Bus Priority in London – getting more out of what we have

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EVERY JOURNEY MATTERS

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Introduction

Transport for London (TfL) operates the most frequent and extensive bus network in the world with around 675 routes and 9,300 vehicles. This service is vital to the economic and social wellbeing of London with 2.32 billion bus journeys made in London last year.

Buses transport more people than any other public transport mode in London. They form key links to town centres and other destinations across the city and are one of the most efficient uses of road space, playing an important role in delivering the Heathy Streets Approach outlined in the Mayor's Transport Strategy.

iBus transponder units were fitted on all London buses in 2009. Using GPS technology, this allowed TfL to know the exact location of each bus at all times. It also gave us the ability to provide bus priority at traffic signals (c.1900 locations). The iBus units communicate with Virtual Detector Points (VDPs) associated with traffic signals to help alter timings to favour a smooth journey for buses and minimise delay as much as possible.

Recent work in Network Performance Delivery has explored how we can increase levels of Bus Priority on London's network by utilising equipment in innovative ways and analysing data on the UTC system never previously considered.

Bus Priority in London and the UTC System

Transport for London's Network Performance Delivery (NPD) team is responsible for setting up, operating and optimising London's traffic control system in order that the network suits everyone. A key part of this includes Bus Priority (BP) in SCOOT, known as PROMPT (**PR**iority and inf**O**r**M**atics for **P**ublic **T**ransport).

Bus Priority (BP) at junctions works by either extending the current green signal time at the end of a stage to allow a bus through (an "Extension"), or by shortening opposing stages to get the approach that the bus is on back to green in a shorter period of time (a "Recall").

At junctions where standard BP (SBP) is not suitable Differential Bus Priority (DBP) can be implemented. DBP uses bus schedule information and prioritises only delayed buses. This allows an increased amount of priority to be given to late buses.

Below is a summary of BP equipment and configuration in London (data taken from July 2020);

- 1909 sites with Bus Priority
- 1516 sites with BP on UTC
- 1155 on UTC running SBP
- 361 on UTC running DBP
- 393 sites with BP on VA
- 6134 VDPs (Virtual Detection Points)

The following three graphs give an overview of BP activity on the UTC system. Figure 1 represents the daily total of buses seen, and shows an increasing number from October 2018 to February 2020. This figure represents every time a bus is detected at a VDP by the UTC system.

Figure 1 – Daily total (average) of buses seen by the UTC System

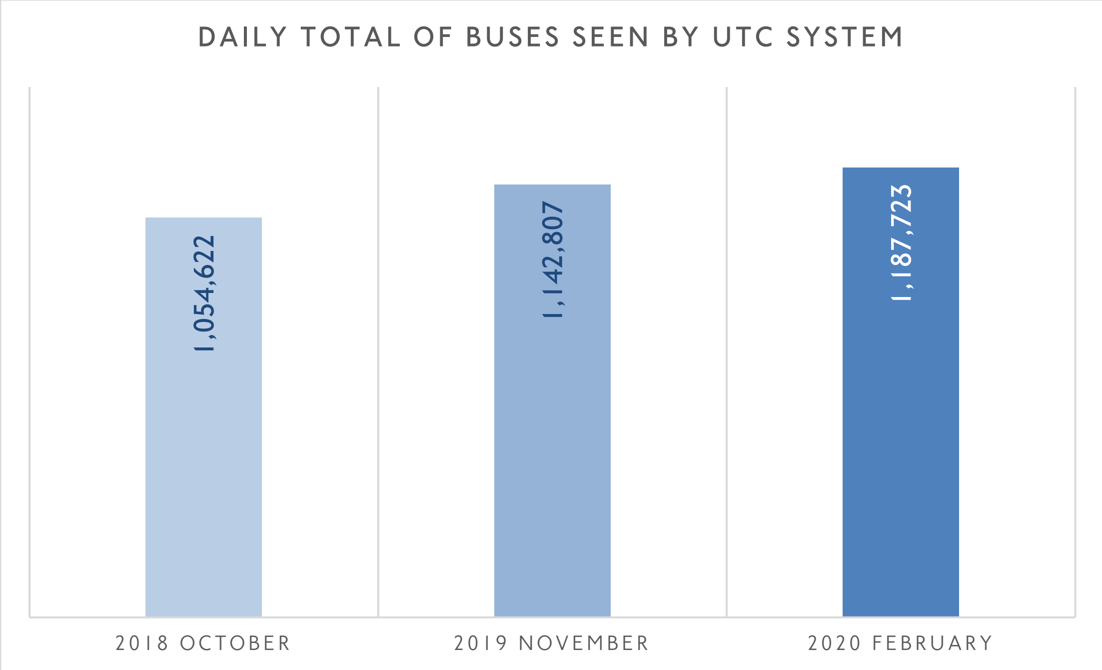
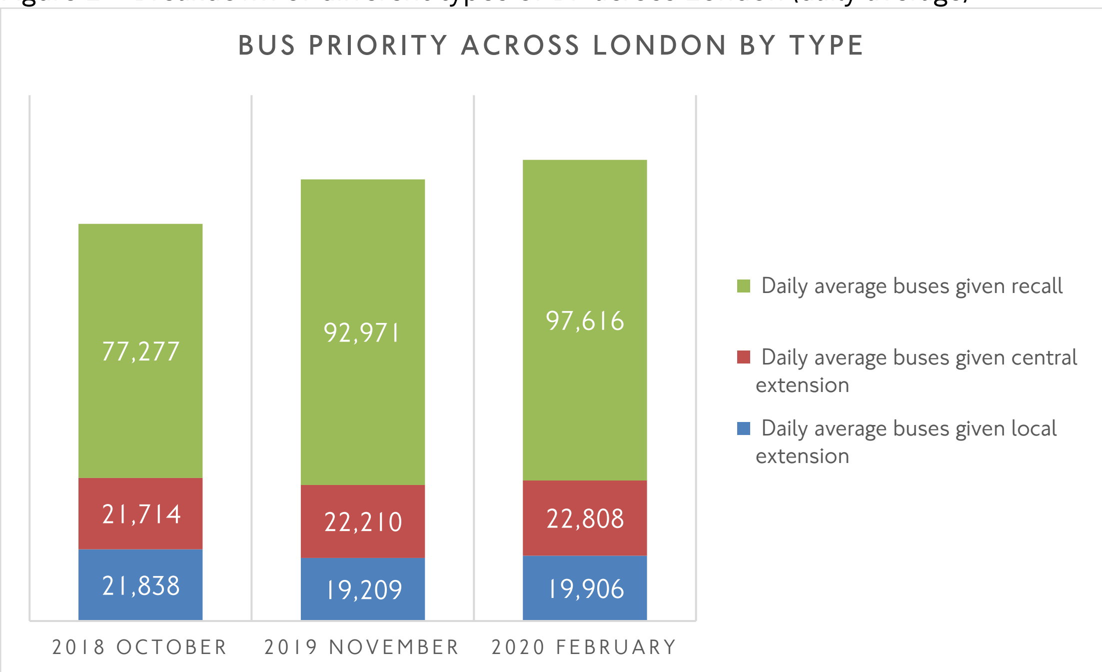


Figure 2 shows the breakdown of different types of BP granted at signals. Recalls comprise the bulk of BP activity, with Central and Local Extensions being similar in number. Extensions are rarer as a form of priority as the bus has to be approaching the signal in a smaller time "window" for this type of BP to be possible.

