Untangling Canford Bottom

The A31 Canford Bottom roundabout, is a Highways England, signalised 'hamburger' style site, towards the south of England, outside Bournemouth. Figure 1 shows the site location. With six signalised approach arms, four of which are local authority roads and two the A31 trunk road, the site can be incredibly busy throughout the week and especially so on Fridays and weekends in holiday season. Being relatively compact for the volumes of traffic it carries, circulatory links are short, with vehicle queuing space as limited as 20m in places. Figure 2 illustrates the general layout.

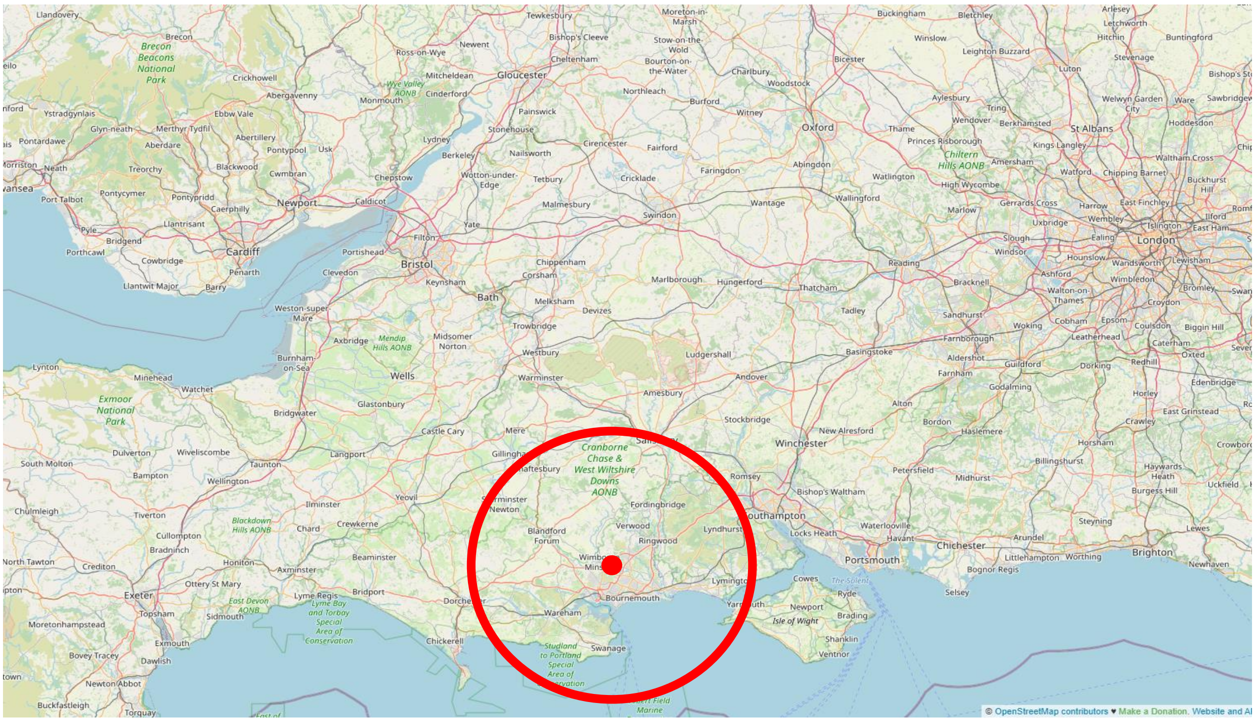

Figure 1 Site location

Figure 2 Canford Bottom Roundabout Layout

Over recent years, Highways England Area 3 and their Maintainer Kier, have received various complaints from the public regarding the site, and in general there were concerns over the complexity and coordination of the signals, along with a number of collisions and high levels of congestion in the area.

