SPRUCING UP YOUR ITS

Sheffield City Council - August 2017

Brent Collier

Stephanie Cooper

Ben Hallworth

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Sheffield City Council

INTRODUCTION

This paper will describe two different networks in Sheffield and how the SPRUCE system has been used to target various issues at each of them. These are just the Sheffield story on how they tackled the problems, they would not be the only way to tackle them;

Both examples have balancing the requirements of an Outer/Inner Ring road traffic with the need to prioritise public transport movements across them. In **Example 1 at the Wicker** it is buses and in **Example 2 at Manor Top** it is both trams and buses.

To tackle this Sheffield turned to the existing SPRUCE system, they needed to call on its ability to:

- Deal with the specificity of our problem (so many variables)
- Be developed and tested centrally
- Be flexible (if on street changes, it needs to change too)
- Talks to all the systems (and any we might have in the future)
- Can be improved upon (isn't a one stop shop)
- Collect data from anything and everything (whether that's detectors, google, etc)

Sheffield has been using SPRUCE to give bus priority to approximately 200 sites for 10 years, and knew it had great capability so decided to explore its potential further. In brief SPRUCE is able to:

- Monitor junctions - a basis for making a range of informed timing interventions (or storing for historic data collection),
- Give and recover from priority to selective vehicles
- Tweak plans -- override normal UTC plans with different synchronized plans (e.g. 'priority' or 'compensation' plans),
- Raise cycle times - alter timings in a variety of different ways ('extensions', 'recalls', 'holds', 'short term offsets', 'cumulative offsets' etc.),
- Link isolated junctions or MOVA - Can 'pick up' controllers from VA, and provide priority timings via UTC before 'dropping back' to VA,

…and to do all this centrally via the UTC system.

SPRUCE BACKGROUND

SPRUCE is in operation in 4 districts within the UK; Leeds, Sheffield, Bradford and Edinburgh. Strategies have now been implemented at over 500 signals**,** including bus priority, controlling city wide coordinated bus movements, two different tram networks and emergency vehicle priority systems.

'SPRUCE' (standing for Selective PRogramming in a UtmC Environment) started as the software-based Priority Tool originally developed by Leeds and Sheffield City Councils under the DfT sponsored UTMC01 project. After successful trialling of a prototype version of the software in both Sheffield and Leeds, a software development contract with TSEU (now Telent) developed SPRUCE into a robust software product system (briefly known as STM by Telent). Its constant development has been documented over the years in a number of JCT Symposiums.

ARCHITECTURE

The architecture is based around an SQL database. This stores data required to run: node configurations, plans, AVL (Automatic Vehicle Location) detector inputs, and the programmable logic that drives the system.

The logic within SPRUCE is programmed in a high level code that would look familiar to anyone used to dabbling in basic coding and uses a spreadsheet like setup with sheets and cells.

SPRUCE is installed on to a typical server and interfaced with the UTC system (both Siemens and Dynniq supported).

STRATEGIES

SPRUCE is basically a strategy implementation system which is used to control to street via the plan level of a UTC system. SPRUCE is designed to provide a solution to almost all control situations – ultimately limited more by the imagination of the user than by the software.

Provided as a tool with no inbuilt strategies it is up to the engineer to conceive and write their own strategy. There is now a growing library of strategies, some examples of these include:

- Bus Priority - simple standardized recall/extension strategy
- Bus Priority using bus density – this new strategy looks at the buses on each approach to a junction and uses this to adjust the stage green times accordingly.
- Tram Priority - network manipulation initialised minutes ahead of time to provide zero delay for minimal disruption. Used for any infrequent priority vehicles.
- Tram Recovery - manages the transition from local LRT tram priority back to fixed time UTC without stage skipping and allows compensation.
- Fire Priority Green wave - using AVL technology gives Fire Appliances green waves with route choice options.
- Isolated Network Linking - allows the linking of networks that benefit from having one or more running isolated under VA or MOVA control, the strategy allows adjacent junctions to be linked accordingly.
- Traffic Condition Response - using flow and queue detection, cycle times, green splits and offsets are adjusted at a single or network of junctions.
- Bespoke Strategies - there have been numerous other strategies designed and implemented to tackle more specific network problems

Future strategies are set use data from Sheffield's Common Database, these data sources include:

- ANPR
- Google link data
- Air Quality

BUSES - WICKER / INNER RING ROAD

The Wicker network is a major inbound/outbound bus route that cuts across the Inner Ring Road and there is significant delay through the network for buses. With short greens across the key traffic routes and a number of bus stops directly before junctions lead to a rather haphazard progression for buses. There are over 90 buses an hour in each direction, many of which are running late.