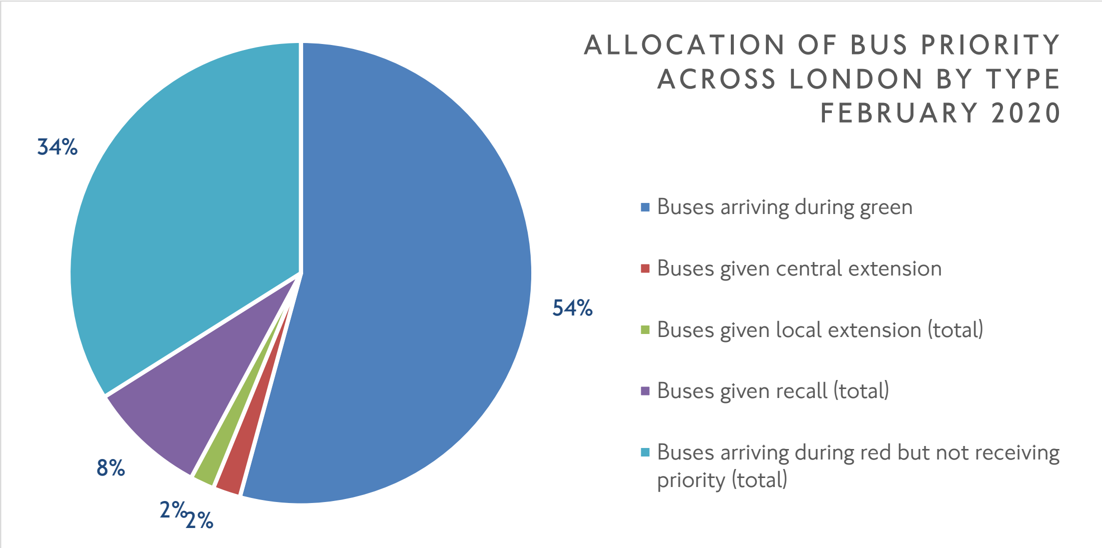
Figure 2 – Breakdown of different types of BP across London (daily average)



Both Figures 1 and 2 show increasing trends which is reflective of NPD's continued work to install and implement BP and make system changes to give as much priority to buses as possible. The innovative techniques described in this paper are helping to contribute to these trends.

Figure 3 shows data from February 2020 only, giving a percentage breakdown of BP activity for all buses detected. Over 50% of buses receive no priority as they arrive during green, and no priority is required. 34% of buses are detected but receive no priority, due to network and system constraints.

Figure 3 – Allocation of BP across London by type (February 2020)



Given that many junctions still do not operate BP, there are numerous locations where bus journey time improvements could be made. Unfortunately, due to limitations in BP hardware availability and funding, London's BP network is currently only being maintained, not expanded. It is for these reasons that the innovative techniques described in this paper have been explored and are now being implemented.

Innovative Techniques to Increase Levels of BP on the UTC System

1. Moving existing VDPs to adjacent junctions

- **Camberwell Road, LB Southwark (J08/043 & J08/277)**

The first case study relates to moving VDPs between junctions to enable BP to function at a location that didn't previously have the capability.

Camberwell Road in the LB Southwark (see Figure 4) has 14 bus routes and serves as a key North-South public transport corridor. Within this UTC SCOOT region, J08/043 (Camberwell Road / Albany Road) operates BP, with 4 VDPs (see Figure 5) but J08/277 (Camberwell Road / Bethwin Road) to the south had no BP capability.

Figure 4 – Location map of J08/043 & J08/277

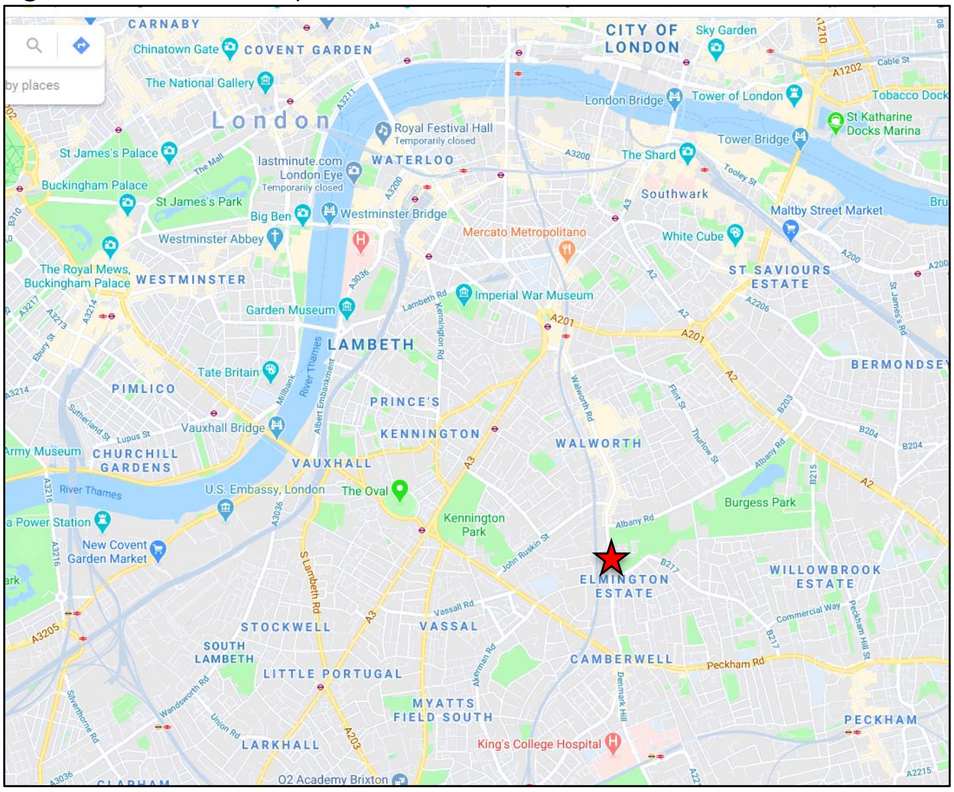


Figure 5 – J08/043, the 4 VDPs and giveway right turn movement for iSB3.