Canford Bottom Roundabout, along with a number of other Highways England Area 3 sites, was selected to be part of a 'quick win' reoptimisation project, resourced by 4way Consulting (design/validation), Kier (project management) and telent (installation works and Regional Technology Maintenance Contract (RTMC) signal maintenance contractor). The aims of the project were:

- Identify causes of problems at key signalised installations.
- Where possible, immediately implement improvements in the signal control, typically through MOVA or SCOOT validation.
- Design 'quick win' improvements for the signal control, typically through controller and MOVA reconfiguration and very minor physical enhancements.
- Implement and validate the improvements and monitor success.

An initial desktop review was followed by a site visit in November 2019, to start the process and identify key attributes and problems at the site. These were:

- Site operated 6 stream, linked MOVA for majority of day, with a UTC Fixed Time (FT) plan in operation during weekday evening peaks. Two controllers in operation (ST900 ELV), running the northern and southern halves of the site.
- The controller and MOVA operation was incredibly complex, with the complexity such that it was unrealistic to reverse engineer the operation in a timely fashion to implement any validation improvements in the MOVA operation.
- All approaches are primarily single lane, with short flares to two or three lanes on final approach to the signals. Common for vehicles on approaches to be bunched behind a slow moving vehicle, leaving a large gap in front and long queue behind the slow vehicle.
- All exits primarily single lane, although both A31 exits have an 80-100m two to one lane merge.
- High number of HGVs using A31, including multiple occurrences of long, wide, heavy or slow vehicles and also of slow farm vehicles. See Figure 3.
- The site can suffer significant exit blocking on southbound A31, especially during the evening peak. See Figure 4. It was believed the FT plan was put in place for the evening peak due to MOVA struggling in the exit blocked conditions. Exit blocking could also occur on the northbound A31 exit, although less severely and less frequently.
    - Exit blocking was found to be the single biggest cause of congestion. Under exit blocked conditions, queues can quickly build especially on A31 and the two local authority roads on the eastern side of the site. When the A31 exits were clear, queue lengths were generally short.
- Under MOVA control, the coordination of the signals was inconsistent, sometimes acceptable, but often erratic and inappropriate. Coordination of the signals through the A31 cut through was such that vehicles could clear easily, or may get stopped multiple times, and take three cycles to clear the site, even in otherwise ‘free-flow’ conditions. Coordination around the circulatory was also often inconsistent, which seemed to contribute to drivers struggling to understand the signal arrangement. Stop/start/stop type behaviours were seen across the multiple stop lines around the site. Internal blocking of conflict areas and box junctions was common, delaying other movements. Common to see, hear, or even smell, the impact of heavy, abrupt braking as vehicles received an unexpected red signal.
- Frequent red light running observed, sometimes seemingly unintentional, as drivers struggled to understand the signal layout and operation, at other times seemingly intentional.

Figure 3 Multiple occurrences of large, slow vehicles on A31

Figure 4 Southbound A31 exit blocking

Following the initial visit, plans were made to enhance the operation of the site, through changes to the controller and MOVA configuration. The changes would concentrate on:

- Improving coordination along A31, through the internal cut through, ensuring consistent and appropriate movements, minimising stop/start behaviours.
- Improving coordination around the circulatory, to provide consistency in operation, minimising stop/start behaviours and blocking of conflict/box junction areas.
- Making MOVA control more resilient, such that it can be in operation 24 hours a day, irrespective of the presence or absence of exit blocking.
- Achieving all of the above, with a simpler configuration of the controllers and MOVA.

Original plans to simplify the site's MOVA operation had considered removing some of the signals on the minor approaches to the site and to recable the controllers to amend the stage streams, allowing all A31 movements to be on the same controller. During the design phase these possibilities were discounted, due to difficulties in providing a to-standard and workable priority control arrangement and costs in Traffic Management to ensure a safe and resilient period to recable and test any physical controller modifications. Planned changes in MOVA therefore settled on maintaining all the signalised locations, and also maintaining all the existing stage streams.

To achieve the consistent level of coordination desired, it was known that some level of compromise in the level of flexibility given to MOVA would be required. This was going to lead to controller configuration changes, which given the busy, hamburger nature of the site, would mean significant traffic management (TM) requirements and overnight works to implement, which would be costly. It was also likely to mean there would be ‘no going back’ once the changes were implemented.