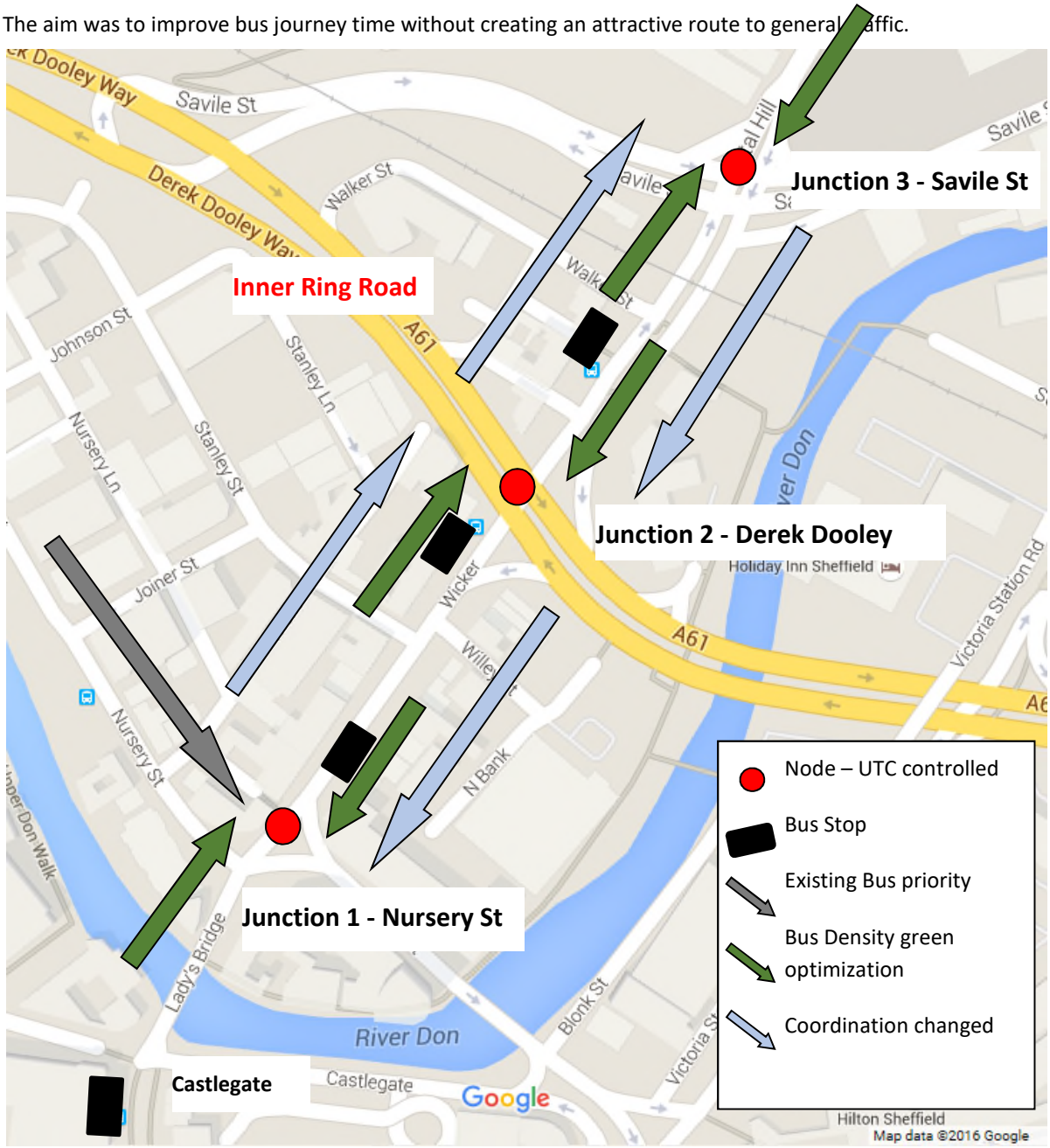
The bus route consists of 3 signal controlled junctions, all operating on Fixed Time plans;

Junction 1 – Wicker / Saville Street

Junction 2 – Wicker / Derek Dooley Way

Junction 3 – Wicker / Nursery Street

The aim was to improve bus journey time without creating an attractive route to general traffic.



STRATAGIES

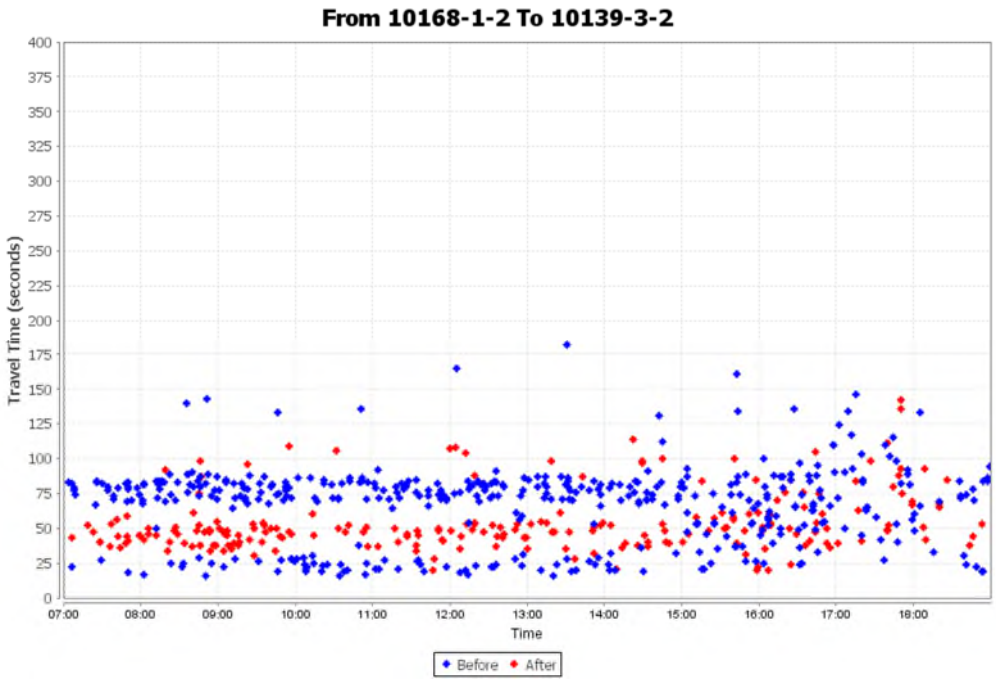
Due to the volume of buses along the corridor the usual bus priority strategies that look at changing signal timings for each individual bus were not appropriate – this led to new SPRUCE strategy being developed. This new strategy looks at the bus density on each approach to a junction and adjusts the stage green times accordingly. This strategy will help minimise attracting other traffic to the route by targeting the bonus green time to buses.

