EDGE Hagley Road Terminus

Introduction

The Edgbaston LRT Extension (EDGE) runs from Centenary Square, along Broad Street and then terminates on Hagley Road. The extension runs under fiveways underpass and there are 4 tram stops along the route, **Figure 1**. The Hagley Road stop serves as a tram terminus and the associated junction is controlled by traffic signals, **Figure 2**. Along the tramway there are three signalised crossings, and three junctions including the terminus/Hagley Road junction. All traffic signals have LRT priority functionality.

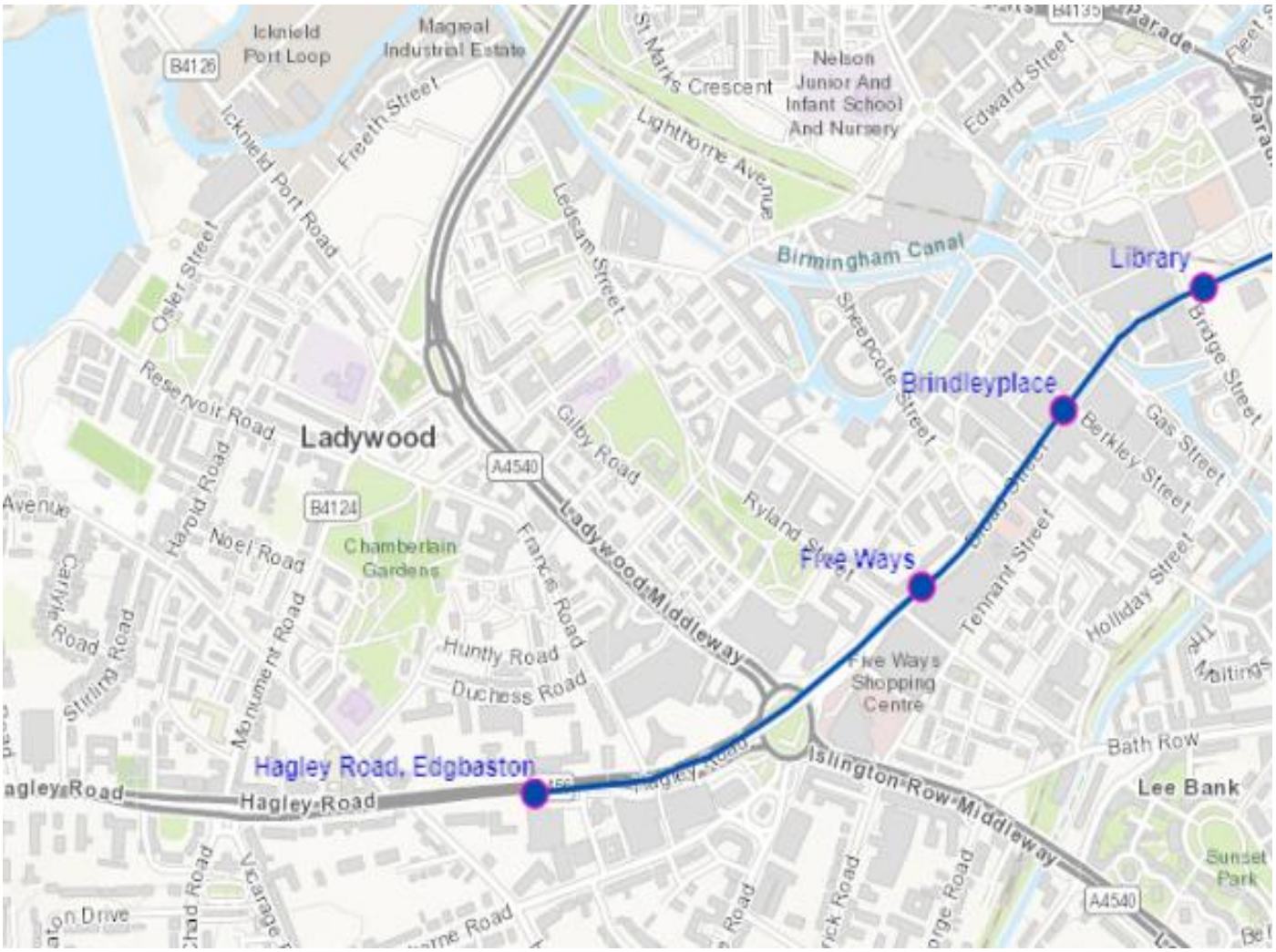


Figure 1 – Edgbaston Extension (EDGE)

The tramway along Broad Street is typically shared with traffic, until it gets to fiveways where traffic is required to use fiveways roundabout but the tram can use the underpass. Buses are allowed under the underpass. As the tram exits the underpass it intersects with Hagley Road to enter the terminus

