Delta Force! Meeting stakeholder requirements giving priority for pedestrians, tram and buses in Birmingham.

Introduction

The Midland Metro Alliance (MMA) has delivered several major tramway extensions across the West Midlands, including the Birmingham Westside, Birmingham Eastside, Wolverhampton City Centre and Wednesbury to Brierley Hill extensions. These projects support regional connectivity, regeneration and sustainable transport objectives.

This paper examines the development of the traffic signal strategy for the Bull Street/Corporation Street tram delta junction. It focuses on the operational challenges associated with integrating tram priority, pedestrian facilities, bus movements and tram point control, while maintaining a safe and efficient operation for all users.

The Bull Street/Corporation Street junction forms part of the Birmingham Eastside Metro Extension (BEE). BEE runs from the Bull Street/Corporation Street junction along Lower Bull Street and New Canal Street, through Digbeth, to the junction with Alcester Street. Although the extension is still under construction, two sections (Sections 1 and 2) recently opened to passenger service, connecting the existing tramway to a new tram stop at Millennium Point (**Figure 1)**. The Bull Street/Corporation Street is a 4 arm junction for traffic, but also a Delta junction for the tramway. A tram delta junction is a triangular track junction where three tram routes meet, allowing trams to travel between any of the three directions without reversing. It is called a delta junction because its track layout resembles the Greek letter Δ (delta).

As noted previously, Bull Street/Corporation Street is a four-arm junction connecting Upper Bull Street, Lower Bull Street, Upper Corporation Street, and Lower Corporation Street. Trams approaching from Wolverhampton via Upper Bull Street can either turn left onto Lower Bull Street towards Millennium Point or right onto Lower Corporation Street towards Centenary Square, Broad Street, and the Hagley Road terminus. Trams arriving from Lower Bull Street can either turn left onto Lower Corporation Street or right onto Upper Bull Street towards Wolverhampton. Similarly, trams entering the junction from Lower Corporation Street can turn right onto Lower Bull Street or left onto Upper Bull Street. This arrangement provides operational flexibility, allowing trams to operate between all connected corridors (**Figure 2**).

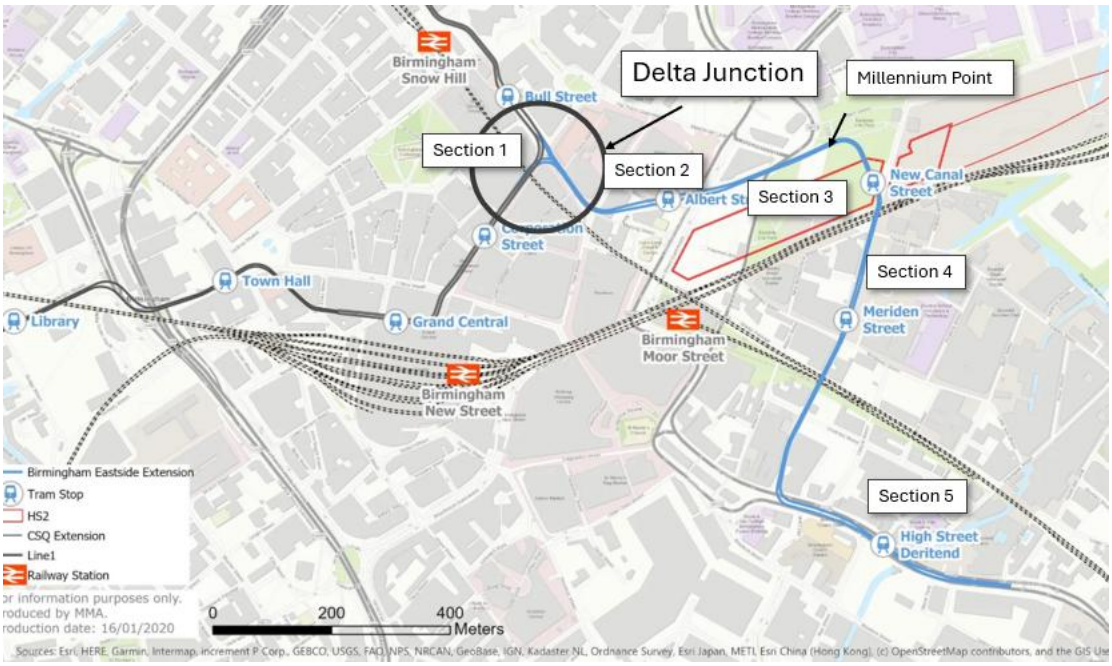


Figure 1 – Birmingham Eastside Extension (EDGE)