Below the different strategies at each junction are briefly discussed:

JUNCTION 1 – WICKER / NURSERY STREET

The inbound/outbound bus movements here are in different stages. The new SPRUCE strategy calculated bus density alters the inbound and outbound stage green times according to bus demand. The coordination between the junctions was also altered to try and favour buses, although with bus stops in both directions this gave limited benefits.

The benefits from adding the strategy can be seen below, the travel time between the two junctions has been monitored and the majority of the **blue** BEFORE data is in a higher band showing it takes most buses two cycles of the traffic signals to clear the junction. The **red** AFTER data shows the majority of buses now in the lower band, with the slight compromise being the very lowest band that did have some BEFORE buses cannot now be used. This was achieved by the BEFORE buses chasing the greens and on balance the AFTER situation delivers safer signalling with an improved average journey time.

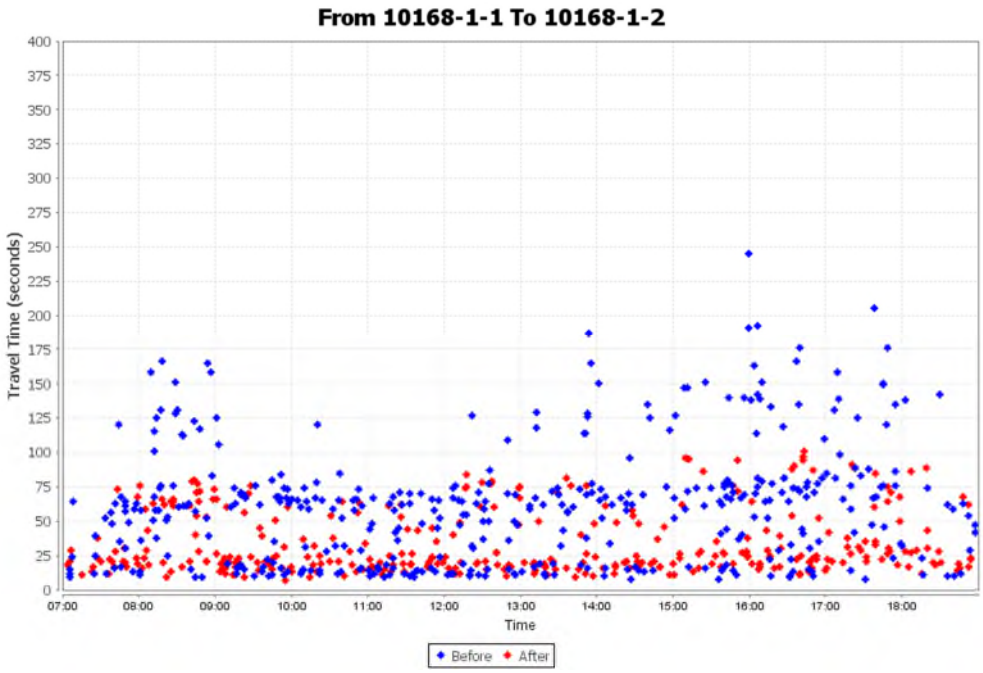


JUNCTION 2 – WICKER / DEREK DOOLEY WAY (INNER RING ROAD)

This junction suffered from buses frequently missing green due to insufficient green time. The bus route cuts across the Inner Ring Road so a fixed timing change was not possible, and it was important to not make the route attractive to other vehicles.

Using the SPRUCE bus density to alter the inbound/outbound stage green time. It is able to make several small step changes in green time in response to bus density.

The benefits from the strategy can clearly be seen below, the travel time between the two junctions has been monitored and the **blue** BEFORE data is on average higher than the **red** AFTER data, with the AFTER data having nearly eliminated the higher values over 100s. The slight banding shows the number of cycles the buses take to pass through the signals.



JUNCTION 3 – WICKER / SAVILLE STREET

The inbound/outbound bus movements here are in different stages. The new SPRUCE strategy calculated bus density alters the inbound and outbound stage green times according to bus demand. The Saville Street (cross movement) green remains unaffected.