Of the 4 VDPs at J08/043, 2 of them monitor 14 routes each, whereas the other 2 monitor just one route each. Additionally, one of those (iSB3) monitors buses that immediately join a gap accepting right turn queue, making the bus difficult to precisely track and BP hard to grant accurately (see Figure 5). It was therefore concluded that two of these VDPs were underutilised and could be better used to give greater BP elsewhere.

Given the close proximity of J08/277, the clear line of sight, and the underused nature of 2 VDPs at J08/043, there was opportunity to reposition iSB1 & iSB3 to improve BP. iSB1 and iSB3 were therefore reassigned to 08/277 to the south to allow for BP to function there – where 14 routes travel North-South (see Figure 6).

Figure 6 – Updated located of VDPs, with two VDPs (*shown in blue*) moved to J08/277

Figure 7 shows the Before and After bus counts for iSB1 – previously only one route was detected, ranging from 2-5 buses per hour (and none overnight), whereas in the new location up to 70 buses per hour are detected, with detection across all 24hrs in the day. This clearly is a far better use of the VDP and more BP can be offered.

Figure 7 – Before & After bus counts on iSB1

Bus Counts For Detector B08/043/1 (before)

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Coun
01:00	2	0	0	2	
02:00	0	0	0	0	
03:00	0	0	0	0	
04:00	0	0	0	0	
05:00	0	0	0	0	
06:00	0	0	0	0	
07:00	0	0	0	0	
08:00	3	0	0	3	
09:00	2	0	0	2	
10:00	3	0	0	3	
11:00	3	0	0	3	
12:00	5	0	0	5	
13:00	3	0	0	3	
14:00	4	0	0	4	
15:00	4	0	0	4	
16:00	4	0	0	4	
17:00	4	0	0	4	

Bus Counts For Detector B08/043/1 (after)

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Coun
01:00	43	0	0	43	
02:00	18	0	0	18	
03:00	14	0	0	14	
04:00	14	0	0	14	
05:00	18	0	0	18	
06:00	34	0	0	34	
07:00	51	0	0	51	
08:00	68	0	0	68	
09:00	65	0	0	65	
10:00	67	0	0	67	
11:00	70	0	0	70	
12:00	68	0	0	68	
13:00	68	0	0	68	
14:00	68	0	0	68	
15:00	73	0	0	73	
16:00	67	0	0	67	
17:00	67	0	0	67	

Ordinarily, BP is configured on an individual site basis, but if sites are in close proximity, with good line of sight, equipment can be shared across multiple sites. This gives us the potential to increase the number of locations that have BP without the need for additional hardware. Also, there is potential to rationalise the existing equipment we have deployed and reallocate it to other suitable locations elsewhere that have no BP or aren't suitable for sharing with other sites.

2. Adding new detectors to an existing junction for use at an adjacent one

- **22/188 and 22/105 in Wimbledon TC**

The second case study focuses on adding new VDPs to a junction with BP, but using them for an adjacent junction.

Wimbledon Town Centre in the LB Merton (see Figure 8) has high concentration of traffic signals and 11 bus routes. Within this SCOOT region, J22/105 (Hartfield Road / Hartfield Crescent) operates BP, with 10 routes per hour and a suitable VDP. However, the upstream junction, J22/188 (Hartfield Road by Graham Road) had no BP configured (see Figure 9).

Figure 8 – Traffic signal installations in Wimbledon Town Centre

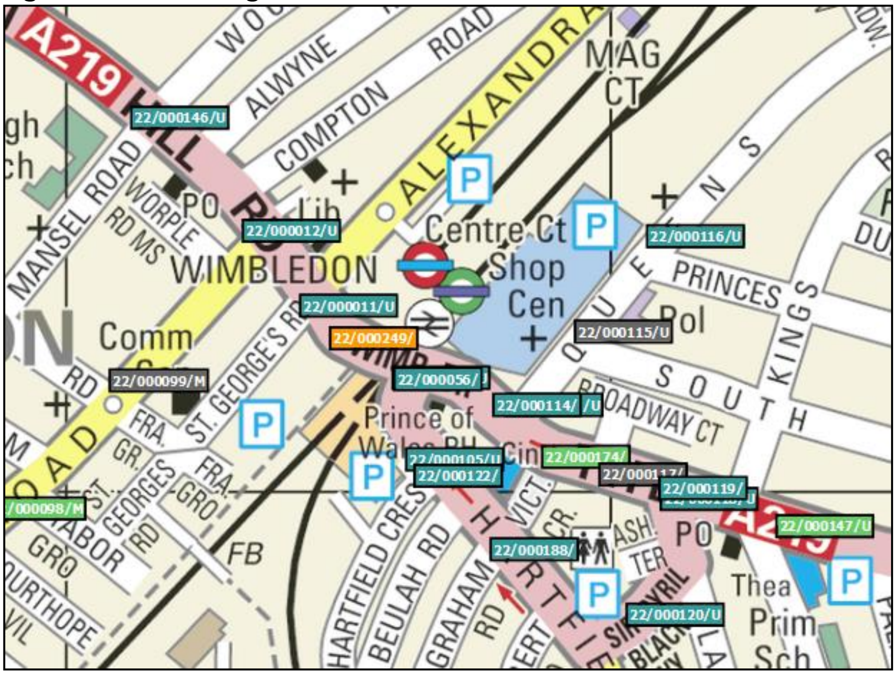


Figure 9 – Initial BP configuration at 22/105 – note one VDP on the approach to 22/105, none at 22/188

Similar to the first case study, 22/105 has excellent line of sight to 22/188 making the sharing of BP equipment a possibility. However, J22/105 only had one VDP configured, so rather than repurposing underutilised VDPs, new ones needed to be added. A new controller configuration (PROM) was created for this, with two new VDPs being added (iSB1 & iSB2), which did incur a small cost. Figure 10 shows where these new VDPs were positioned.

Figure 10 – Updated BP configuration at 22/105 – note two additional VDPs (*shown in blue*) on the approach to 22/188

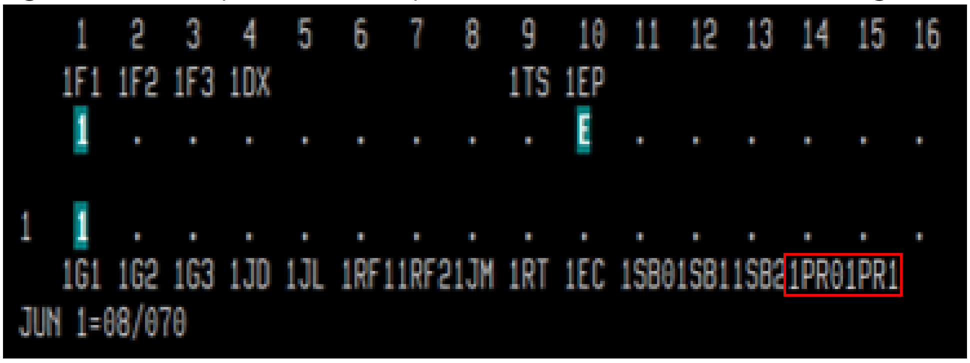
Prior to this change, 22/188 was not configured with bus priority, and buses that had stopped in the layby to board/alight passengers would have to wait for its next window of opportunity within the UTC SCOOT plan to re-join the one-way system. With new VDPs in position, BP was able to be setup, and priority granted to buses. UTC system messages run shortly afterwards for a day showed a total of 148 recalls for buses in the layby, with an average saving in delay of 20 seconds per bus.