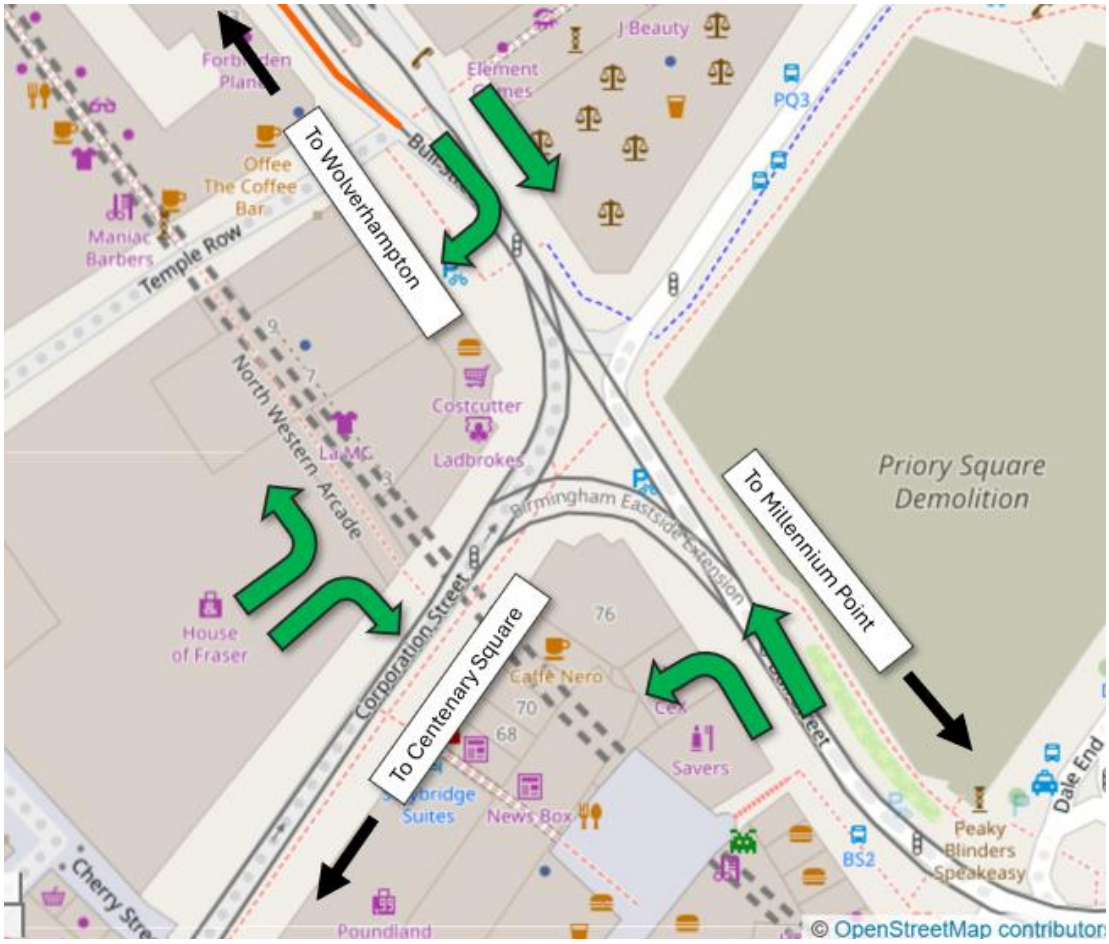


Figure 2 - Tram movements at Bull Street/Corporation Street

Site Characteristics

The key site characteristics are summarised below:

- Traffic stop lines are positioned in advance of the tram points, as the points move whenever a route change is requested. For safety reasons, vehicles and pedestrians must be clear of the points during this movement. This arrangement results in reduced junction intervisibility and necessitates increased intergreen times.
- While not uncommon, the junction incorporates a combination of Toucan and pedestrian crossing facilities across all approaches. The Toucan crossing on the Upper Corporation Street arm can operate only once per signal cycle. Due to the site layout and tram operations, cycle times can be relatively long, influenced by factors such as significant lost time and slow-moving traffic.
- The Delta Junction accommodates a variety of users on all approaches, not solely tram movements:
    - **Upper Bull Street:** Non-Motorised Users (NMUs), general traffic, and trams.
    - **Upper Corporation Street:** NMUs and buses.
    - **Lower Bull Street:** NMUs, buses, and trams.
    - **Lower Corporation Street:** NMUs, service vehicle traffic (very low volumes), and trams.
- At the operator's request, the points indicator signals are mounted on the same poles as the tram stop/proceed signals.
- The Upper Bull Street tram stop is located immediately adjacent to the junction on Upper Bull Street.
- The High Street/Dale End junction is situated approximately 100 metres south-east of the Delta Junction along Lower Bull Street.

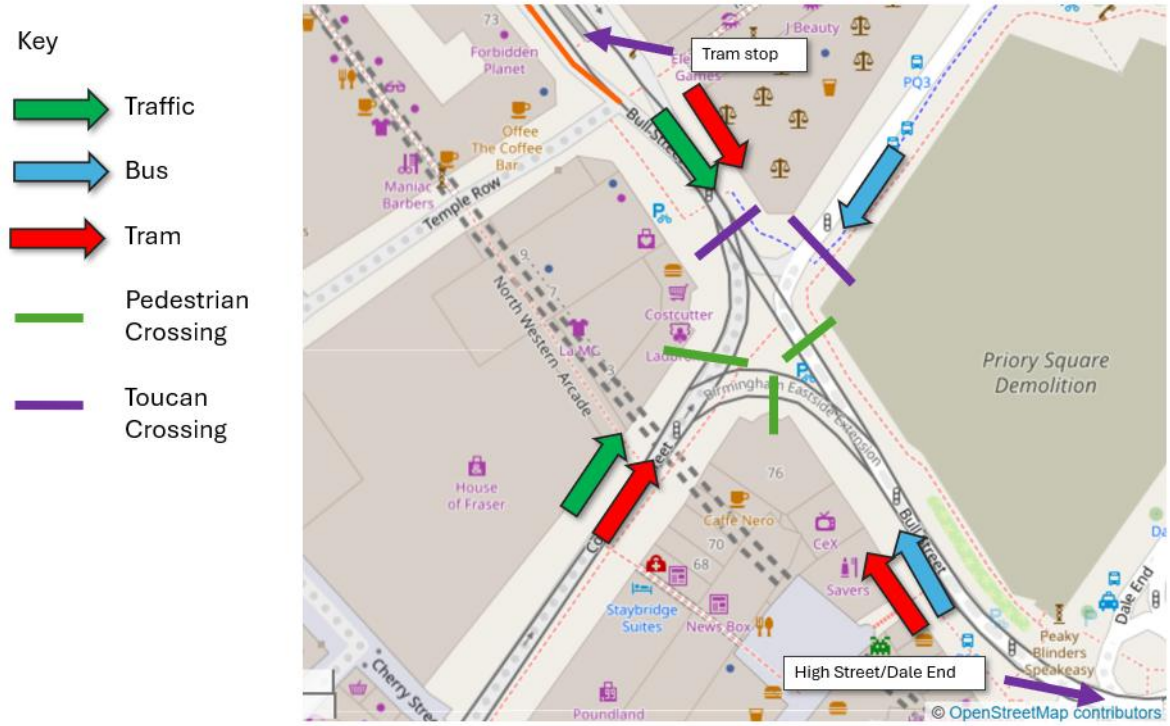


Figure 3 – Site Characteristics

Stakeholder Requirements

As the design developed, the following stakeholder requirements were identified and requested to be incorporated into the site operation -

- ***Tram priority***: as this was a tram project, tram priority had to be provided at the junction.
- ***Design to include allowance for future Automatic Route Setting (ARS) functionality*** : automatic route setting will look to set the points automatically before the tram arrives at the junction, the design had to ensure this could be incorporated in the future.
- ***Tram Stop/Proceed and Points Indicator never conflict:*** The tram proceed signal must always replicate the points indicator; they were not allowed to show conflicting information for safety reasons.
- ***No change mind scenario:*** Once a driver had selected their route, they should not be allowed to change their mind and would be committed to that route.
- ***Allowance for the Toucan phase across Upper Corporation Street to run more than once a cycle:*** The Toucan phase only ran once in the controller cycle as it demanded an all-red pedestrian stage.
- ***Look to minimise the impact of the bus timetable:*** the junction serves a number of bus routes and the design had to consider limiting the impact on these routes.