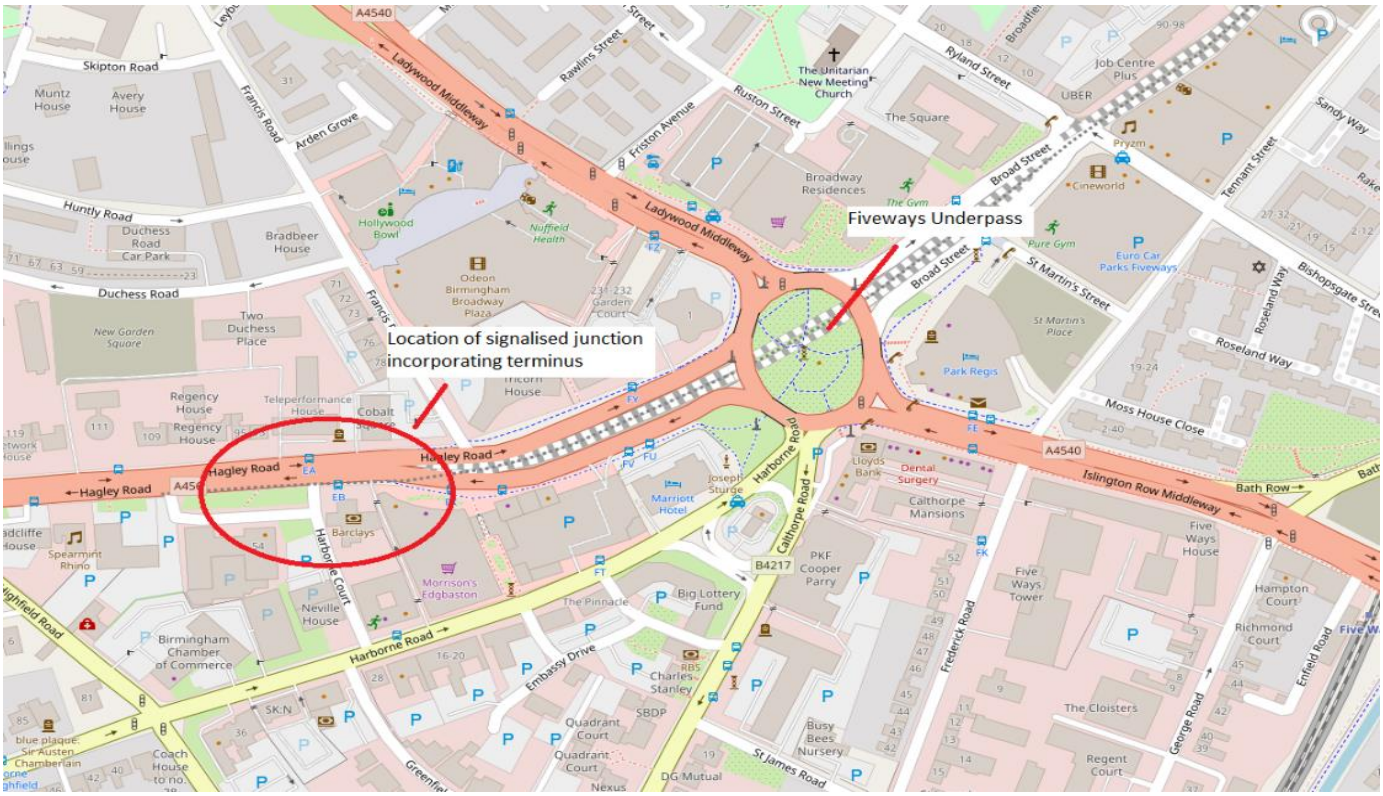


Figure 2 - Hagley Road Terminus Junction Location (@OpenStreetMap contributors)

LRT Priority Principles Overview

At traffic signal-controlled junctions each LRT phase, controlled by the traffic signal controller, typically has four detectors associated with it. These detectors and their functionality are summarised in **Table 1**. In the traffic signal controller, a prepare detector input will often request an immediate move to a traffic signal stage which the associated LRT phase can run in. The prepare detector LRT influences do not typically call the LRT phase. The advance detector is often configured to call the LRT phase. The LRT phase will run for the length of the configured maximum phase time or until the stop line cleared influence has been triggered, whichever is first. If the tram does not clear the stop line before the maximum phase timer has expired, the stop line detector will put in a further demand, this can be as a normal VA demand or a priority request. Once the LRT phase has lost right of way the intergreen will be extended until the cancel detector has been triggered, once triggered the controller reverts back to normal operation. **Figure 3** shows the order of the LRT detection along the tramway.

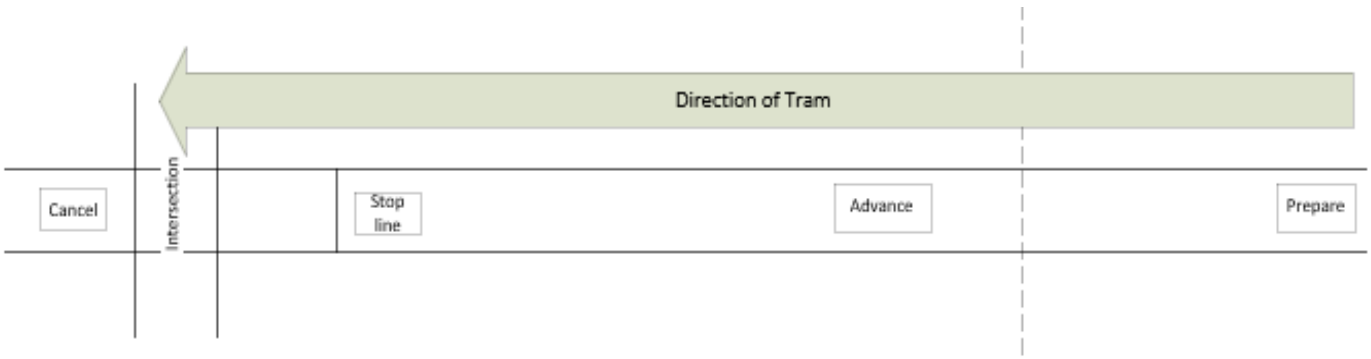


Figure 3 – LRT Detection Positions along Tramway

Tram Detector Type	Typical Functionality
Prepare	Implements a prepare stage for the tram
Advance/Demand	demands the LRT phase/stage the LRT phase runs in
Stop line	Stop line presence – inputs demand for the tram; Stop line cleared – terminate the LRT ROW and junction goes to the interstage
Cancel/Cleared	Allows controller to exit the interstage

Table 1– LRT Detection and functionality

LRT priority does however have its limitations. Once LRT priority mode is activated, when reverting back to normal operation it can be difficult for the traffic signal control strategy to compensate those traffic phases effected by the LRT priority sufficiently. Also, if the control strategy is not local controlled such as SCOOT or UTC fixed time plans, these control strategies will not be aware that LRT priority has been implemented. They will keep running in the background and when they pick up control are likely to be out of sequence and not allocate the appropriate time to the traffic phases which need to be compensated. Furthermore, LRT priority is typically served on a first come first served basis, so a tram that approaches the junction after another tram will not get through the junction in priority mode and will be treated as a standard vehicle, unless the controller is configured to allow it with inhibit times set to 0 seconds.

The Safety Issues identified at design stage.