As with the first case study, this technique allows us to increase our coverage of BP without the need for additional BP hardware. It has proven successful as a low cost solution to providing additional BP on the network.

3. Converting available bits on the UTC pattern to create new VDPs – Denmark Hill

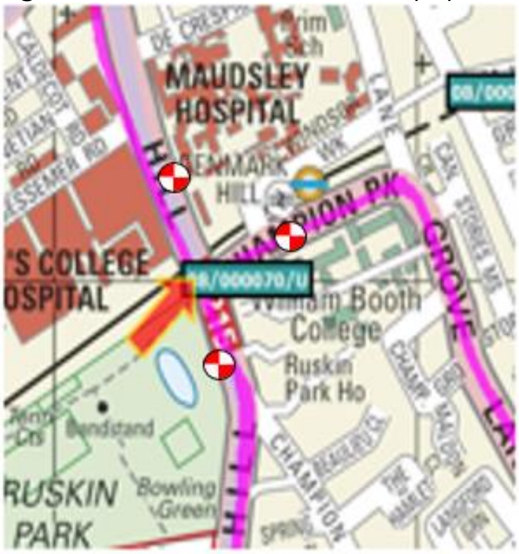
UTC bits patterns have been historically configured and future proofed with both SB (bus detection) bits as well as PR (Priority) bits (see Figure 11). SB bits are essential for BP at a junction, whereas PR bits are only required if a junction were to run Differential Bus Priority (DBP). Both SB and PR bits are similar in that they are both wired into the iBus unit and therefore already in the controller prom. Many locations in London do not require DBP, therefore there is an opportunity to convert not required PR bits into SB bits, giving greater BP possibilities at junctions that need additional VDPs. The following example expands upon this.

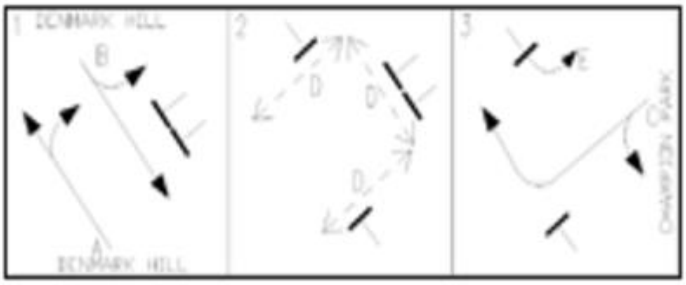
Figure 11 – Example of UTC bit pattern with both SB & PR bits configured



The junction of Denmark Hill / Champion park (J08/070) in LB Southwark has 10 bus routes, BP configured, and a single VDP on each approach (see Figure 12). However, southbound bus routes travel both straight ahead (southbound) and turn left on Champion Park. These two movements are represented by Phase B (in Stage 1) and Phase E (in Stage 3) (see Figure 12 for signal staging). Having only one VDP on this approach does not allow the unique identification of routes or movements. Therefore appropriate BP cannot be assigned accurately as SCOOT does not know what phase the bus will move in.

Figure 12 – J08/070 location map, position of VDPs and signal staging method of control





The solution to this problem is to create VDPs for each unique bus movement so SCOOT is able to accurately detect and model where buses are in the traffic queue. A new PROM with new VDPs could be added (as in Case Study 2), but this incurs a cost and delay. An alternative is to convert the unused PR bits already configured at J08/070 into new SB bits to allow VDPs to added. This can all be done in the BP configuration at a very low cost, and in a small amount of time. J08/070 does not meet the criteria for DBP given the low bus flows and relatively good junction capacity so in this example the loss of ability to run DBP was not a cause for concern. Figure 13 shows the updated UTC pattern once the PR bits were converted to a suitable SB bit. Figure 14 shows the new VDP added to the southbound approach.

Figure 13 – updated UTC bit pattern with PR bits converted to SB3

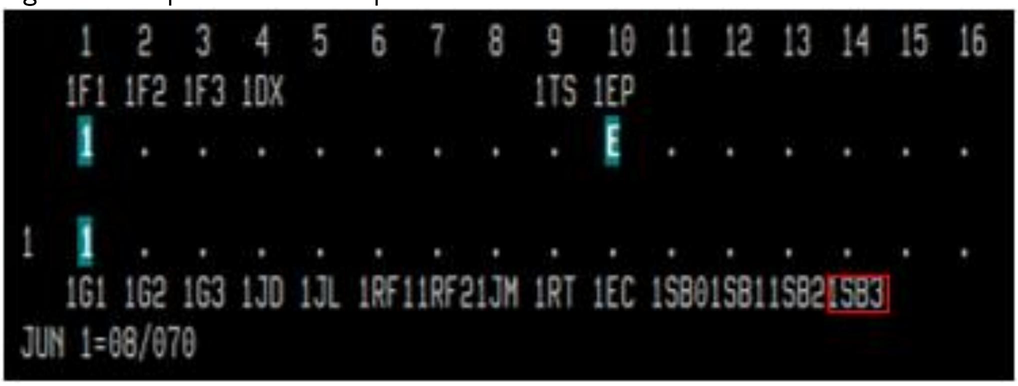
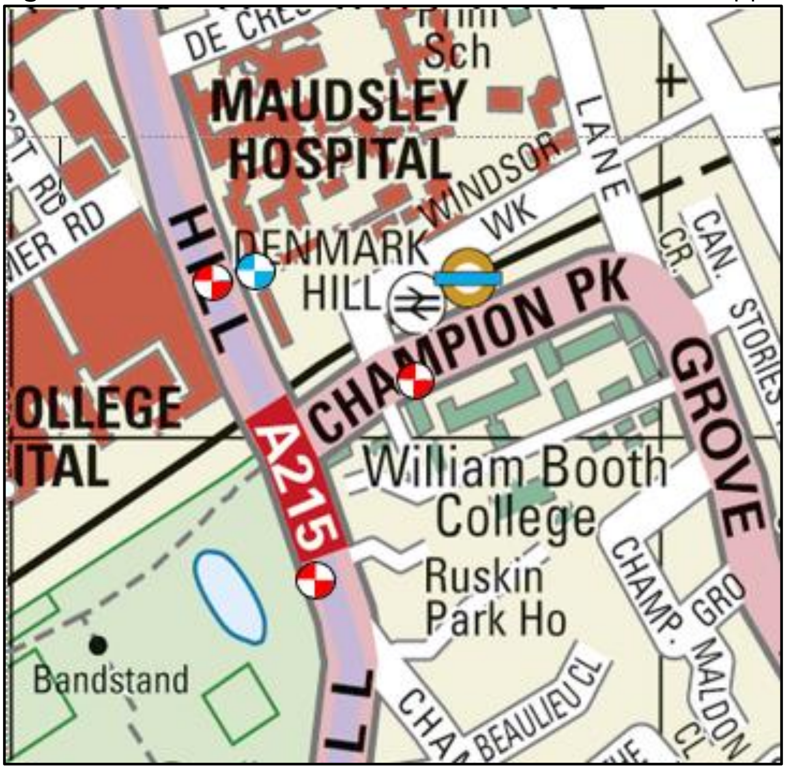