Tram Priority

As ARS is still to be incorporated on the Birmingham tram network, the tram priority could not be provided in the normal way – move to a prepare stage ready for the approaching tram, show the

tram proceed signal, once the stop line has cleared end the proceed signal, and then clear the intergreen delay timer. As each approach served two tram routes, the prepare function couldn't be used as there was no way to know which route the tram was going to take, therefore this facility was provided but switched off in the controller configuration.

To demand a proceed signal, the tram driver must stop on the COMMAND/BACK UP loop (**Figure 5**) and select a route. The points indicator unit then sends an output to the traffic signal controller requesting the corresponding tram phase. Upon receipt of this input, the controller goes into tram priority mode. Due to each approach which the tram operates on having two routes, the traffic signal staging had to consider this to ensure any traffic or buses waiting behind the tram were not delayed unnecessarily. Using phases L and M as an example, **Figure 4,** if the tram approaches the junction and wants to turn right from Upper Bull Street (phase M), there are two potential scenarios –

1. The tram arrives and the junction isn't in either stage 6 or 7 – driver requests route, tram priority triggered and after safety timings have run controller moves to stage 7
2. The tram arrives and the junction is in stage 6 - driver requests route, tram priority triggered, immediate move to stage 7 (subject to safety timings) - note there is an 8 second intergreen between phases L and M.

Phase J and K and phases N and O all have other phases running within their respective stages, therefore phase minimums and intergreens need to be considered before changing to the stage for the other route. Note the junction typically cycles through stages 3 (reversion), 6, and 9; the approaching tram will demand one of these stages as it approaches the junction due to the traffic detection, so any phase minimums etc should have timed off or almost timed off by the time the driver has selected the route.

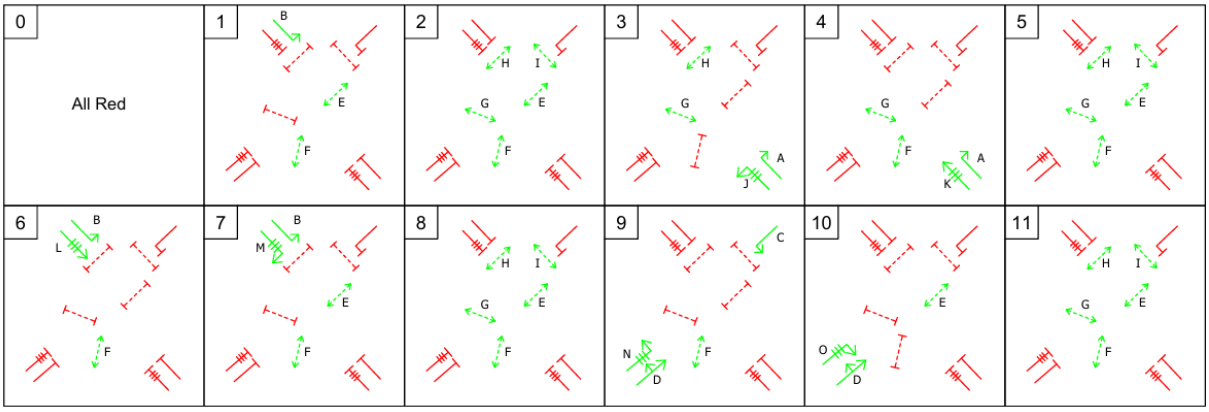


Figure 4 – Bull Street/Corporation Street Staging Plan

The tram phase changes from Stop to Proceed once the points indicator input demands the route. By this point, the points indicator is already showing the selected route direction. To prevent any conflict between the points indicator and the tram proceed signal, the tram phase will not receive a revertive demand if the stop line input is absent. Normally, if the stop line input is not triggered, the tram is assumed not to have reached the stop line, so no revertive demand is applied.