At design stage a few safety issues were highlighted by the other design disciplines and the Independent Competent Person (ICP) which needed to be resolved during the design process, these were (with reference to **Figure 4**)-

1. Fiveways underpass line of sight, and queuing traffic on Hagley Road. Tramways operate a line of sight policy and forward visibility for trams is limited when exiting the underpass.
2. Morrisons delivery vehicle egress within the junction and the scissor crossover and how the points interfaced with the LRT signals.
3. Safety team concerned that drivers would drive into the terminus from Hagley Road.

1 - Fiveways underpass line of sight, and queuing traffic on Hagley Road.

The tramway runs through the Fiveways Underpass (**Figure 5**) and crosses Hagley Road and then enters the Terminus. The tramway crossing Hagley Road was deemed a safety concern, due to the vertical alignment on the egress of Fiveways underpass meaning tram drivers to not have line of sight as they approach the junction. Tramways use line of sight operation, therefore a tram should be able to stop before a reasonably visible stationary obstruction ahead, from the intended speed of operation using the service brake (UK Tram, 2018). This section of Hagley Road is notoriously busy and as the tram exits the underpass the driver would not have sufficient time to stop at the speed of operation if traffic was queueing over the tramway. Furthermore, any traffic exiting Fiveways Roundabout, onto Hagley Road would need to be guided such that it did not enter the tram terminus. **Figure 5** shows the conflict zone on Hagley Road where the tramway crosses as it exits the Fiveways Roundabout underpass to enter the Hagley Road Terminus via the scissor crossover.

All stakeholders, including the tram operators, were concerned about the perceived safety issue and couldn't easily identify a workable solution. The issue was one that those working on the project had not encountered before. In line with the LRT priority principles we had to develop a solution that would ensure that the LRT received priority, albeit without compromising safety. We worked collaboratively with the project Rail Signalling Engineer and Interface Team, to ensure the most robust design solution could be implemented.

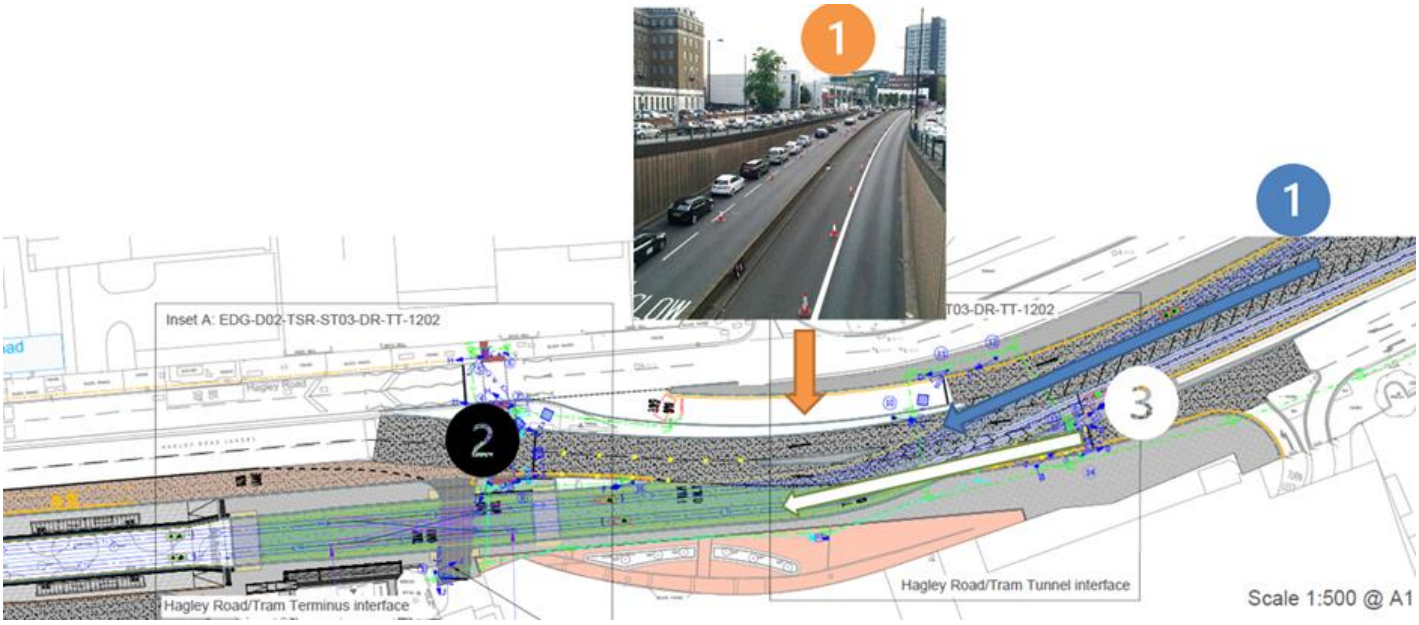


Figure 4 – Safety issues identified as the Terminus site.

When developing the solution, we drew upon lessons learned from a previous LRT extension in Birmingham. We had learned that tram transponder devices when over a tram loop will only send an output from the tram detection controller to the traffic signal controller for a maximum of 5 seconds. This meant that the proposed solution could not rely on a constant presence on a tram loop. Furthermore, in developing the solution it was important to understand that when an LRT request is input into the controller, the controller will not hold proceed for the tram for the length of the influence period timer, it will only hold proceed for the length of the maximum green timer set, which is different to how other LRT controller influences work.