Figure 14 – J08/070 with two VDPs on the southbound approach, SB3 shown in blue



Once the PR bits were converted to a new SB bit (SB3), this could be linked to a new VDP on the southbound approach to J08/070. Unique bus movements could then be assigned to each VDP. Figure 15 shows the original and updated bus counts – previously multiple routes were captured at SB0, whereas now routes are uniquely captured on SB0 & SB3.

Figure 15 – Original and updated bus counts once bus routes were uniquely identified on the southbound approach to J08/070

Bus Counts For Detector B08/070/0

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Cou
01:00	29	0	0	29	
02:00	12	0	0	12	
03:00	6	0	0	6	
04:00	4	0	0	4	
05:00	6	0	0	6	
06:00	21	0	0	21	
07:00	35	0	0	35	
08:00	48	0	0	48	
09:00	45	0	0	45	
10:00	41	0	0	41	
11:00	47	0	0	47	
12:00	44	0	0	44	
13:00	42	0	0	42	
14:00	41	0	0	41	
15:00	47	0	0	47	
16:00	46	0	0	46	
17:00	40	0	0	40	

→

Bus Counts For Detector B08/070/0

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Cou
01:00	9	0	0	9	
02:00	2	0	0	2	
03:00	2	0	0	2	
04:00	1	0	0	1	
05:00	2	0	0	2	
06:00	12	0	0	12	
07:00	17	0	0	17	
08:00	25	0	0	25	
09:00	18	0	0	18	
10:00	19	0	0	19	
11:00	21	0	0	21	
12:00	20	0	0	20	
13:00	17	0	0	17	
14:00	21	0	0	21	
15:00	18	0	0	18	
16:00	18	0	0	18	
17:00	18	0	0	18	

Bus Counts For Detector B08/070/3

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Cou
01:00	21	0	0	21	
02:00	10	0	0	10	
03:00	4	0	0	4	
04:00	3	0	0	3	
05:00	3	0	0	3	
06:00	10	0	0	10	
07:00	18	0	0	18	
08:00	24	0	0	24	
09:00	22	0	0	22	
10:00	26	0	0	26	
11:00	24	0	0	24	
12:00	25	0	0	25	
13:00	25	0	0	25	
14:00	29	0	0	29	
15:00	25	0	0	25	
16:00	22	0	0	22	
17:00	29	0	0	29	

As can be seen in Figure 15, routes are now separately detected and can be assigned accurate BP based on what movement they are undertaking.

Prior to this change being made, BP was inhibited on this approach (due to the inability of SCOOT being able to accurately model buses and assign priority). However, since the change was implemented, BP was enabled and over a typical 24hr period 70 BP recalls were permitted, and over 30 extensions were granted.

4. High Priority Routes – PR bit manipulation

DBP uses bus schedule information to determine whether a bus is early, on time or late. Depending on its status, a bus will be assigned a combination of PR bit returns which then allows PROMPT to make a BP decision.

When configuring BP in the bus configuration routes are coded and standard priority levels set. The configuration of PR0/PR1reply and the associated lateness of the bus has been standardised and below are the four possible combinations once a bus is detected:

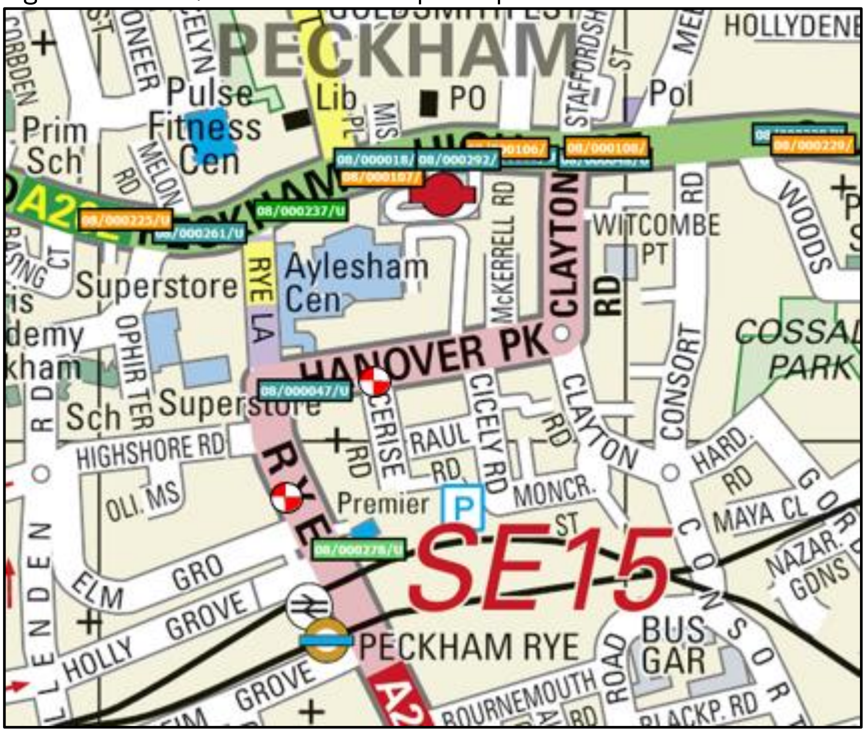
1. A SBn bit with no PR bits indicates a bus within one minute of schedule or early
2. A SBn bit with a PR0 bit indicates a bus 1-3 minutes behind schedule
3. A SBn bit with a PR1 bit indicates a bus 3-5 minutes behind schedule
4. A SBn bit with both PR0 and PR1 bits indicates a bus over 5 minutes behind schedule

Scenario 1 grants no BP, with ever stronger BP being granted from scenarios 2 to 4.

The following example details how a recent study sought to test whether certain routes could be prioritised at a junction operating DBP regardless of lateness by manipulating PR bit returns different to those standard values shown above.

J08/047 (Peckham Rye / Hanover Park) is located in the LB Southwark, just south of the A202 Peckham High Road (TLRN) (see Figure 16). The junction has 14 bus routes, including 5 night bus routes and is already configured to run DBP.

