementation sequence

6.5 Adjusted Risk Profile

A Multi Criteria analysis has been developed that assess the short medium and long-term mitigations and assess the adjusted risk score based on the different interventions. The assessment has made a high-level assessment of cost, programme, impacts on timetable, ability to deliver with the existing lever frame. The risk ratings were jointly reviewed at a risk workshop held on the 6th July 2018 with representatives from KiwiRail Signalling, KiwiRail Network Control, and Transdev. The table in **Figure 30** below shows this assessment.

MCA Analysis						Risk of Collision Occurring				Compatible with:	
Mitigation	Cost	Programme	Technically Possible	Timetable	Possible w/ Current L-Frame	Probability	Consequence	KiwiRail Risk Rating	NRSS Score Equivalent Rating	ETCS 1	ETCS2
Current Situation	N/A	N/A	N/A	Neutral	Yes	**Unlikely**	**Major**	**High**	**12**	N/A	N/A
Signaller Process	Low	<1yr	Yes	Low	Yes	Unlikely	Major	**High**	12	N/A	N/A
Speed Review	Low	<1yr	Yes	Neutral	N/A	Unlikely	Major	**High**	12	N/A	N/A
Reduce Speed to 10 or 15km/h	Low	<1yr	Yes	High	Yes	Unlikely	Moderate	**Medium**	6	Yes	Yes
ROW Indicators (Incl. Route lock)	Low	<1yr	Yes	Medium	Yes	Rare	Major	**Medium**	8	Yes	Yes
Warner signal on platform starters	High	2-5yr	Yes	Low	No	Unliklely	Major	**High**	12	Yes	Yes
Train Stop 99, 100, 101 and 102	Med	1-2yr	TBC	Neutral	Yes	Unliklely	Moderate	**Medium**	6	No	Yes
Train Stop 46 & 76	Low	1-2yr	Yes	Neutral	Yes	Unlikely	Moderate	**Medium**	6	No	Yes
Train Stop 105, 106,107, 109, 111 and 112 (platform starters)	Med	1-2yr	Yes	Neutral	Yes	Possible	Minor	**Medium**	6	Yes	Yes
Train stop 104, 108 and 110 with signal relocation (platform starters)	Med	1-2yr	Yes	Neutral	Yes	Possible	Minor	**Medium**	6	Yes	Yes
Route Lock 99, 100, 101 and 102	Low	<1yr	Yes	High	Yes	Rare	Major	**Medium**	8	No	Yes
Route Lock 47 and 49	Low	<1yr	Yes	Medium	Yes	Rare	Major	**Medium**	8	No	Yes
Junction Re-Lock	High	2-5yr	Yes	Neutral	No	Unliklely	Major	**High**	12	Yes	Yes
Providing standard overlaps for directing signals (swinging if required)	High	2-5yr	Yes	High	No	Rare	Major	**Medium**	8	Yes	Yes
Removal of Directing Signals	Low	<1yr	Yes	High	Yes	Rare	Major	**Medium**	8	Yes	Yes
Removal of Inbound Directing Signals and relocation of home signals	High	2-5yr	Yes	High	No	Rare	Major	**Medium**	8	Yes	Yes
Relocation of Crossover(s)	Med	1-2yr	Yes	Low	No	Rare	Major	**Medium**	8	Yes	Yes
New Location Hut	Med	2-5yr	Yes	Neutral	Yes	Unliklely	Major	**High**	12	Yes	Yes
Introduction of Min overlaps	High	2-5yr	No (layout)	Low	No	Unliklely	Moderate	**Medium**	6	Yes	Yes
ETCS Lvl 1 (incl. re-lock)	V. High	5+	No (layout)	Medium	No	Rare	Minor	**Low**	2	Yes	Yes
ETCS Lvl 2 (incl. re-lock)	V. High	5+	Yes	Improves	No	Rare	Minor	**Low**	2	Yes	Yes
ATO	V. High	5+	Yes	Improves	No	Rare	Neglilible	**Low**	1	Yes	Yes

Cost Key:	Low <$1M
	Med $1M-$5M
	High $10M-$20M
	V. High >$100M

Figure 30: Multi criteria analysis and adjusted risk profile[18]

6.6 Residual Risk

The mitigations above except for ETCS leave a residual risk of overspeed. As many of the overlaps are very short, even moderate over speeding of as little as 10km/h could pose a significant hazard in the event of a SPAD on some routes. The only way to mitigate this would be the implementation of ATP – either ETCS Level 1 or Level 2.