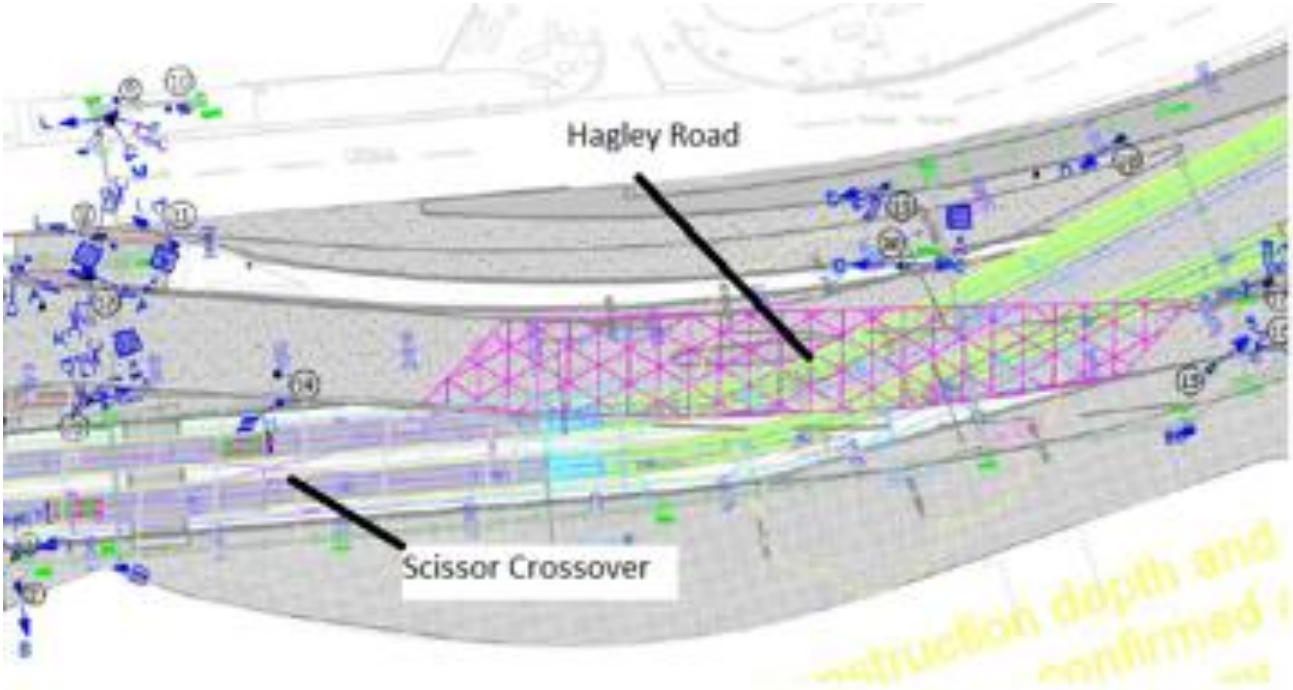


Figure 5 –Hagley Road Terminus Entry

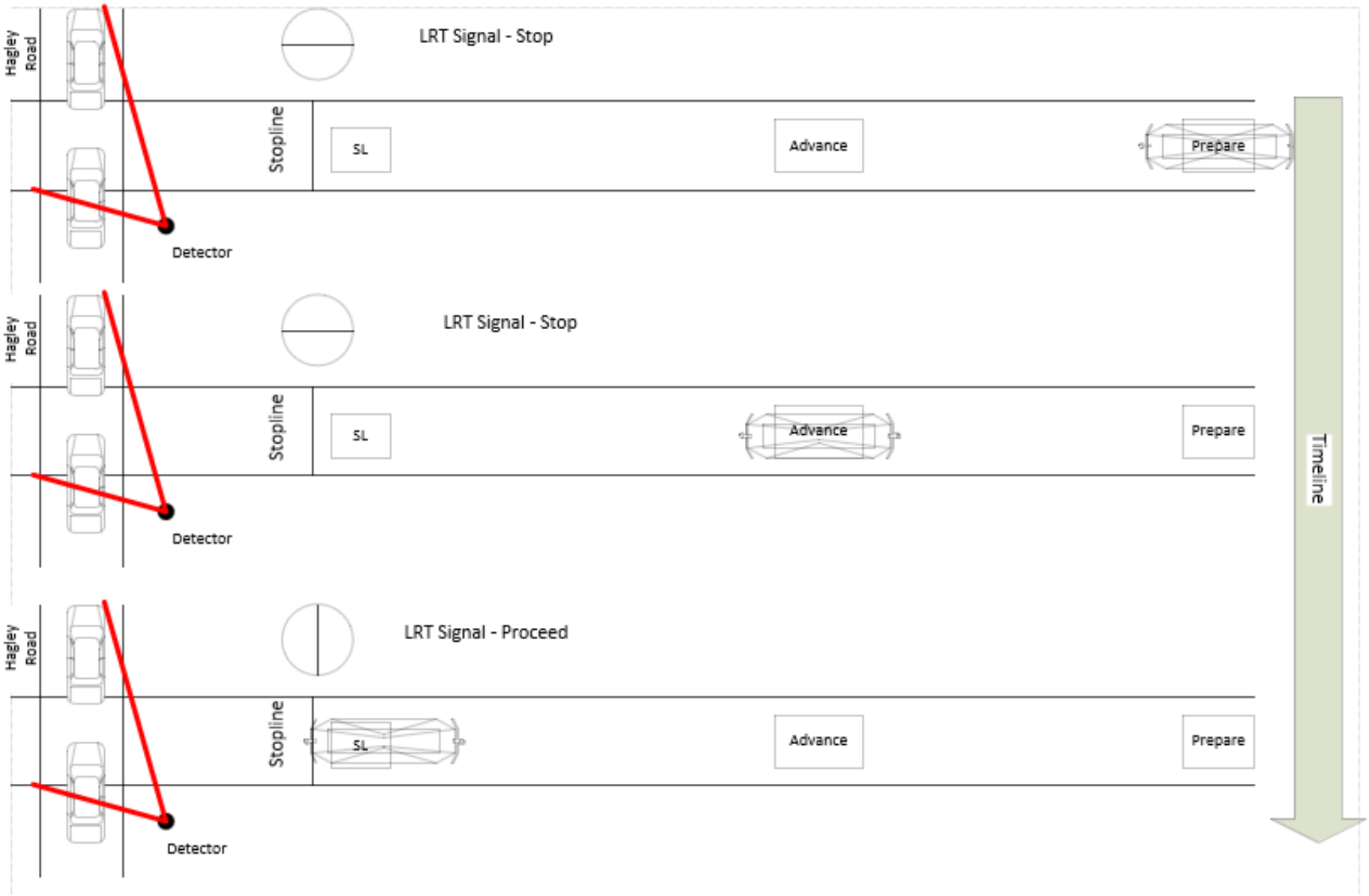


Figure 6 – Traffic queuing on Hagley Road and tram only shown priority at the stop line