Figure 16 – J08/047 location map and position of VDPs



Different BP thresholds are set which apply depending upon the bus lateness (see Figure 17). Priority level 1, indicating a bus 1-3minutes behind schedule, allows BP extensions, but not recalls. Priority levels 2 and 3 (3-5minutes behind schedule and over 5mins behind schedule respectively) offer both BP extensions and recalls, with higher values set in SCOOT for priority level 3 to offer the best chance of BP occurring.

Figure 17 – Priority levels configured in the SCOOT system.
(Note: The higher the BESAT & BRSAT value the more likely BP will occur. A value of 0% is used to indicate that that particular mode (extension or recall) is not permitted for a bus of that priority level.)

PRLR	BESAT	BRSAT
0	0	0
1	120	0
2	140	120
3	160	140
4	0	0
5	0	0
6	0	0

Buses detected, and what priority level has been assigned, can be analysed in the UTC system. Figure 18 (left table) shows a daily count of buses at J08/047, giving both total count and the priority level count. These figures have been generated according to the standard DBP configuration (detailed above). Note the P3 counts that correspond to buses over 5minutes behind schedule.

But, what if a certain route were deemed more important than other routes at J08/047 – it could be a high patronage route, a high frequency route, an express route or a high revenue route? At J08/047 the BP configuration was modified so that whenever a Route 37 was detected, both PR0 and PR1 are returned, thus designating that bus "behind schedule" (priority level 3) regardless of its actual schedule deviation. Priority 3 BP thresholds then apply and the maximum possible opportunity for BP for that route is given.

The right hand table in Figure 18 show the daily P3 count once this change was made to the BP configuration. It is evident that the hourly totals are higher than the P3 count in the left hand table. This proves the theory that a certain bus could be configured as "high priority" if there was a requirement to do so.

Figure 18 – Priority level counts before (left) and after (right) Route 37 test was configured and undertaken

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Count
01:00	55	32	13	4	6
02:00	24	0	0	24	0
03:00	18	0	0	18	0
04:00	15	0	0	15	0
05:00	24	0	0	24	0
06:00	44	0	0	44	0
07:00	75	53	15	6	1
08:00	93	64	19	6	4
09:00	89	57	14	14	4
10:00	85	55	17	3	10
11:00	90	58	18	5	9
12:00	93	50	20	9	14
13:00	89	55	22	7	5
14:00	88	59	15	10	4
15:00	89	52	14	15	8
16:00	86	55	9	11	11
17:00	84	45	15	8	16

Hour Ending	Total Count	P0 Count	P1 Count	P2 Count	P3 Count
01:00	50	29	10	1	10
02:00	20	0	0	20	0
03:00	18	0	0	18	0
04:00	17	0	0	17	0
05:00	23	0	0	23	0
06:00	46	0	0	46	0
07:00	72	43	8	9	12
08:00	87	55	16	4	12
09:00	86	49	10	10	17
10:00	83	45	7	7	24
11:00	91	55	14	7	15
12:00	93	58	16	5	14
13:00	92	56	10	11	15
14:00	88	49	14	5	20
15:00	87	47	16	7	17
16:00	85	45	8	10	22
17:00	90	49	10	12	19

This study proved the concept and this methodology has now been employed for a recently launched Express bus route in West London, the X140. At all junctions, the X140 has been configured as "high priority" to offer the maximum BP possible.

A further development of this, is to add a PR2 bit on the UTC bit pattern in the PROM, to give a further level of differentiation, and priority, between routes. With even higher values configured in SCOOT this would offer even greater BP for "high priority" routes if desired. Figure 19 illustrates this. The drawback of this technique is that a new PROM is required which incurs a greater cost than just manipulating the BP configuration as detailed in this study.

Figure 19 – Addition of PR2 bit allows specific Priority Level 4 values to be added in SCOOT. If desired, levels 5 & 6 could be configured also.

PRLR	BESAT	BRSAT	SKSAT	
0	0	0	0	No PR bits return
1	120	0	0	PR0 only
2	140	120	0	PR1 only
3	160	140	0	PR0 and PR1 return
4	199	199	0	PR2 only
5	0	0	0	PR0 and PR2 return
6	0	0	0	PR1 and PR2 return

5. Bus Recovery / SCOOT Override Data

When BP occurs in SCOOT, there is a period of time where SCOOT may be overridden to both assist the bus through the junction (when priority is granted), and as a period of recovery takes place. SCOOT Traffic Handbook Release Note 484 describes Recovery as the process of resynchronisation with the normal SCOOT stage timings after bus priority has finished. Four methods of recovery are available and which method operates is configurable; different methods can be configured for use after extensions and after recalls. The configuration can be on a node basis but normally the same methods would be used throughout the area.

By analysing SCOOT message data, it is possible to ascertain how long a junction spends in Override. As part of a recent study, three specific elements to Override Time were considered;

1 – Junctions with a very low amount of time spent in Override – this could indicate a junction that has very low BP activity or a fault. Could time be spent reviewing this site to increase BP performance, or indicate poorly located BP equipment that could be relocated elsewhere?

2 – Junctions with a large amount of time spent in Override – this could highlight a junction with too much BP activity, or a junction struggling to recover from BP. More time spent in Override is less time spent on SCOOT control, optimising timings for all users. Time spent reviewing system parameters could improve BP performance at this location also.

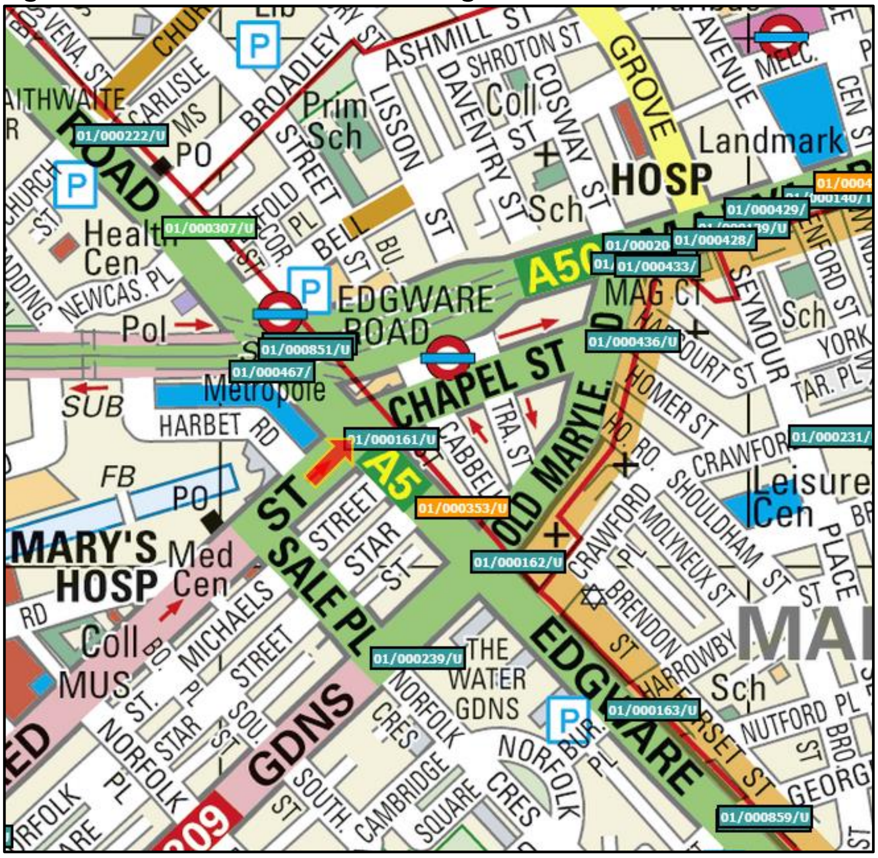
3 – **Junctions which "max out" in Override** – the maximum time spent in Override is 240secs. After this time expires, regardless of the resynchronisation, the junction is handed back to SCOOT. Junctions which frequently "max out" suggest an inability to recover, and warrant review to see if system parameters can be adjusted to improve Recovery. As mentioned above, whilst in Override, SCOOT is not optimising effectively so reviewing these junctions could improve both general and BP performance.