ETCS will also have a number of residual risks depending on the implementation. As noted above if ‘proper’ signalling overlaps are not provided then mitigations such as low fixed release speeds will need to be implemented. As the safety margins are very tight for some conflicts it may be possible for trains to SPAD after coming to a stop and the protecting route locking is released leaving some (albeit a low) risk of collision. In a number of degraded operations situations such as onboard or track side equipment failures there will also be significant residual risk.

There is additional residual risk of SPAD and Collision with ETCS (Level 1 or Level 2 with signals) if the services using Diesel Locomotives are not fitted out. These of course could be fitted out, but at high cost.

Note - If ETCS Level 2 is installed without track side signalling then the Wiararapa and Shunt Locos would all have to be fitted with ETCS.

6.7 Opportunities

ETCS provides an opportunity to increase speed limits if protection provided (e.g. lift speed to 25km/hr or higher) This could save approximately 25 seconds for the train to clear the Wellington

[18] Where the treatment is to a specific group of signals/conflicts the risk has been assessed on the treatment of those signals/conflicts and not the overall Wellington 'A' Box area risk

junction area. – only really possible with overspeed control (e.g. ETCS) The speed could also only be increased for 'straight' routes or beyond the low speed trackwork such as the slips.

Developing a strategy for the end state for the Wellington Station area so that any work undertaken now is building towards and allowing for the end state is essential. Developing new cable routes, signalling location buildings should be considered early in the implementation of any changes.

7 Conclusions

The current mitigation strategies that are in place in the review area are very effective and have been used to good effect to date. Based on an SFAIRP approach there is more that can be done to lower the risk of SPADs and collisions. The risk of a collision within the review area without undertaking mitigations is low but the consequence is still high due to the risks of a fatality occurring if two trains did collide, even at the low speed of 20km/hr.

The assessment of the collision points has determined that approximately a quarter of the signals have safety margins that are below the absolute minimum emergency stopping distance from 20km/h (~20m) of the Matangi unit and another 10% of routes that would be at high risk of collision once safety factors are applied (safety margin of 20m-30m).

The review of the SPAD data has shown that the review area by incident has a considerably higher chance of a SPAD occurring than the rest of the WEA. Based on the review of the data between 2011 and 2015 there have been 21% of the SPADs but with only ~7% of the total no. of WEA signals in the review area. This means that it is three times more likely for a SPAD to occur within the review area than in the rest of the WEA. This is not unexpected given the number of train movements in the area but does highlight the importance of the ‘A’ Box signals.

The SPAD data review also identified that the outbound directing signals including 99, 100, 101 and 102 signals (“Second Signals”) and the inbound directing signals including 46, 47, 48 and 49 signals (“Platform Arrival Signals”) likely carry a higher probability of a SPAD than many other signals leading to the need to make improvements SFAIRP.

To reduce the probability of a SPAD and hence a collision the following mitigations have been assessed and grouped into a short, medium or long-term timeframe.

Short term the following mitigations have been identified. For all of the short-term mitigations it has been identified that the current mechanical lever frame signalling system cannot be added to or adjusted easily. All the short-term mitigations are based on these being no change to the lever frame system and include:

- Signaller process reinforcement
- Speed review
- Trial of a train stop on one of the tightly constrained directing signals
- Additional train stops at other signals where practical, including relocation of some platform starting signals (104, 108 and 110 signals) – if the train stop standard is going to be substantially altered it will be preferable to add additional train stops after the trial to ensure reliable operation.