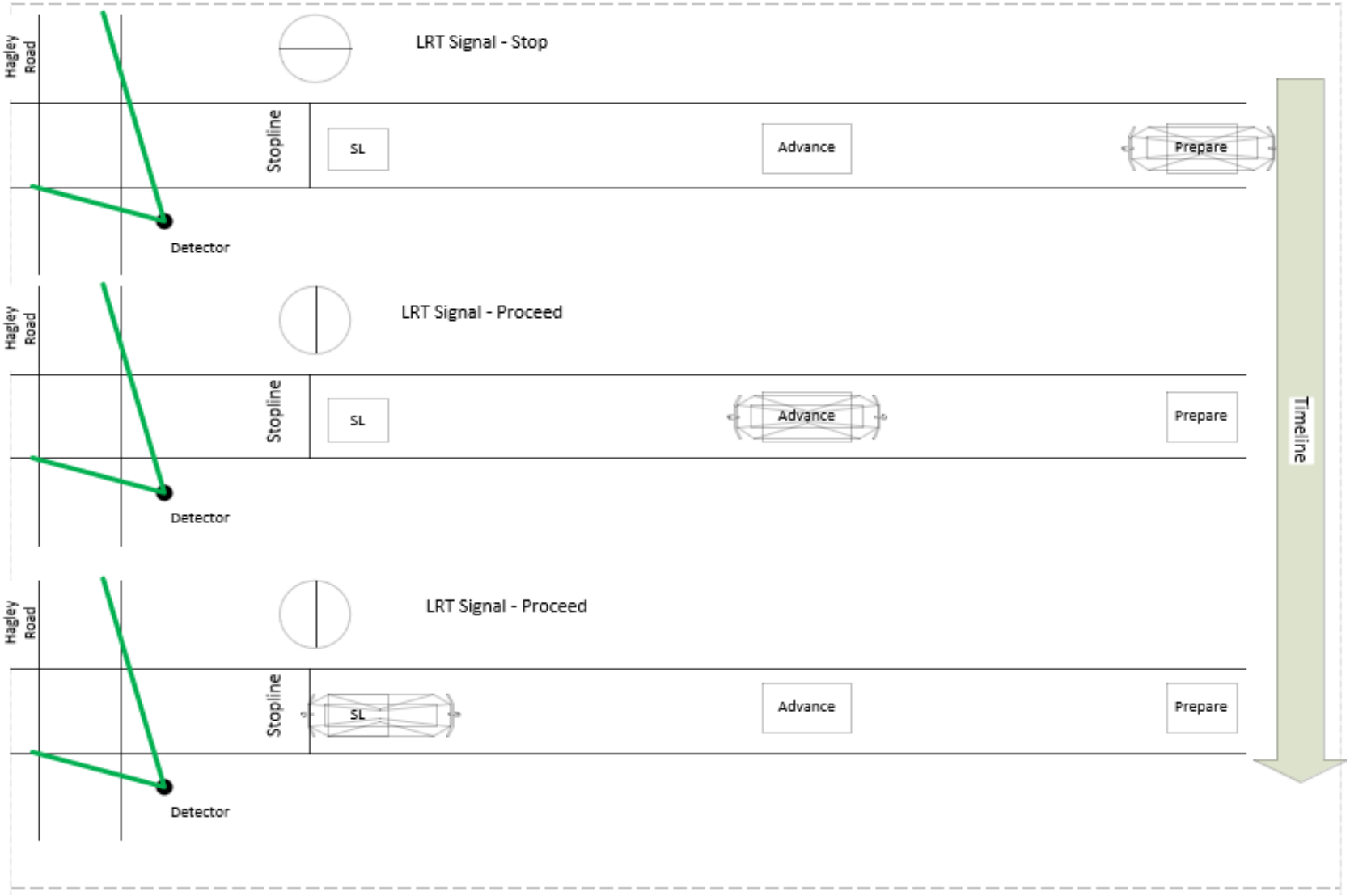


Figure 7 – No traffic on Hagley Road tram priority given when tram triggers advance detector