For this study, SCOOT message data for the entire UTC system was acquired over a period of months and the worst offending junctions identified and investigated. Investigations were undertaken to understand why Override time was very low, very high, or reaching maximum value.

Example 1 – Low Recovery Time junction, J01/161 Edgeware Road / Praed Street / Chapel Street)

J01/161 (Figure 20) was identified as a low recovery time junction, with opportunity to increase BP performance. SCOOT message data acquired revealed this junction spent on average only 60 seconds per day in Override.

Figure 20 – Location of J01/161 (Edgeware Road / Praed Street / Chapel Street)



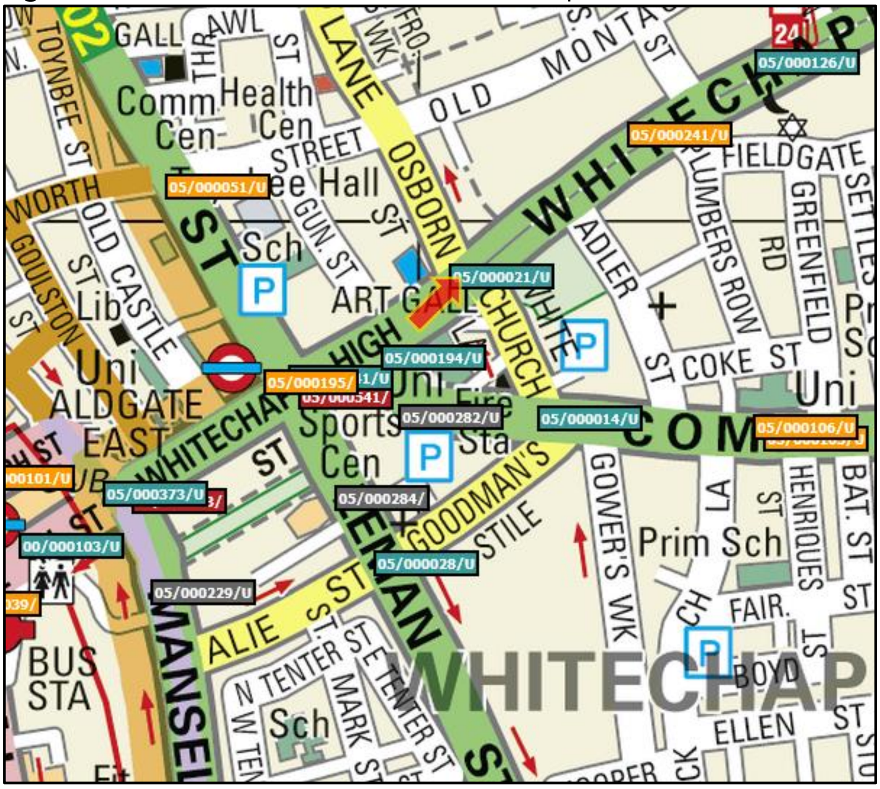
A thorough review of this junction was conducted and numerous system BP parameters updated to enable BP to be more active. Previously only central extensions were permitted on Edgeware Road but, after review, both recalls and extensions were permitted on all approaches. Suitable BESAT & BRSAT values were entered to facilitate this without overly impacting junction operation.

Further SCOOT message data was acquired after system parameter changes were made and the time spent in override increased (from 60 seconds per day) to over 22,000 seconds (366 minutes) per day. This clearly indicates a significant increase in BP activity at this junction.

Example 2 – Low Recovery Time junction, J05/021 (Whitechapel Road / Osbourne Street / Whitechapel High Street)

J05/021 (Figure 21) was also identified as a low recovery time junction, with opportunity to increase BP performance. SCOOT message data acquired revealed this junction spent on average only 656 seconds per day in Override.

Figure 21 – Location of J05/021 – Whitechapel Road / Osbourne Street / Whitechapel High Street



As with J01/161, a review of the junction was undertaken to assess BP system parameters. On this occasion, one of the bus detectors was found to be inhibited meaning that no BP was occurring on one of the approaches to the junction. As part of the review, the bus detector was enabled and updated with appropriate parameters.

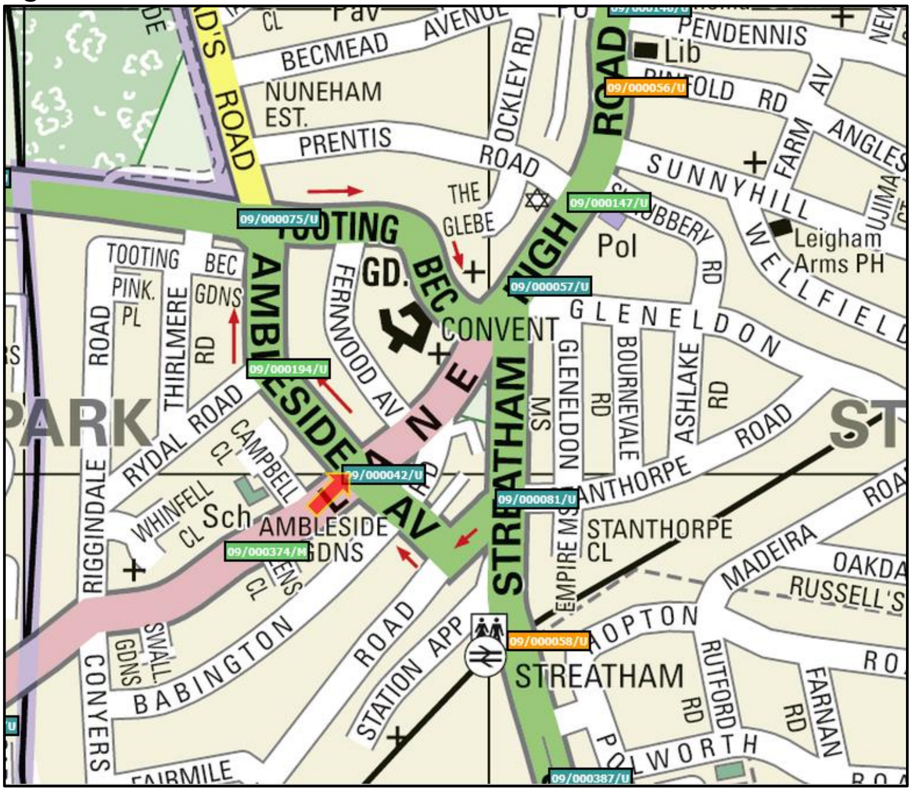
After the changes were made, SCOOT message data was acquired, and the time spent in override increased (from 656 seconds per day) to over 4378 seconds per day. Again, this indicates an increase in BP activity at this junction.