If the tram driver overshoots the COMMAND/BACK UP loop and cannot make a route request or the points cabinet (which controls the points indicator) has failed, then route requests have to be made via Urban Traffic Control (UTC). An operational process has been developed for this scenario.

Design to include allowance for future ARS functionality

All inputs currently used in operation, with the exception of the prepare function, will also be used by the ARS. Once ARS is operational, the prepare function will be switched on within the controller and the ARS will be commissioned.

TRAM Stop/Proceed and Points Indicator never conflict

The tram system's points indicator controller sends an input to the traffic signal controller when the route has been selected, the points are locked and the points indicator is displaying the route direction. Upon receipt of this input the traffic signal controller will show the respective tram proceed signal. The tram proceed signal cannot be demanded in any other way except through a special UTC control bit. This must be provided in case of the following scenarios –

- Tram driver doesn't stop on the COMMAND/BACK UP loop and cannot select a route;
- Points cabinet has failed and cannot send the output or set the points indicator;
- Tram driver selects the wrong route; or
- Tram driver selects the route but for some reason is unable to make it beyond the stop line.

Any of the above scenarios are managed by the operators operational procedures. As noted earlier, revertive demands for the tram phases have been removed as there is a risk the points indicator unit could be showing a different direction when the revertive demand is served.

No change mind scenario

This requirement was implemented by the tram systems team. When the tram is over the COMMAND/BACK UP loop, the driver is only able to select the route once. After route selection, they are unable to select another route until the tram has cleared the COMMAND/BACK UP loop.

Allowance for the Toucan phase across Upper Corporation Street to run more than once a cycle

To ensure the junction operated safely and efficiently, the Toucan crossing across Upper Corporation Street (Phase I, shown in **Figure 4**) was restricted to operating no more than once per signal cycle. To offset this constraint, an element of pedestrian priority was incorporated into the design by allowing the all-red pedestrian stage to be introduced at multiple points within the cycle, as illustrated in **Figure 4**. The all-red pedestrian stage is represented by Stages 2, 5, 8 and 11 within the controller staging sequence. Although the stage may be called at several points in the cycle, it is permitted to run only once per cycle. This is achieved through a 90-second inhibit timer, which is initiated when the all-red pedestrian stage terminates. While the timer is active, any subsequent all-red pedestrian stages are prevented from running. For example, if the controller is operating Stage 3 and a demand is registered for Phase I, the next available all-red pedestrian stage will be Stage 5. Once Stage 5 has run, Stages 8, 11 and the subsequent occurrence of Stage 2 are inhibited from serving further Phase