To ensure the planned changes in MOVA were going to be successful, a temporary trial of the intended ‘style’ of operation was undertaken, over 1 week, in December 2020, outside of any specific Covid-19 ‘lock down’ restrictions. This involved new CLF plans being put in place on the original controller configurations.

The CLF operation concentrated on achieving consistent and appropriate coordination of the signals on the A31 (including the cut through, by use of phase delays at end of green to clear the internal reservoirs), along with ‘best as possible’ coordination around the circulatory, reducing stop/start/stop/start behaviour and minimising risk of blocking of other movements.

Overall, this CLF trial proved the success of using the more consistent and enhanced coordination of key movements around the site, along with reduced stop/start/stop behaviours. However, the phase delays used, whilst successful at clearing the internal A31 reservoirs did introduce long interstage periods, and obviously the fixed nature of the CLF did not react to changing traffic conditions.

To provide the desired consistent operation in MOVA, and to minimise lost time in the interstage periods, two specific techniques were developed. Firstly, a method that would give absolute fixed coordination between the two A31 streams on two different controllers, whilst still providing full flexibility in green duration, and secondly a method to give a variable phase delay (on the older controller type without that functionality).

To understand these techniques, it is needed to understand the basic controller and stage arrangements and operation. Figure 5 gives the basic site operation for the A31 nodes (other signalised nodes are in separate streams. Those A31 nodes at either end of the hamburger cut-through are on separate controllers but run very similar stage sequences. Using conventional MOVA linking, it would be straight forward to provide coordination in a single direction only (e.g. southbound) and deliver ‘clean’ start and ends of green for that direction. However, whilst typically the site is busier southbound than northbound, this varies greatly cycle by cycle and with erratic flows, it was considered necessary to coordinate in both directions.