Other reasons for low override times which have been identified include DBP being enabled at all times of day (and not just at suitable time periods) and BP installed at a pedestrian crossing (where only extensions are possible).

Example 3 – "Max out" Override Time junction, J09/042 (Mitcham Lane / Ambleside Avenue)

J09/042 (Figure 22) was identified as a "max out" override time junction. SCOOT message data revealed this junction hit the maximum override timer of 240s between 20 and 25 times times per day. This means it was unable to recover from BP granted and resynchronise with SCOOT, and was therefore dropped off of BP mode and back onto SCOOT in whatever state it was in.

Figure 22 – Location of J09/042 – Mitcham Lane / Ambleside Avenue



An investigation was undertaken and it was found that 7 routes (totalling almost 50 buses per hour) travel through the junction. In addition, BP was configured to allow both extensions and recalls with fairly low thresholds, and various SCOOT stage minimums were applied.

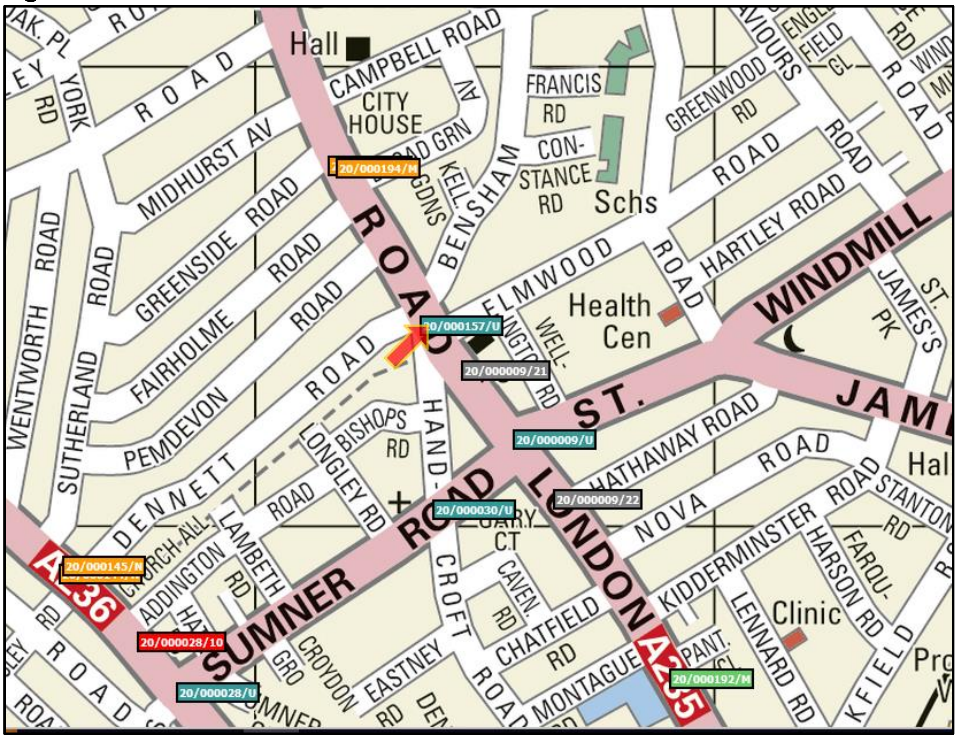
This configuration (with high numbers of buses requesting recalls coupled with minimums on SCOOT stage length) resulted in BP being granted, but then recovery being very restricted for how it could alter junction timings to resynchronise. As a result, resynchronisation could not occur within 240seconds and the max timer was reached.

Options have been identified to resolve this issue, but testing is on hold (at the time of writing) due to changes in traffic patterns resulting from the coronavirus pandemic. These options include adjusting the thresholds for granting BP, removing some of the restrictions on SCOOT stage lengths, and reviewing the recovery method (currently set as "degree of saturation").

Example 4 – High Recovery Time junction, J20/157 (London Road / Sumner Road)

SCOOT message data revealed J20/157 (see Figure 23) to be a high Override time junction – spending 20600 secs per day in Override.

Figure 23 – Location of J20/157 – London Road / Sumner Road



Investigation revealed 8 bus routes travelling through this junction, with up to 80 buses per hour. Both extensions and recalls were configured, with recall thresholds especially being noticeably low given bus numbers and average junction degree of saturation.

It was concluded that the thresholds to allow recalls were set too low, meaning that once a recall was granted, the junction was unable to recover quickly and therefore spent a long time in override. Given that this wasn't identified as a "max out" junction, recovery does occur, but the data suggests it still taking longer than desired.

As with example 3, testing to resolve this high override time is on hold (at the time of writing) due to changes in traffic patterns resulting from the coronavirus pandemic. Adjustments to the BP thresholds or recovery method are two solutions being considered.

In Examples 3 and 4, the type of recovery method configured is briefly mentioned. UTC junctions in London are broadly configured using the "Degree of Saturation (DoS)" recovery method (where target degrees of saturation of used for recovery), but as noted in the introduction to this section, four recovery methods are available. As part of this work, different recovery methods are being investigated to see whether they are more suitable at certain junctions than using DoS.

All four examples given above illustrate how SCOOT message data can identify problems with BP operation at junctions. This data led approach allows us to target staff resource at these locations and further junctions identified by SCOOT Override message data are being reviewed this financial year to maximise the use of BP equipment.

Conclusion

This paper has outlined a number of innovative techniques that have allowed us to maximise the usefulness of our BP equipment and increase our BP capability. In the examples shown, we have significantly increased the number of opportunities for buses to get through the network with lower delay, and often at extremely low cost. TfL's network managers have been trained on how to implement these techniques, and we provide a constant source of support to them. Our hope is that this sharing of knowledge leads not only to more BP on the network, but also further innovation.

These techniques also open up brand new opportunities for us in the future, such as prioritising express or high patronage bus routes. We are constantly trying to improve our knowledge of the system, and will continue to look for new ways to getting the most out of what we already have.

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