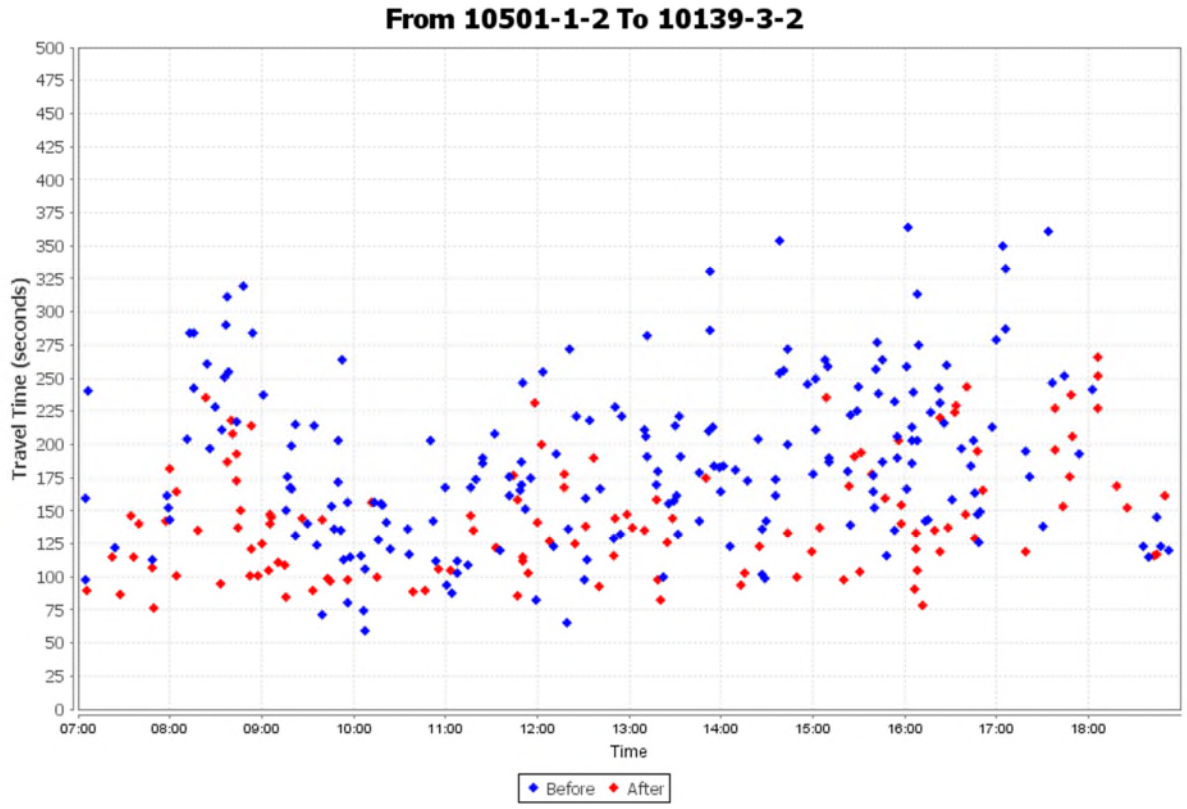
The coordination between Saville Street and the Derek Dooley signals has been changed to favour the bus movements.

OVERALL RESULTS

The overall journey time benefits are summarized below. These give the combined effect of each of the individual strategies that were discussed above.

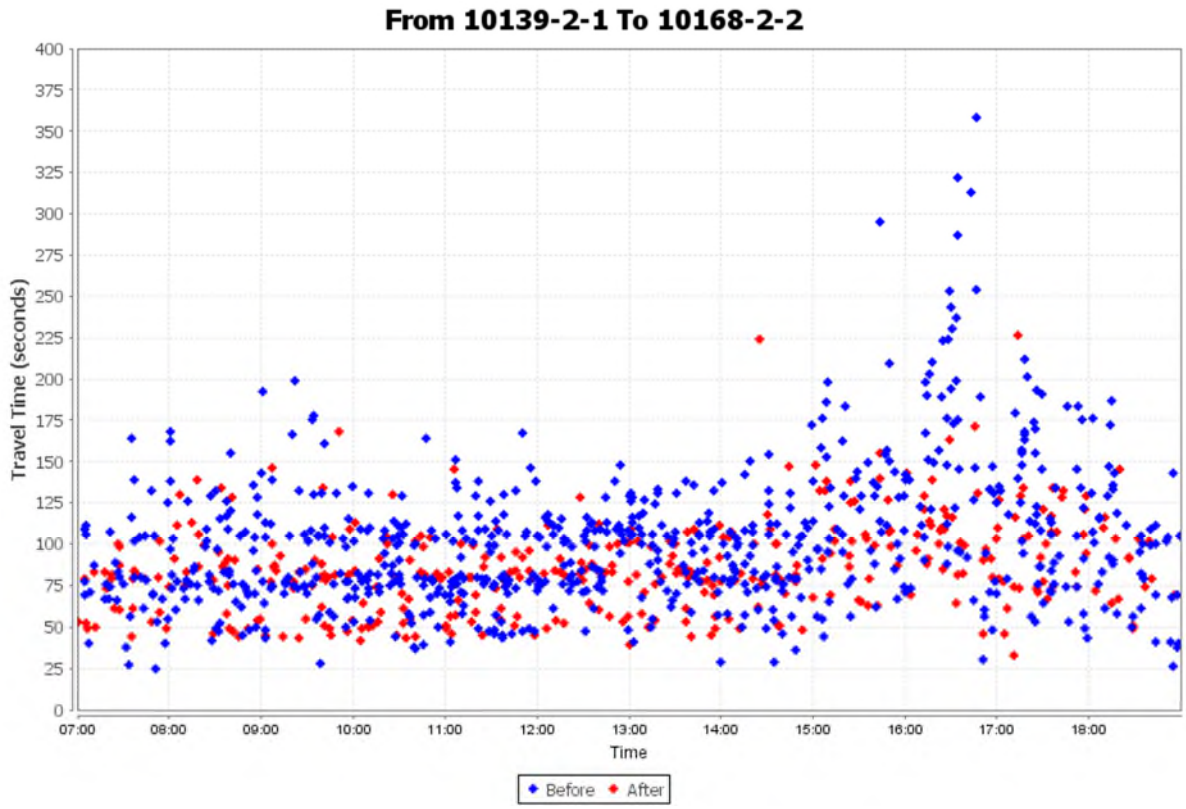
The total inbound benefits across the network strategy can be seen below. The **blue** BEFORE data is on average higher than the **red** AFTER data, with the AFTER data having nearly eliminated the higher values.