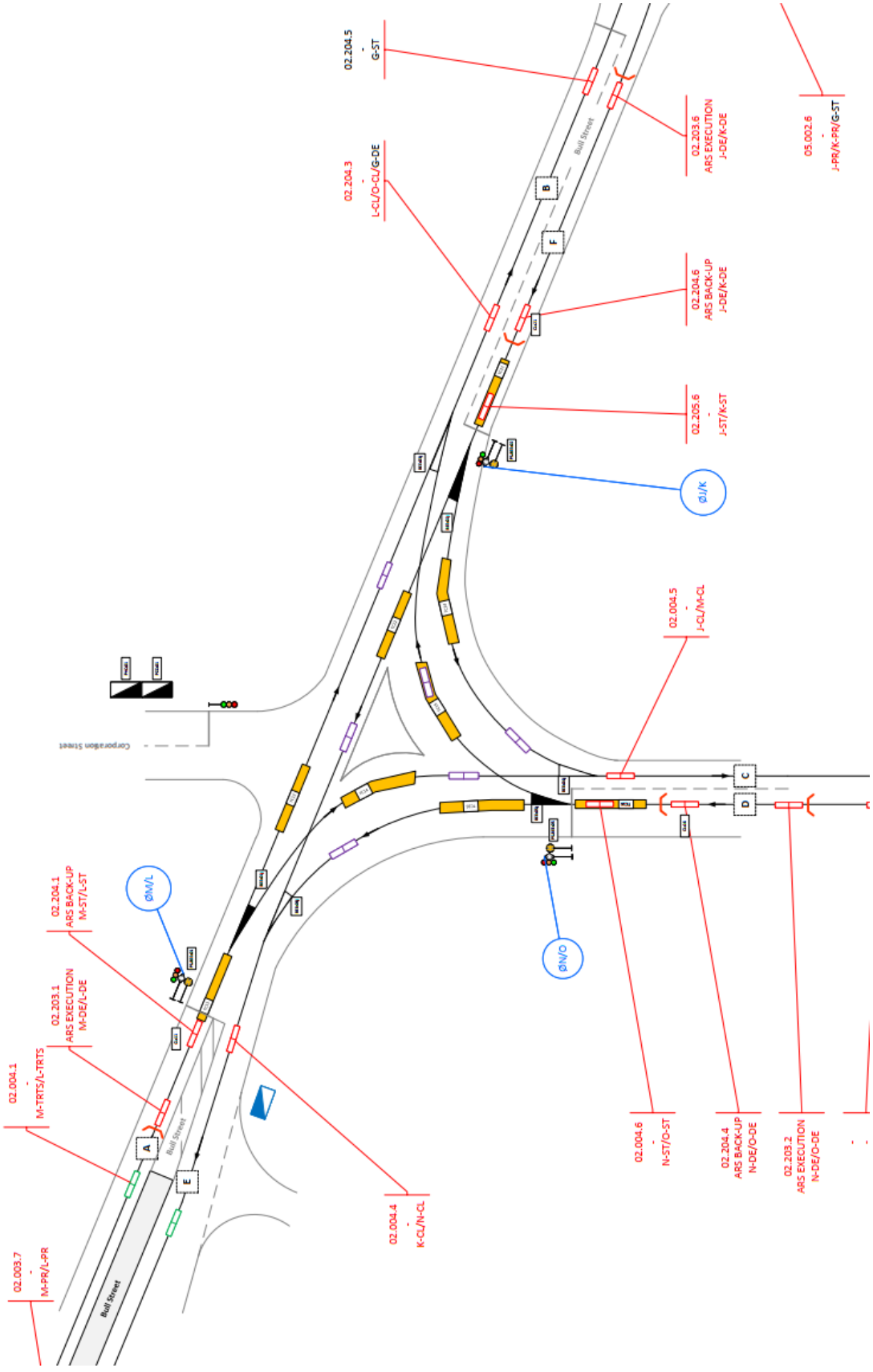


Figure 5 - Delta junction tram loop schematic

I demands while the 90-second timer remains active. If an additional demand for Phase I is received during the inhibit period, the controller stores the demand and services it at the next available all-red pedestrian stage once the inhibit timer has expired.

This arrangement enables pedestrians and cyclists to be accommodated earlier within the signal cycle, reducing waiting times while maintaining the operational efficiency and capacity of the junction. This facility operates only in normal Vehicle Actuated (VA) mode. It does not operate when the controller is under UTC or Cableless Link Facility (CLF) mode. As the junction has tram priority facilities its primary method of control is VA.

Look to minimise the impact of the bus timetable

Providing priority for buses at this location was particularly challenging, as the junction had already been designed to prioritise both pedestrians and trams. Consequently, it was decided that buses would receive a degree of priority, albeit not through conventional bus-priority measures. Applying traditional bus-priority techniques would have introduced competing demands with the established tram-priority strategy.

To mitigate the impact of tram priority on bus operations, the controller's reversion stage (Stage 3) was configured to favour the approach carrying the highest bus volumes, namely Lower Bull Street. This was especially important given the close proximity of the Dale End/High Street junction, located approximately 100 metres upstream of the Lower Bull Street stop line. Additionally, a soft VA link was implemented to hold the Lower Bull Street approach on green when buses were approaching from the Dale End/High Street junction. This not only improved bus journey times but also reduced the risk of vehicles queuing back and causing exit blocking at the Dale End/High Street junction. As traffic volumes on the remaining approaches were relatively low, this arrangement helped minimise bus delays while maintaining the effectiveness of the junction's pedestrian and tram priority functions.