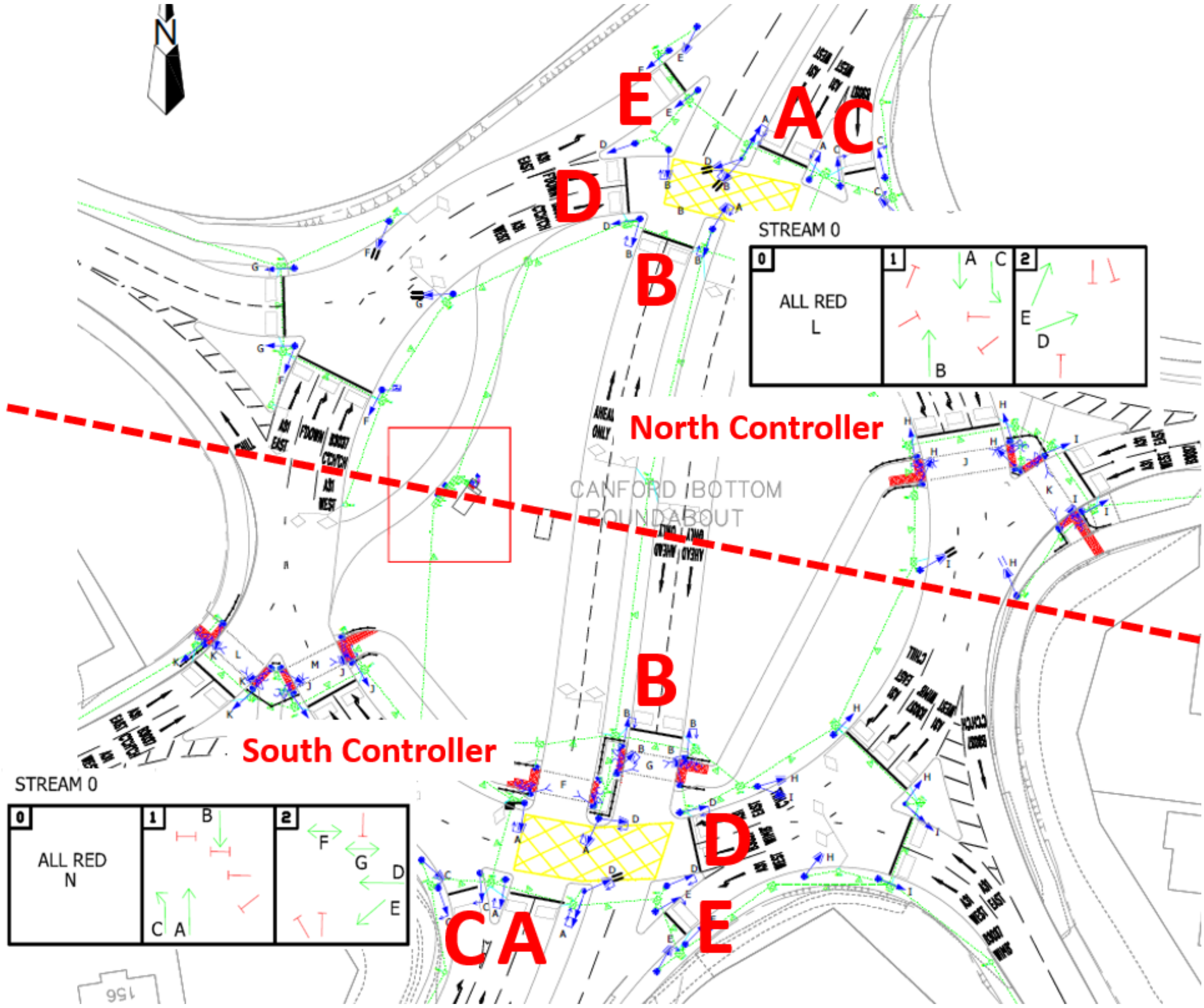

Figure 5 Basic A31 Controller and stage stream operation

Using conventional linked MOVA in both directions (which is similar to the original operation) can result in the southbound green, holding northbound green, which holds southbound green (e.g. north controller stage 1, holding south controller stage 1, which holds north controller stage 1 etc). To get around this issue, various techniques can be used, but from author experience these can lead to unwanted flexibility creeping in (e.g. one controller drops out of sync) or virtually fixed time performance being introduced. Neither was desired.

The desired performance was that, without fail, both controller stage 1 would start together and then end together, with a variable duration of those stage 1, based on traffic conditions. Then, following a phase delay on the internal cut through movements, both stage 2 would start together and end together.

To achieve this, whilst the two streams are on separate controllers, they would need to be controlled as if they were in the same stream, on the same controller, with a single MOVA stream in control of all A31 movements. The schematic in Figure 6 highlights the concept.