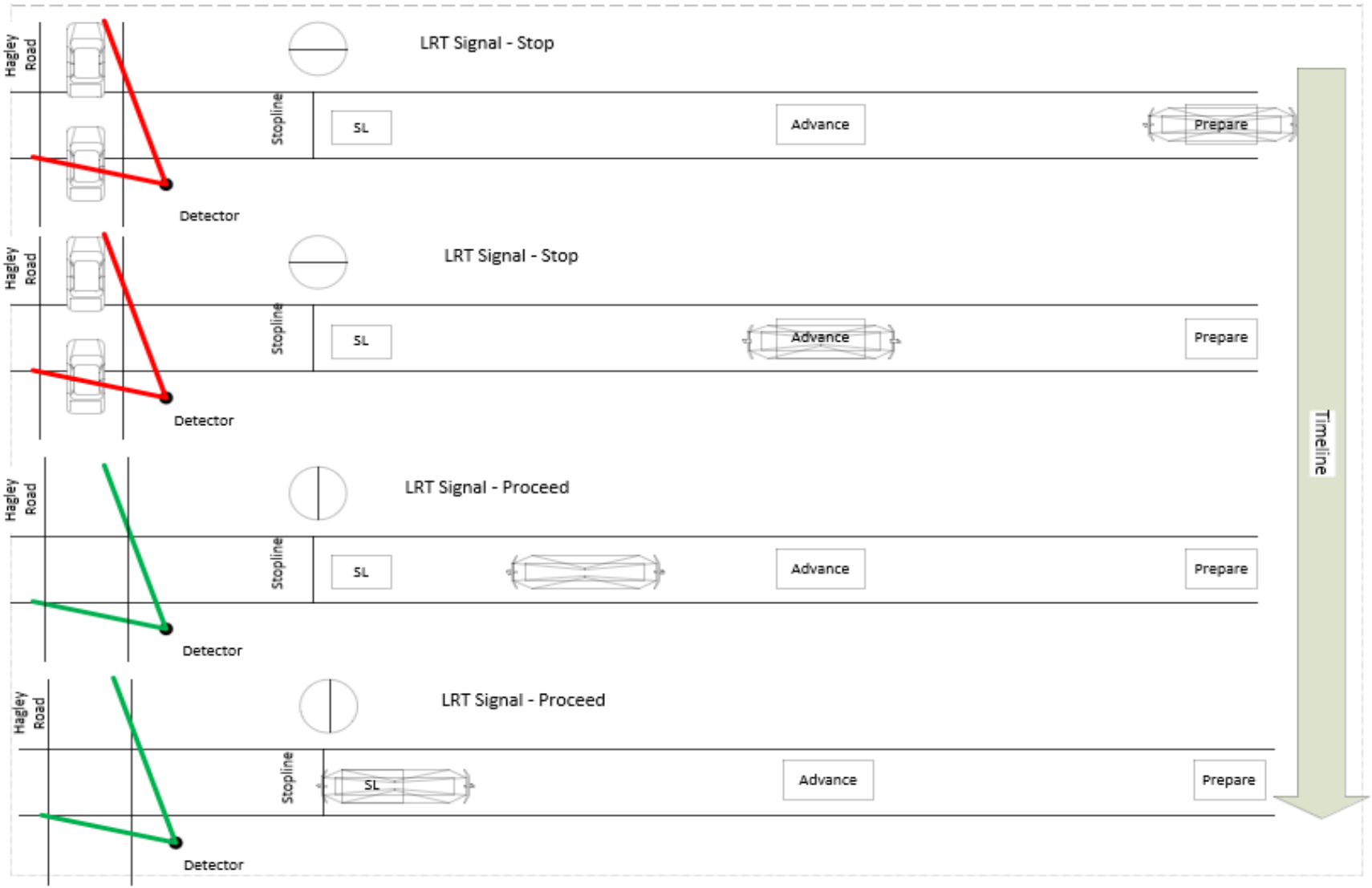


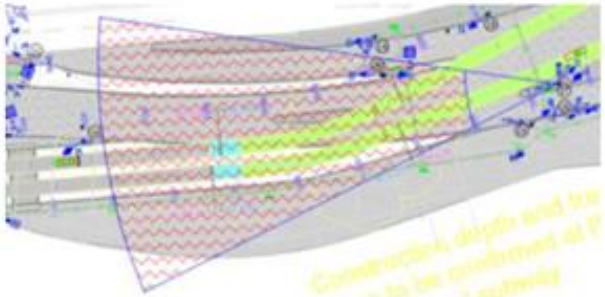
Figure 8 – Traffic queuing on Hagley Road and clears between advance and stop line detection

Detector	Benefit(s)	Dis-benefit(s)
Induction Loop	• High percentage detection rate • No occlusion issues	• Traffic Management (TM)/closures required for install • Maintenance incurs TM and civils cost • Cannot be installed in close proximity to ironworks/track • No configurable detection zone
Magnetometer	• Wireless transmission means no duct infrastructure	• Detection rate can be unpredictable • Failure incurs TM and civils cost • Battery life assumes long term maintenance schedule for renewal – at cost • No configurable detection zone
Above Ground Radar	• Installation requires no major TM • Multi-zone configuration available • Many models configurable via Bluetooth	• Can experience occlusion • Some features restricted by vehicle speed • Rain effects operation • May not detect in fog etc
Above Ground Video	• Installation requires no major TM • Multi-zone configuration available • Many models configurable via Bluetooth	• Can experience occlusion • Some features restricted by vehicle speed • Rain effects operation • May not detect in fog etc • False detects • Issues detecting at night
Above Ground Thermal	• Installation requires no major TM • Multi-zone configuration available • Many models configurable via WiFi or a Cloud based system • Operation in the dark and adverse weather • Robust	• Cost of equipment

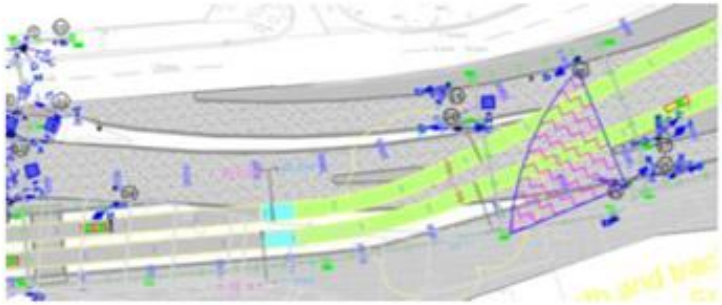
Table 2 - Benefit/Disbenefit analysis of above ground detection types

Thermal Detectors

- Configurable Detection Area 1



- Configurable Detection Area 2



* Detection zones are indicative – detailed design to be provided by the supplier

- Thermal detection does not rely on vehicle speeds. Stationary vehicles will be detected
- Configurable detection zones
- Accurate
- Thermal detection is not a directional detection method l
  - but can differentiate vehicles travelling in opposing directions and dismiss those not wanted
- Not affected by weather conditions
- Easier to maintain than loops

Figure 9 – Thermal detection proposed location and detection

The solution we proposed interfaced with the LRT detection system and traffic signal system, using above ground detection to detect stationary vehicles on the track. If a vehicle is detected on the track, we configured the traffic signal controller to inhibit the tram proceed for the associated LRT phase until such time that the vehicle has cleared the track, or that the driver has line of sight of any obstruction. The controller was configured such that if a vehicle is detected within the detection zone for a set time period the controller will inhibit 'Proceed' for the LRT phase. If the detector does not see a queue for a set time period the proceed signal can then be shown. The prepare detector moves the controller to an appropriate stage, also ensuring traffic has been stopped from entering Hagley Road. Various scenarios are illustrated in **Figures 6, 7 and 8.** Where trams are at the stop line, they are judged to have line of sight and priority can be implemented.