Due to the Lever Frame mechanical signalling system, to implement many Medium or Long-term mitigations it would require the relocking the Wellington ‘A’ Box area. This would enable the implementation of a route based interlocking system. This would then enable the introduction of all the changes proposed and would be required for any long-term solutions which are the most effective mitigations for reducing the collision risk. The following medium-term mitigations are proposed which would provide a comprehensive minimisation of collision risk:

- Additional train stops on remaining signals.
- Route locking 49 and 99 signals for the very short conflict but allow the locking to release on time. Note this will leave some residual risk of a train starting against a red signal with insufficient safety margin.
- Swinging of the points beyond the signal for 99, 100 and 101 signals to maximise the safety margin.

Train stops may have a poor return on investment due to a short life span if implementation ends up being close to the Matangi mid-life over haul (starting in approximately 2025) and moving directly to ETCS may be a more cost-effective strategy.

It is only once the Re-Lock has occurred that any substantial track alignment changes could be made without incurring extensive signalling costs which may not even be achievable due to the capacity of the mechanical lever frame. For the implementation of ETCS (either Level 1 or Level 2) a track alignment assessment would be required to understand what track alignment changes could be made to improve the end state layout and comply with minimum requirements for ETCS implementation – considering the residual risk that would remain if the layout was not improved.

Long term the following mitigations could be implemented once the Re-Lock has occurred:

- Possible provision of ROW indicators to reduce dispatch process time and improve station capacity
- ETCS Level 1 or ETCS Level 2

ETCS Level 2 would likely need significantly less track reconfiguration, would reduce the risk of a collision to "so far as is reasonably practicable" and improve the timetable/capacity if implemented.

The development of the strategy for implementing the interlocking and bring forward these activities so that over a longer period of time any interim short-term work is fed through the new location and new duct route would reduce re-work and costs in the longer term.

7.1 Possible Next Steps

The list below is the possible next steps that could be taken to progress implementing risk mitigations. This list will require discussion with other to validate:

- Speed gun or data log assessment of current speed of services
- Model the 49 and 99 (conflict 1) route locks w/ time-offs to understand timetable impact
- Establish a trial of a train stop in one of the constrained locations such as 99, 100 and 101 signals utilising axle counters for train detection if necessary
- If Train Stop trial is successful, undertake business benefit assessment of install vs waiting for ETCS
- Undertake ETCS Level 2 layout assessment for the Wellington Station area to understand what track and signalling layout changes would be preferred in the long term and assess the residual risk of that layout
- Confirm the RS1 infrastructure changes and timing with consideration to resource levelling and the likely impact on the timing of the re-lock of the 'A' Box area
- Develop a migration strategy for Wellington Station area relocking based on the results above
- Develop and integrate the Wellington 'A' Box migration strategy with the overall WEA signalling strategy
- Identify the location and requirements for the new signalling location building
- Establish costs of potential medium-term mitigations to decide if full train stop implementation is warranted or possibly superseded by ETCS implementation (train stop's may have a very short life and therefore a poor business case for implementation)
- Assess the wider WEA for possible infrastructure changes due to ETCS implementation

Appendix A Glossary

Ref	Definition
AEA	*Auckland Electrified Area*
ALARP	*As low as reasonably practicable*
ATP	*Automatic Train Protection*
EMU	*Electric Multiple Unit*
ETCS	*European Train Control System*
ETP	*Electronic Train Protection*
JV	*Johnsonville Line*
NIMT	*North Island Main Trunk Line*
NRSS	*National Rail System Standard*
NZTA	*New Zealand Transport Agency*
RGS	*Railway Group Standards (UK)*
RSSB	*Rail Safety Standards Board (UK)*
SIL	*Safety Integrity Level*
SPAD	*Signal Passed at Danger*
WEA	*Wellington Electrified Area*

Appendix B Contributors / References

Table 6: References for this report

Name	Organisation	Year
Wellington Rail Network Operational Risk Modelling Report	*Interfleet*	*23/07/2015*
Wellington Station Director Signal Capacity Investigation	*KiwiRail*	*06/04/2017*
AMRP ETCS Risk Assessment SP1B and SP1C	*Siemens*	*31/03/2015*

Appendix C Wellington Station Area Signalling SPAD Distance to Conflict Drawings