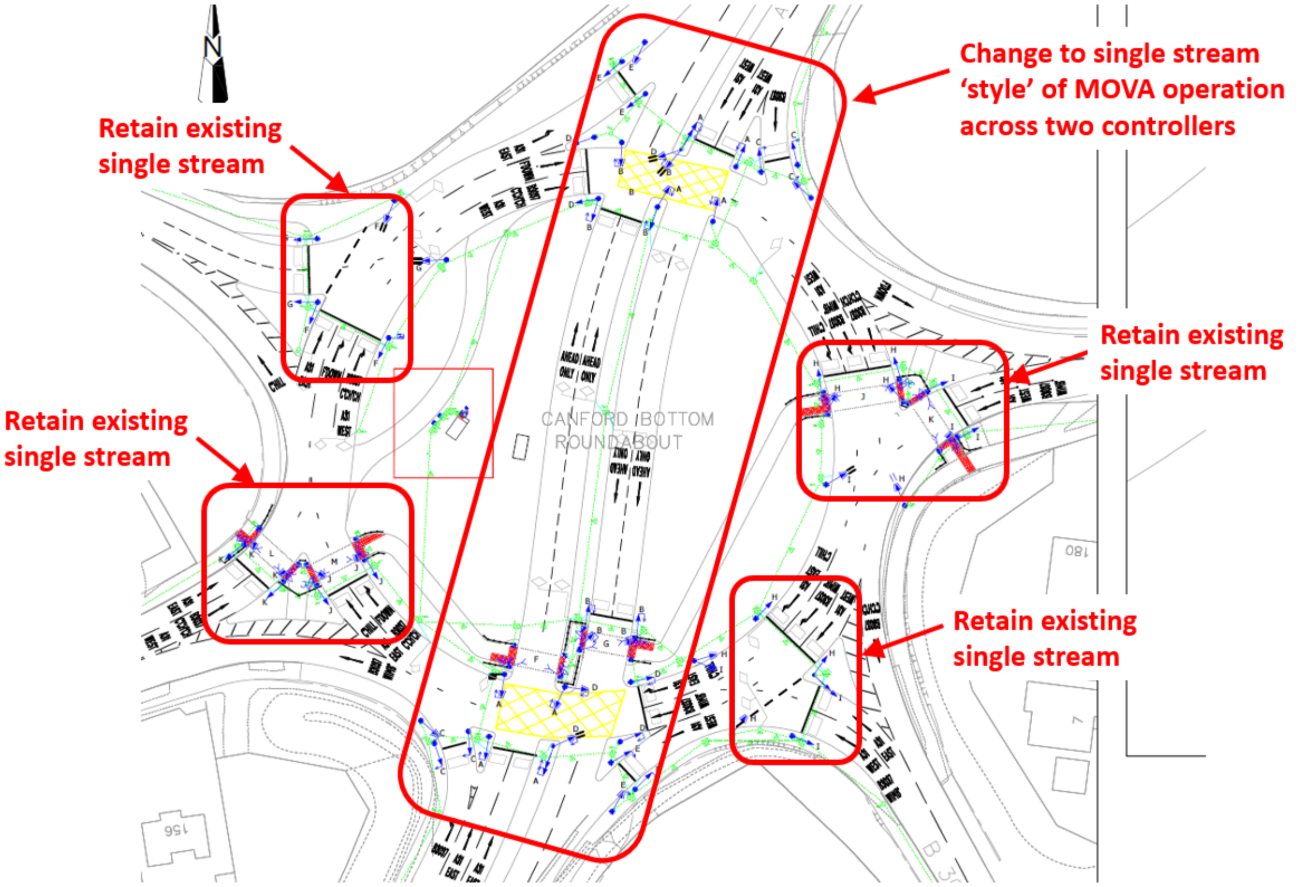

Figure 6 MOVA stream arrangement

To technically achieve this arrangement a number of elements were used:

- Multi core link cables installed between both north and south controllers.
- All detector inputs on the north controller, for the A31 stream, sent as mimic along the link cable to the south controller.
    - All detectors on the north and south A31 streams passed to MOVA, as if they were in a single stream.
- Phase confirm bits for the north controller A31 stream sent along link cable to the south controller.
    - North controller phase confirms and similar in south controller paired together and passed to MOVA as a single stage confirm reply for each respective stage (A31 in stage 1, both circulatories in stage 2)
- Force bits received from MOVA at the south controller, and as well as controlling the relevant stages there, they are sent as mimic along link cable so that they are similarly received and used at the north controller.
- The above details are described schematically in Figure 7.