This gives an **inbound delay saving of 35s**.



The total outbound benefits across the network strategy can be seen below. The **blue** BEFORE data is on average higher than the **red** AFTER data, with the AFTER data having nearly eliminated the higher values.

This gives an **outbound delay saving of 16s** and a total **round trip average saving of 51s.**


From 10139-2-1 To 10168-2-2
Travel Time (seconds)
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Time
Before
After

TRAMS, BUSES & TRAFFIC - MANOR TOP

This network was written about in 2001 in the report 'UTMC01 Report 4: Laboratory Tests and Field Trials'

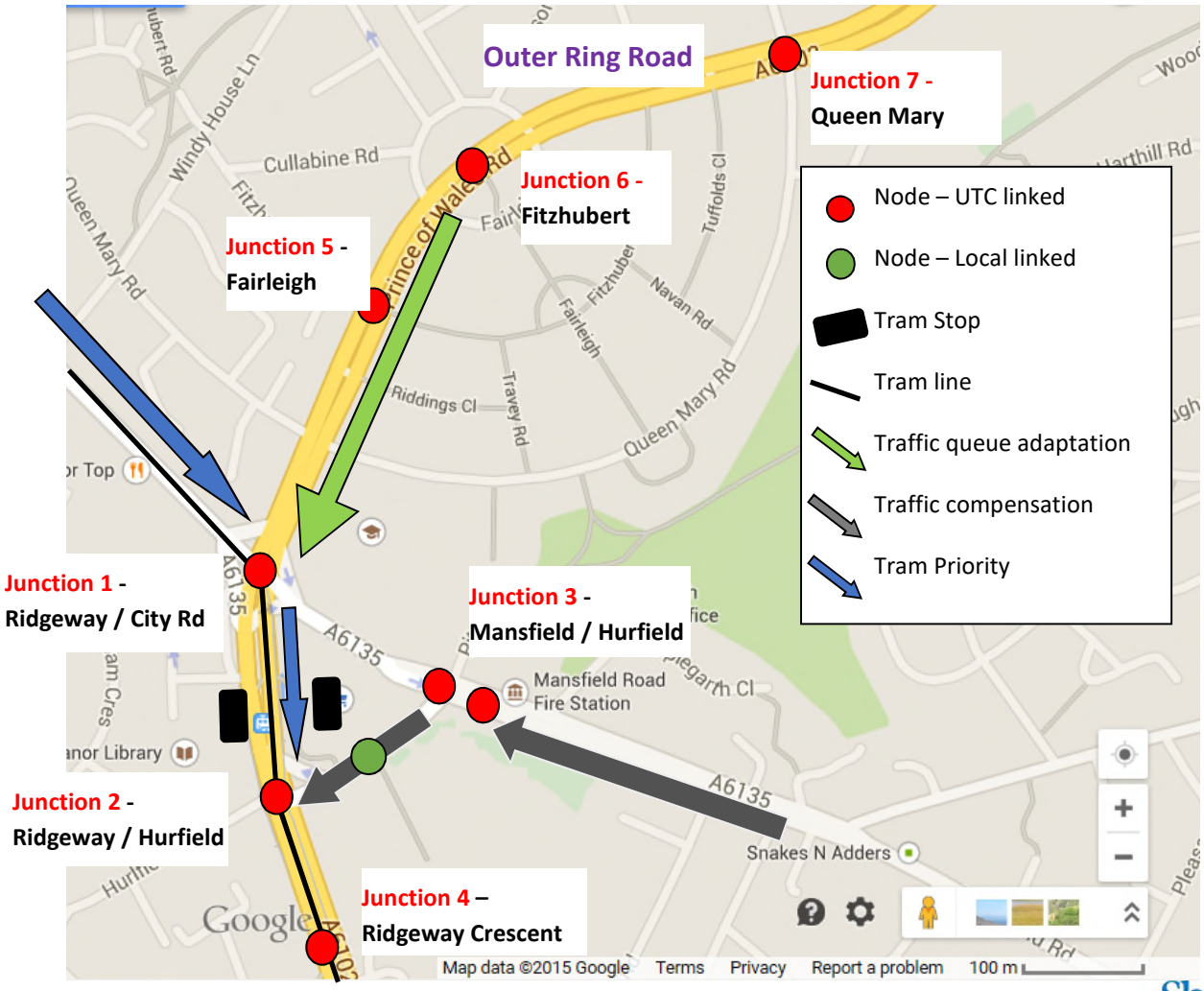
> *This report was the fourth and final scheduled report from the project UTMC01, Selected Vehicle Priority. The project was part of the research programme launched by the Department of the Environment Transport and the Regions (DETR) in 1997.*