Figure 6 shows the scenario in which there is queuing traffic picked up by the above ground detector on Hagley Road and the traffic doesn't clear. In this scenario the tram will only receive a proceed signal when it is detected by the stop line detector. **Figure 7** shows what will happen when there is no traffic on Hagley Road - LRT priority will operate as normal. If there is queueing traffic detected on Hagley Road when the tram activates the advance detector then the proceed signal will not be shown. If the queue disperses and the tramway is clear for a specified number of seconds, the proceed signal will be shown before the tram arrives at the stop line, **Figure 8**. It should be noted that to prevent traffic entering this section the prepare detector will result in the upstream traffic link to Hagley Road being shown a red signal.

Following a benefit/disbenefit assessment of the detection available (shown in **Table 2**), It was determined that the most appropriate detection for this task was thermal detection. **Figure 9** shows the proposed detection arrangement. We also proposed the provision of additional backup detectors for detector fault resilience to ensure that the traffic signal controller failure mitigation is not immediately required. The controller mitigation would result in the LRT priority always being inhibited; this solution only inhibits priority to the LRT phase if the backup detector also fails.

2 - Morrisons delivery vehicle egress

Morrisons have a delivery vehicle egress which crosses the tramway where the scissor crossover is located, **Figure 9**. The egress had to be signalised due to the location of the tramway and the risk of a tram colliding with a HGV.

The scissor crossover presented a further issue. Tramway protocol is that if the tram overshoots the tram signal stop line at a scissor crossover the LRT signals are to go into degraded mode – the LRT signal shows the centre dot meaning trams are to proceed with caution which may contradict what the traffic signals are showing at the Morrisons egress e.g. the traffic signals could be showing a green signal as the tram is proceeding across the scissor cross over with caution. Because of this, it was decided that it was better for the points controller to control the LRT signals at this location and the traffic signal controller to control the traffic signals.

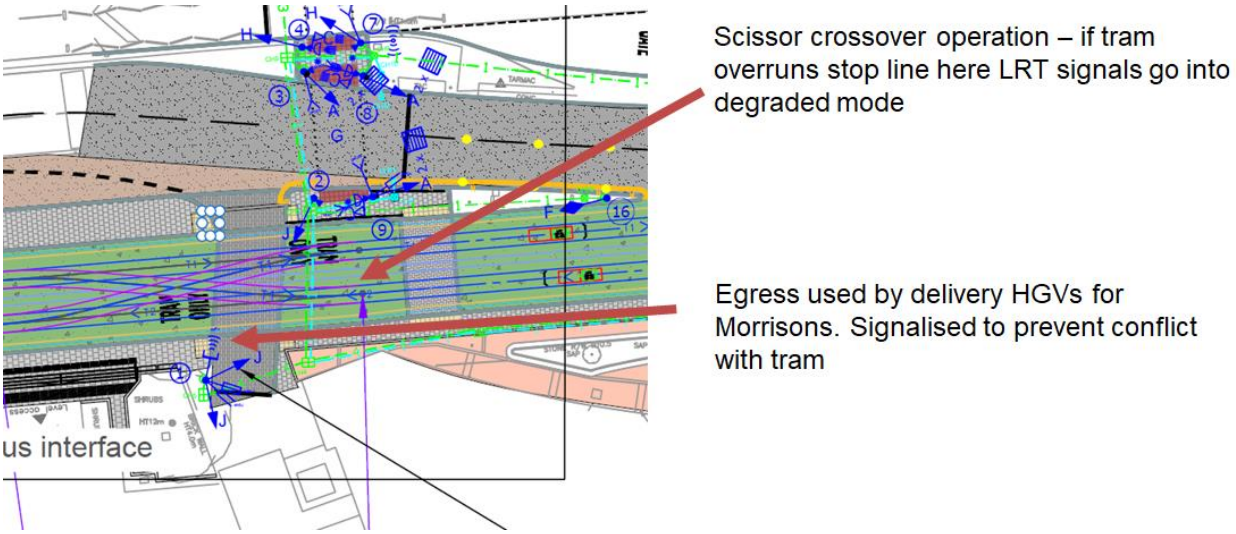


Figure 10 – Morrisons delivery vehicle egress over tramway

This required a very complex interface or 'handshake' between the traffic signal controller and the points controller. In very simple terms, the points controller essentially tells the traffic signal controller when it can show green to Morrisons and the traffic signal controller tells the points controller when it shows proceed to the tram. This interface had an Intense and complex safety verification process carried out by the LRT system supplier and the traffic signal designer and supplier. **Figure 11** shows a short extract from the points controller to traffic signal controller protocol. Collaboration between design disciplines and the suppliers was critical to the implementation of this protocol such that the final solution worked, was safe and resilient.