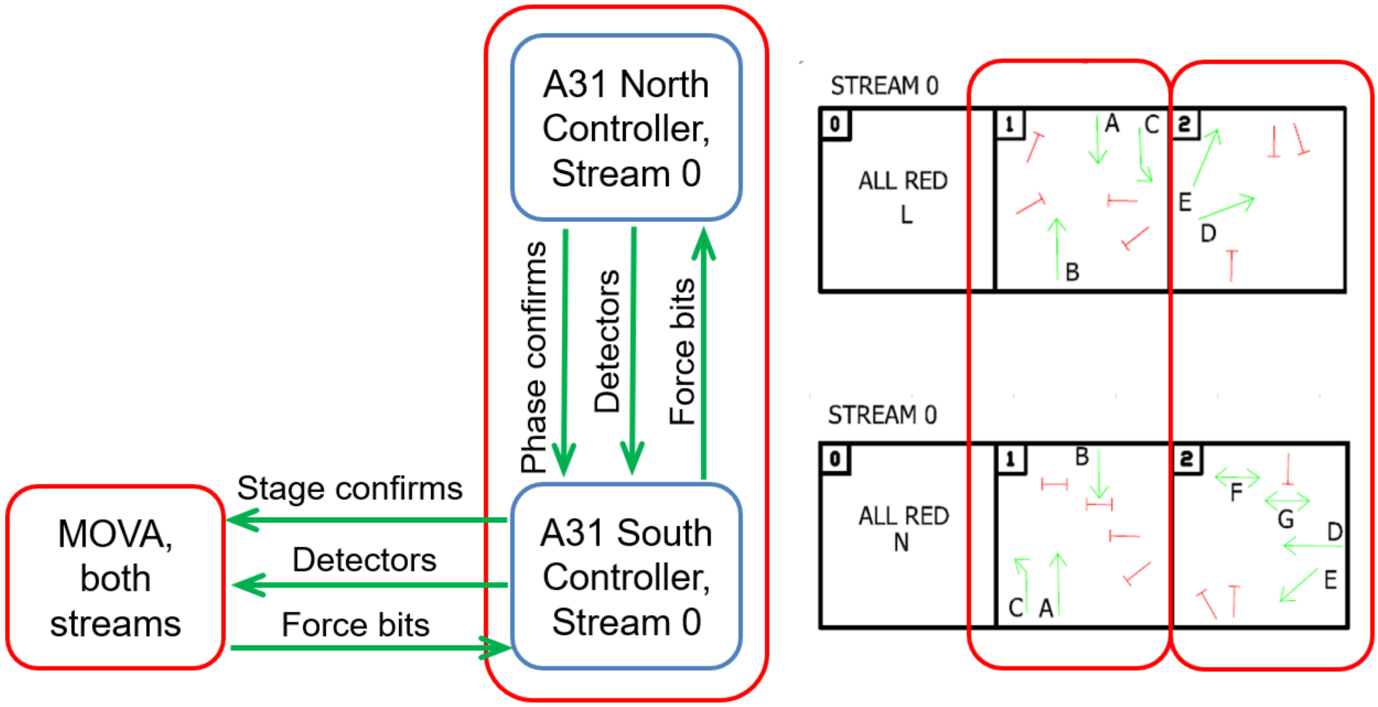

Figure 7 MOVA operation schematic

In addition, a number of minor facilities were built into the south controller conditioning to control the MOVA CRB reply and TO bits in a similar fashion. Also, a facility was built in to override the stage confirm G bit replies for a few minutes when MOVA first starts control, to use solely the south controller stages: This ensures MOVA can reliably take control if the two controllers were not both running stage 1 together in the alternate control mode.

When configured and tested, the above arrangement utilised a comparatively small amount of special conditioning, a conventional single stream dataset and no traditional MOVA linking facilities at all for the A31. The resulting performance gave 100% reliable coordination for the A31 from the very first cycle and has operated faultlessly since. As intended, the A31 movements through the site, both northbound and southbound start and end green times together, greatly reducing stop/start/stop behaviours, reducing congestion, driver frustration and red light running. Validation for this 'single stream' was carried out conventionally and straight forwardly over approximately one week, including all morning, evening, weekend and holiday peak periods. MOVA was able to balance and control traffic (including pedestrian) movements on all A31 and circulatory phases very well.

During CLF testing, it was apparent that using fixed phase delays, of 7s, to clear the internal reservoirs at the end of green, whilst very successful at clearing those reservoirs, could at times also introduce unnecessarily long interstages. This was particularly noticeable on the northbound movement, as this is typically quieter than the southbound, and can end green without vehicles present (as end of green was controlled by the busier southbound movement) but could also be seen on the southbound movement.

To reduce the long interstages when possible, it was desired to introduce a variable phase delay feature, to vary those phase delays using presence/absence on existing vehicle detectors, but that feature was not available in the existing controller type. An alternate arrangement, of a 'variable phase delay-alike' was developed using standard controller functionality in an unusual way:

A phase delay would otherwise have been used, to hold both phase B (internal reservoirs) at green following the end of stage 1 (A31), as the controller moves to stage 2 (circulatory). To replicate such a phase delay, new intermediate stages were introduced, between stages 1 and 2, which had the internal reservoirs phase at green within them. Figure 8 illustrates this, with the intermediate stage illustrated as stage '1a'.