Testing and Commissioning

Following completion of the design stage, a rigorous test and commissioning (T&C) process was carried out on BEE sections 1 and 2, before they could be handed over to the operator so driver training could commence. The junction was initially commissioned for traffic and pedestrians only in 2021. Full testing and commissioning of the tram operation commenced in 2025, with Sections 1 and 2 opening to passenger service in April 2026. The T&C process involved:

Rigorous testing of the controller configuration – The Swarco team developed a configuration that met the brief. Many hours of pre-testing were undertaken before the flop file was tested with stakeholders. Many stakeholders witnessed the testing of the simulation to make sure they were happy with the operation of the site.

Extensive overnight testing the installation and interfaces - As the tram systems were already in place and operational due to the existing tramway, much of the interface testing had to be completed on street. The Midland Metro Alliance, Swarco and the tram systems team undertook extensive overnight testing of all controller and signalling interfaces. Several software integration issues were identified during testing and subsequently resolved through collaborative working between the traffic signal and tram system teams. The system had to pass the full T&C dossier before the extension could be opened for driver training.

Validation – Following successful handover to the operator for driver training and shadow running, which are all undertaken before the route opens for passenger service, the team went out to site to validate the timings and tram priority with stakeholders in attendance to ensure the sites operated as efficiently as possible with minimum impact on all users.

Since commissioning, the junction has successfully accommodated tram movements on all three approaches while maintaining pedestrian accessibility and minimising impacts on adjacent bus services.

Lessons Learned

The development and commissioning of the Bull Street/Corporation Street Delta Junction provided several valuable lessons that may be applicable to other tramway and multi-modal signal-controlled junctions.

Early engagement between traffic signals and tram systems teams is essential: The most significant lesson from the project was the importance of involving traffic signal and tram systems engineers from the earliest stages of design development. The operation of the junction was heavily dependent on interactions between the traffic signal controller, points control system, tram signalling equipment, and operational procedures. Several requirements, including route selection, points indication, tram priority, and fail-safe operation, required detailed understanding across both disciplines. Early collaborative workshops enabled key operational principles to be established before the controller strategy was developed, reducing the risk of redesign and interface conflicts later in the project.

Operational requirements should be fully defined before controller development: Many of the complexities within the controller configuration originated from operational requirements rather than traffic management requirements. Examples included the requirement for tram proceed signals and points indicators never to conflict and the need to accommodate future ARS functionality. Defining these requirements at an early stage allowed the team to develop a controller strategy around fixed operational principles, reducing the likelihood of significant software changes during testing and commissioning.

Tram priority and traffic efficiency must be considered together: Providing tram priority in isolation would have resulted in unnecessary delay to buses, pedestrians, cyclists and general traffic. The final solution demonstrated that effective tram priority does not necessarily mean absolute tram priority. Instead, the controller strategy sought to balance the operational requirements of all users while maintaining safe and reliable tram operation. The use of multiple insertion points for the pedestrian stage, careful selection of reversion stages, and the consideration of nearby junction interactions were all critical in achieving this balance.

Design for future functionality wherever practicable: Although ARS is not currently deployed on the West Midlands Metro network, provision for its future implementation was incorporated within the traffic signal design. This approach avoided the need for extensive future modifications and ensured that subsequent system upgrades could be implemented with minimal impact on the traffic signal operation in the future. Future-proofing signal control strategies can often be achieved at relatively

low cost during the design phase but may become significantly more complex and expensive once a system has been commissioned.

Interface testing should not be underestimated: While the controller strategy functioned correctly during simulation, the majority of challenges encountered during commissioning related to the interfaces between systems rather than the controller itself. Testing confirmed that successful operation depended not only on correctly written controller logic but also on reliable communications between the traffic signal controller, points control equipment, tram signalling system and UTC infrastructure.

Conclusion

The Bull Street/Corporation Street junction represents one of the most operationally complex signal-controlled tram junctions on the West Midlands Metro network. The requirement to accommodate a tram delta junction, future ARS functionality, pedestrian and cycle facilities, and adjacent bus operations resulted in a highly bespoke controller strategy.

Through close collaboration between the Midland Metro Alliance, Swarco, the tram systems team and key stakeholders, a solution was developed that safely integrates tram signalling with traffic signal operation while maintaining flexibility for future network enhancements. Subsequent testing and validation demonstrated that the design met the project's operational requirements and successfully supported the opening of the Birmingham Eastside Extension sections 1 and 2.

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