The outcome of this project was running a tram priority strategy on Junctions 1 and 2 via the then prototype SPRUCE system. This ran for a few years until the prototype finally fell over and priority was no longer provided. In 2016 it was finally picked up by a scheme that allowed it to be revisited and the priority reinstated with the latest SPRUCE product along with adding a number of other benefits.

The Manor Top network is situated at the intersection of Sheffield's Outer Ring Road with the City Road radial route from Sheffield. The network consists of a cluster of three main signalised junctions (numbered 1 to 3 below) separated by distances of 150 to 200 metres. Junctions 4 to 7 are also coordinated but their linking is less critical.

The Tram tracks runs outbound from Sheffield through the network between Junction 1, 2 and 4 on the Outer Ring Road. Inbound tracks run in the reverse direction.

On the approach to Manor Top, outbound trams run on-street with general traffic. Just before Junction 1, a segregated section of track starts.



Since the demise of the 2002 SPRUCE prototype the outbound tram gets no priority at Junction 1 and suffers random delay. The conflicting Outer Ring Road is already over capacity.

- **Aim 1** - To provide tram priority at junction 1 on the outbound approach to Manor Top

During the PM peak there is queuing on the Outer Ring Road Southbound towards Junction 1.

- **Aim 2** – To monitor traffic congestion in the PM peak on the Outer Ring Road approach and make changes to avoid the build up of congestion.

Junction 2 does have local LRT priority and when it runs there is an associated impact on traffic. This causes significant queuing back through junction 3 and beyond – especially in the AM peak when it can block buses getting into their bus lane several hundred metres back from junction 3.

- **Aim 3** - To reduce disruption caused by local LRT Tram priority by compensating other traffic

STRATAGIES

The SPRUCE strategies designed to target the issues outlined above have been described briefly below.

AIM 1 - TRAM PRIORITY ON CITY ROAD

The tram priority uses the historic journey time profile of trams on the Outbound approach to junction 1 to alter the timings at the Manor Top network to match the trams ETA. SPRUCE calculates the best way the network needs to be moved to match the ETA and then all junctions are slowly offset in anticipation of the trams arrival time. The upstream detection point is 1.5km away and gives around 2 ½ min travel time to prepare the network for its arrival. As the tram moves nearer it passes a number of detectors which the strategy uses to fine tune with increasing accuracy when a tram is due to arrive.

Because this process is started early it minimizes disruption to traffic because small changes are spread over a number of cycles. When a tram is on the final approach it should arrive to correspond with the green window that allows it to pass through the junction without delay.

Because the tram priority relies on consistent tram journey times, if any delays are being regularly incurred because of general traffic congestion in the shared lane (usually during the PM peak) then the priority is suspended until back to normal travel times.

AIM 2 - TRAFFIC CONGESTION ON OUTER RING ROAD

There was existing queue and flow detection on the Outer Ring Road approach to junction 1 (located at Junction 5). This was used to monitor traffic congestion queuing back from junction 1. In response to flow and queue condition the cycle time at the Manor Top junction (and surrounding network) is increased to improve the saturation flow and manage a queue build up. As the congestion level builds the cycle time incrementally increases, this can result in a maximum raise from 70s to 90s.

AIM 3 - COMPENSATION ON RIDGEWAY ROAD / HURFIELD ROAD

At junction 2 tram priority has always been provided by local LRT style priority within the controllers. This priority was always effective at minimizing tram delay but due to the complexity of the network had never been able to compensate back to traffic.

The base signal plan allows two windows for trams to call their priority stage, one window before the affected traffic stage and the other just after, this helps minimize tram delay but took all the time from one traffic stage which was also a bus route. Although there is a bus lane on the approach the queuing can often block buses getting into their bus lane. The SPRUCE strategy monitors which tram window is used and gives back a proportion of the time at the next opportunity.

If the tram stage comes before the affected stage (takes green from the start) then when the traffic stage runs SPRUCE holds it on for a compensation period.

If the tram stage comes just after the traffic stage (takes green from the end) then SPRUCE waits a full cycle until the stage next runs and adds the compensation to the normal green period.