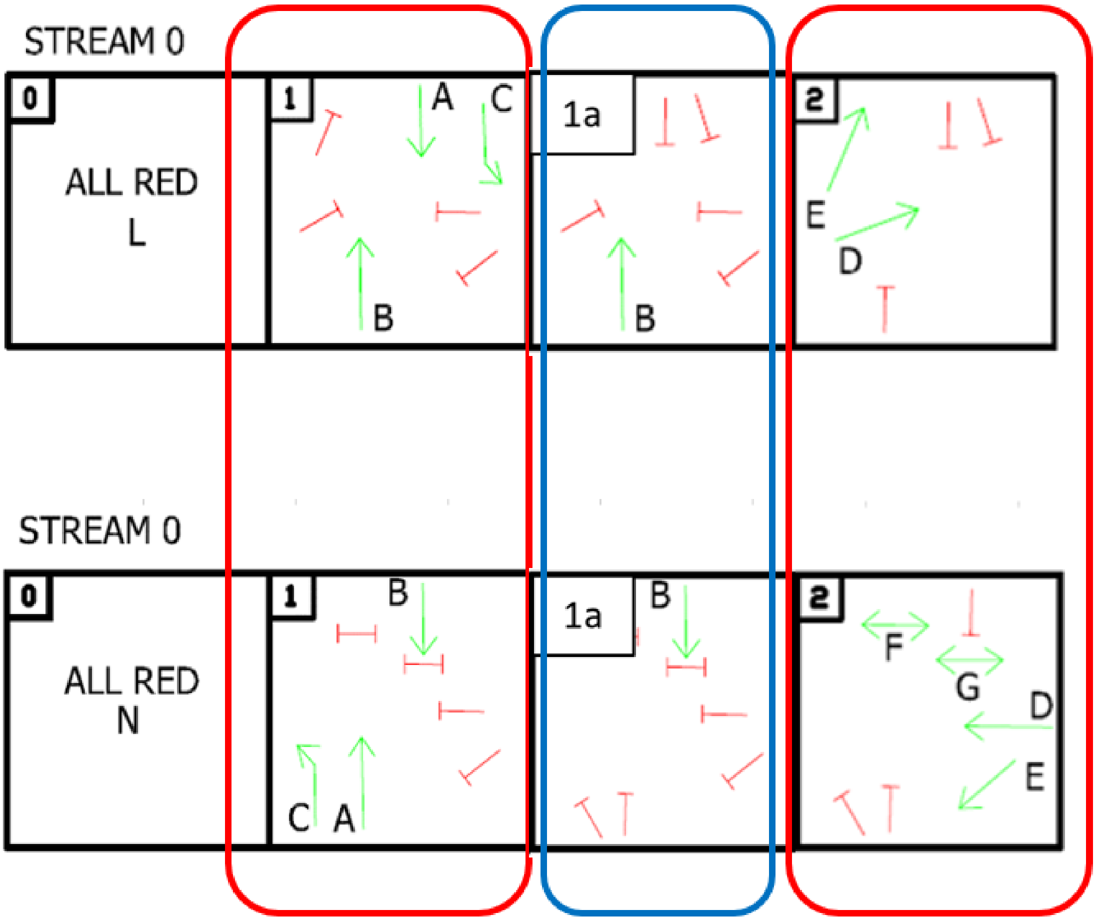

Figure 8 Intermediate internal reservoir clearance stages

At the end of stage 1, using the controller standard Alternate Stage Moves functionality, all movements are taken via stage 1a. The length of the interstage 1 - 1a is then controlled via the Extend All-Red facility and uses the existing vehicle detectors on the internal reservoirs to vary that interstage. As the internal reservoir phases B remain at green during the interstage, we then see a variable clearance time, running independently on each controller, which ensures vehicles can safely clear the reservoir, but then the circulatory phases can start just as soon as possible, giving capacity gains. Both stages 1a are 'hidden' from MOVA and do not have control (F) or confirm (G) bits associated with them. This ensures that MOVA 'sees' a standard interstage period between stages 1 and 2, just as if a phase delay was operating.