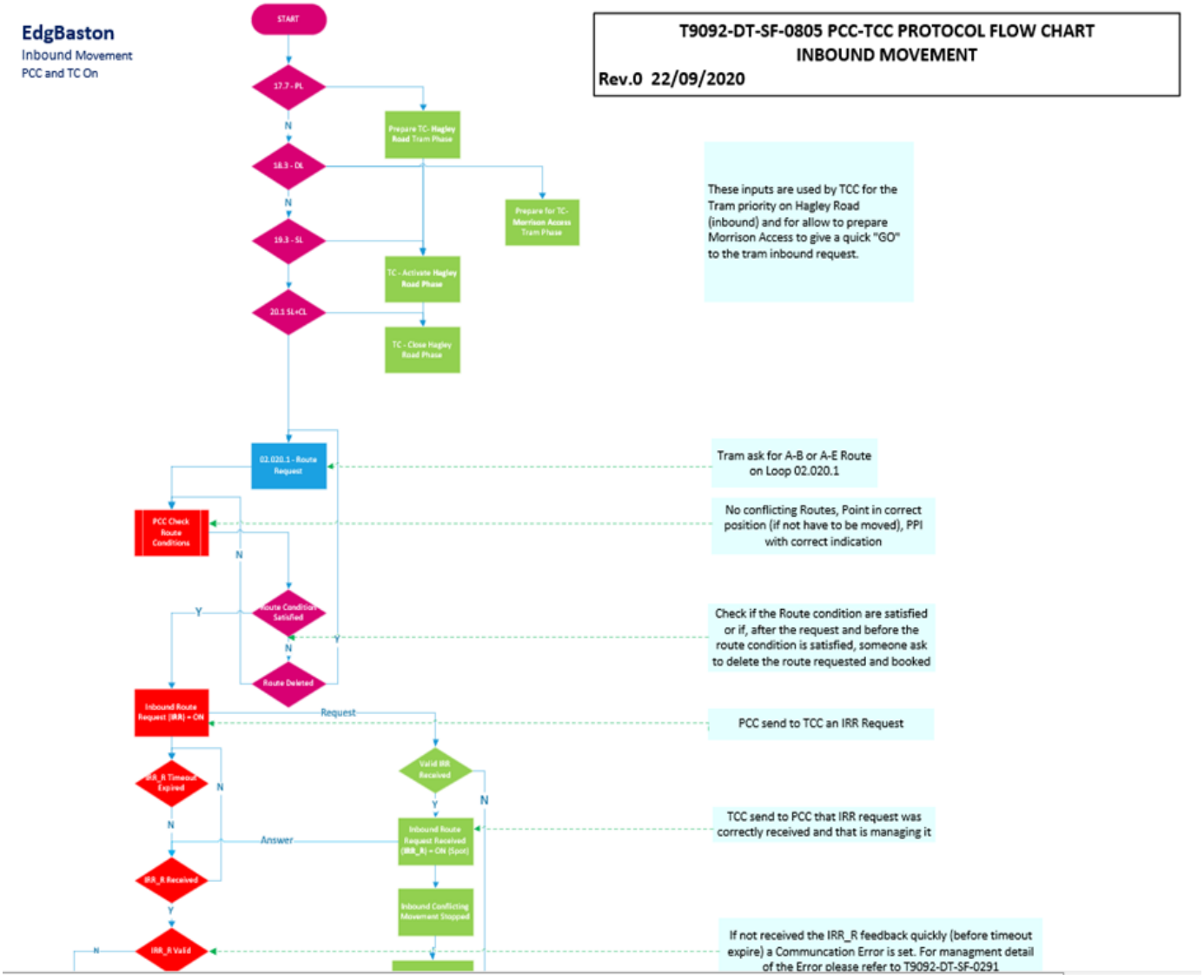


Figure 11 – Points controller/traffic signal controller protocol extract

What happens when a tram overshoots the stop line and the points controller goes into degraded mode?

If the points controller goes into degraded mode the traffic signal controller is configured to blackout the signals (note – they operate as a separate stage stream in the controller). In addition, a detector is provided with a detection zone over the scissor crossover which calls an appropriate stage within the main controller stage stream, to ensure the HGVs exiting Morrisons receive a gap in the traffic so they can exit onto Hagley Road and don't sit over the tramway blocking the tram.

3 – Drivers driving into the terminus from Hagley Road.

There was a concern by stakeholders that drivers entering Hagley Road from Fiveways would drive into the terminus. In order to guide drivers away from the terminus there were a number of intervention strategies implemented such as surface colour, road markings and signing. In addition, the ITS solution was the introduction of Intelligent Road Studs. These are provided by Clearview intelligence and essentially illuminate when the associated traffic signal is green and de-illuminate when red. The aim of the studs is to provide dynamic lining guiding drivers away from the terminus tram gate. They have been provided at other sites in the UK – Switch Island and Sheriffhall RDT

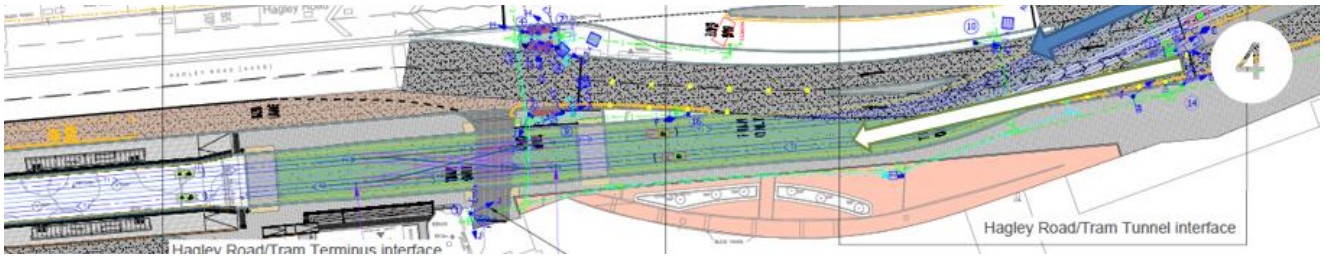


Figure 12 – Intelligent road studs on Hagley Road

Conclusion

The site was commissioned and operational in time for the Birmingham Commonwealth Games in 2022. There were a few teething problems identified during the testing and commissioning process which included a month of shadow running for the tram operator. These were resolved and when traffic conditions returned to some sort of normality after COVID, the route was validated, working with all stakeholders to get the correct balance between transport modes and non motorised users.

The site is now fully tested, operational and working well. Whilst the solution to mitigate tram drivers not having line of site could be deemed simple, it resolved a complex problem providing all stakeholders with confidence that the tram could operate safely with only a small compromise on priority. In addition, it is believed that the proposed solution has not previously been used on a UK tram network. The solution allows priority to be maintained for the tram, but this priority is restricted if there is queuing over the tramway on Hagley Road. The tram will always get priority when it reaches the stop line dependent on controller phase minimums and intergreens. If we had not proposed the solution, then the tram would not receive priority until it reached the stop line impacting on operator service times.

The solution for Morrisons was incredibly complex and required a thorough testing and commissioning process. This solution was only possible through the project team – designers, delivery, suppliers etc. working together to solve a problem. Following a few teething problems identified during the shadow running, this solution is working well and as intended.

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