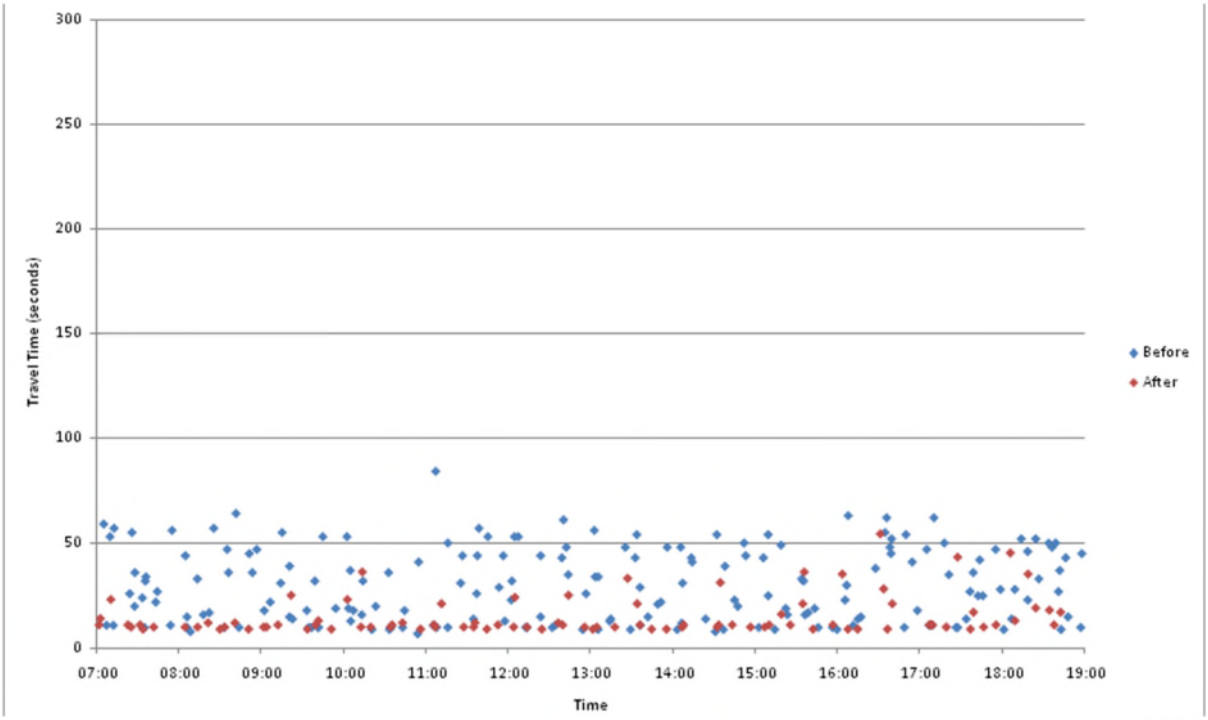
RESULTS

AIM 1 RESULTS - TRAM PRIORITY

The **outbound tram delay on at Junction 1 was reduced by 65%.** For the vast majority of trams this results in zero delay at the signals.

The chart below shows the journey time from the tram detector on City Rd to the Exit detector just after the stopline. The chart shows blue BEFORE data is clearly higher than the red AFTER data.