Combined together, the single stream of the MOVA operation, along with the variable phase delay-alike allowed the A31 movements to run reliable and appropriate coordination, whilst also retaining some flexibility in the interstage/clearance periods. In the absence of exit blocking, this virtually eliminated vehicles having to stop twice on the A31, once on the A31 approach and again on the internal reservoir. Smoothing that movement, which can be busy with HGVs, caravans and other slower accelerating vehicles was seen to be very successful at keeping the A31 moving and minimising delays.

Furthermore, at the same time, the opportunity was taken to overhaul the other MOVA linking at the site, aiming again for greater consistency. This was achieved with fairly conventional MOVA links and was again very successful, minimising delays, stops and queue lengths for local authority approaches and smoothing movements.

Whereas the previous MOVA operation was stopped during times exit blocking was expected (switching a fixed time control), the new operation of MOVA was found resilient in all conditions, from the quietest times in the middle of the night, to the busiest at the height of exit blocking. The coordination was found to be reliable and in exit blocking conditions was particularly good for vehicles travelling on the local authority roads from the west to the east – Previously these would get badly impacted by exit blocking, as the circulatory could ‘snarl up’. With the new arrangement, the circulatory coordination was maintained and as long as those vehicles weren’t heading towards a blocked exit they now receive much more consistent performance.

Positive feedback was received on site from a number of drivers who used the site regularly, and the validation team’s own observations showed very good performance.

Originally, the team had set a number of objectives for the MOVA operation, and it would seem appropriate to review those following the scheme implementation. The original objectives are below, with outcome of these shown in blue:

- Improving coordination along A31, through the internal cut through, ensuring consistent and appropriate movements, minimising stop/start behaviours.
    - A31 coordination now 100% reliable and appropriate. Stop/start/stop behaviours greatly reduced, and variable phase delay-alike used to minimise lost time in interstages. No known complaints received regarding the fully validated performance (no news is good news!).
- Improving coordination around the circulatory, to provide consistency in operation, minimising stop/start behaviours and blocking of conflict/box junction areas.
    - Circulatory movements now receive vastly improved consistency, with the busiest movements having greatly improved coordination. Blocking of conflict areas reduced, seemingly along with red light jumping too. Positive feedback received from drivers on site and no known complaints.
- Making MOVA control more resilient, such that it can be in operation 24 hours a day, irrespective of presence or absence exit blocking.

- MOVA in operation 24/7.
- Achieving all of above, with a simpler configuration of the controllers and MOVA.
  - It is felt that the new operation is now 'simpler' than the previous arrangement but could not be described as 'simple' – It unlikely that any 6 stream, twin controller MOVA hamburger site could ever be described as 'simple'. The table below shows the reduction in configuration/MOVA 'elements', demonstrating particularly the reduction in total level of special conditioning and the number of MOVA priority links.

Signal Control Feature	Previous Configuration Total	Latest Configuration Total
Controller elements		
Special Conditioning Pages	31	16
Special Conditioning Timers	129	46
MOVA elements		
Traffic Links	29	26
Simple Traffic Links	0	13
Pedestrian Links	18	6
Priority Links	46	16
Total MOVA Links	93	61

Overall, it is felt that the signal control at Canford Bottom is now:

- More consistent, with greater resilience to changing conditions, especially exit blocking.
- Has significantly improved coordination for key movements, especially A31.
- Has greatly improved coordination for circulatory movements, reducing blocking on conflict areas.
- And has been achieved with a simpler configuration setup, which should prove simpler to maintain in the future. The solution implemented required the signals to be switched off for only a short time and was planned to utilise other TM being required at the site for lining works. With the minimal amount of new equipment, installation costs were kept comparatively low.

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