Tram journey time from detector on City Rd to the Exit detector

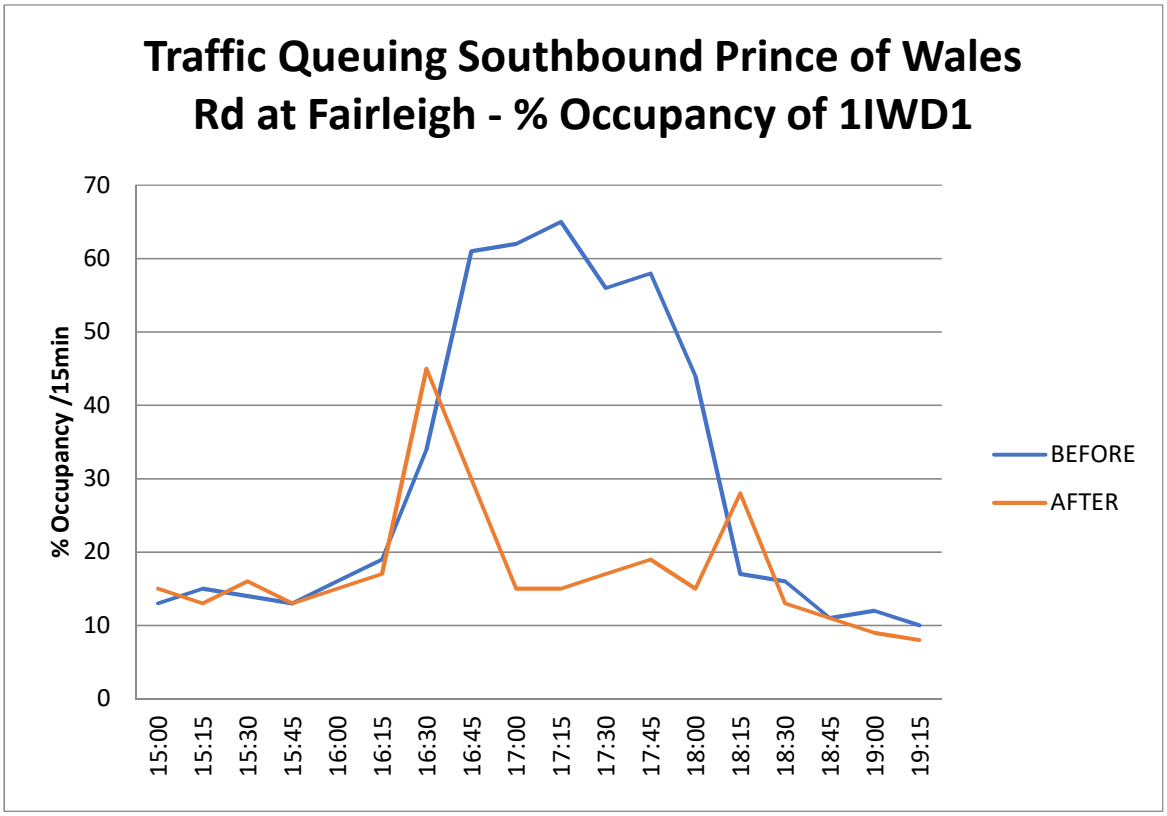


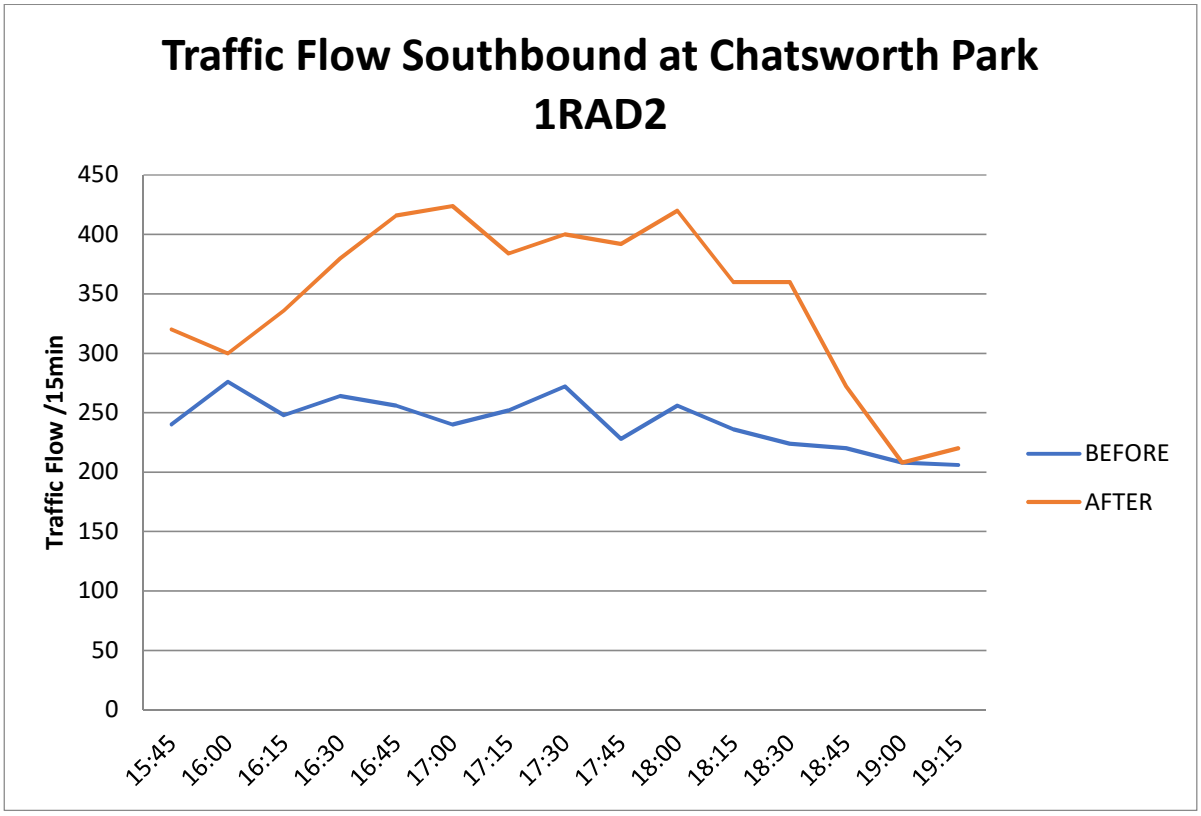
AIM 2 RESULTS – TRAFFIC CONGESTION OUTER RING ROAD

The total benefits across this network strategy are summarised below. The chart below shows the percent occupancy on the queue detector at Junction 5. Over 50% occupancy generally means traffic is queuing over the detector.

The **blue** BEFORE data shows the occupancy rising in the PM peak to over 60% and remaining there until after 18:00. The **red** AFTER data shows a rise in the early peak to 40% but this is when the strategies respond and the queue is prevented from building up at all.

To support the effects and having reduced the queuing on the approach to the junction, the traffic flow after the junction was also monitored. This gave an increase in average PM peak flow of a 25% increase.





AIM 3 RESULTS – TRAM COMPENSATION

Since the junction 2 compensation strategy went live the **traffic flows have increased up by about 10% in the AM peak**. The results of this show that due to the improvements, there is less queuing and we are getting more vehicles through the junction in the hour.

The following data has been collected from traffic counters (Monday – Friday 5 day averages):

- From 07:00 – 08:00, flows have increased by around 30 vehicles
- From 08:00 – 09:00, flows have increased by around 55 vehicles

The following data was supplied by the bus operators and shows **a saving of 107s during the AM peak**.