Using Selective Vehicle Detection to Reduce the Impact of HGV Traffic on MOVA; does it work?

Introduction

Traffic signals, by design, stop traffic and create queues. This is to maximise the efficient use of the roadspace within a junction by grouping up traffic on each movement and releasing vehicles in platoons. While this stopping of traffic is necessary, not all vehicles are impacted to the same degree from having to stop; bigger and heavier vehicles lose more energy, release more brake and tyre dust and take more fuel to get going again.

In 2017 Innovation Funding was secured from Highways England's Designated Funds to undertake a trial to improve MOVA operation at isolated junctions using selective vehicle detection and priority for Heavy Goods Vehicles (HGVs). The project set out to test the following hypothesis:

> *"We can now retrofit equipment to the controller on an existing MOVA site to provide selective detection of large vehicles and thereby modify the MOVA control to reduce stops for large vehicles, improving emissions and air quality, improving junction throughput and reducing fuel consumption"*

Delivery of the project was supported by Nottinghamshire County Council, Via East Midlands, Siemens and Pell Frischmann.

The trial was delivered in the following phases:

- Pre-trial data collection surveys
- Installation, testing and commissioning of Selective Vehicle Detection
- Configuration, testing and validation of MOVA options
- Post-trial data collection surveys
- Review and analysis

A52 Stragglethorpe Road Junction

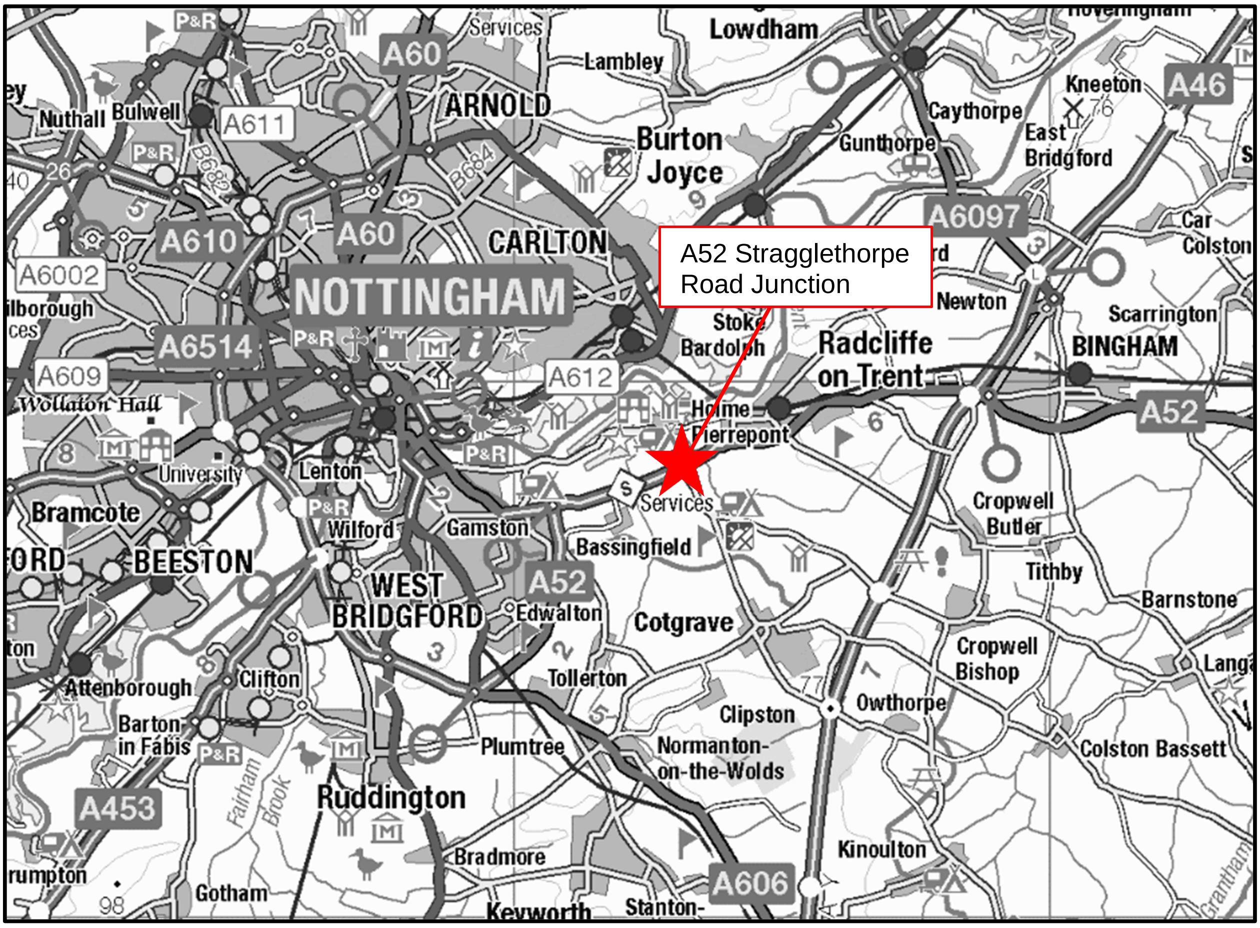

Figure 1 – Junction Location Plan

The site selected for the trial is the junction of the A52 and Stragglethorpe Road to the east of Nottingham City. There were several reasons for this site being selected:

- The site is a relatively simple 'T'-junction with no external influences on the signal control, however it does have some complexity in the MOVA control from demand dependent and alternative stages
- The approaches to the site are relatively direct with minimal flaring or need for extensive lane changing meaning there is a very good lane discipline over the MOVA loops (required for consistent profiling of vehicle types)
- The site is physically constrained with no scope within the existing highway land to widen further, though it suffers from peak time congestion
- The junction is adjacent to residential dwellings and there is an Air Quality Management Area (AQMA) designation covering said dwellings
- Due to the presence of the AQMA there is a permanent air quality monitoring site adjacent to the junction providing long term data for Nitrogen Dioxide (NO_2)
- The site has a moderate proportion of HGVs, typically around 8-10% of the daily flow on the mainline

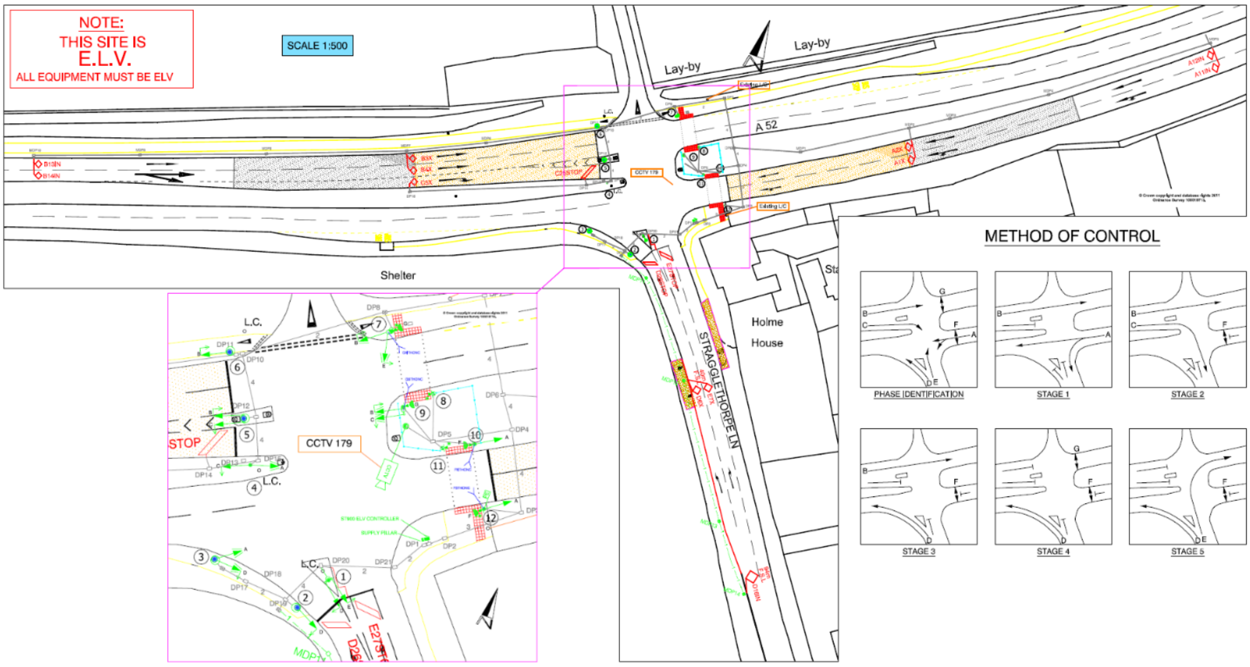

Figure 2 – Junction layout and signal control [extract from Nottinghamshire County Council drawing JH20425/06 Rev B]

The Trial

In keeping with the hypothesis, the specification for the Selective Vehicle Detection (SVD) required a solution that only involved changes to the signal controller and used the existing MOVA (diamond) detection loops. The solution provided by Siemens involved replacing the detector packs within the signal controller with the new SLD4 8+1 packs (the first time these units had been deployed in the UK). The SLD4 8+1 packs were connected directly to the existing loops and provide two outputs for each loop input; the first a traditional on/off state for the loop and the second a configurable output from the selective detection algorithm.

In this instance, the solution also required an upgrade of the controller from an ST900 to an ST950 to support the use of intelligent detector backplanes which are required for the SLD4 8+1.

The selective detection is based on assessment of the detection profile for each vehicle, with classifications assigned by matching against pre-set parameters. The units came pre-configured with these profiles; however, these were developed for square loops not diamond loops. The performance of the SVD output was commented on in the Pell Frischmann MOVA Setup and Validation report as follows:

> *"The general performance of the SVD loops was impressive, particularly given that existing traditional diamond shaped MOVA loops were being utilised rather than the more desirable and effective rectangular loop format. Whilst on site for 6 days, there were only a very small number of occasions noted when either HGV's were not detected and identified by the SVD's or smaller Luton size vans for example were classed as HGV's in error. Almost all buses were classed as HGV's but this had no negative impact and could actually be argued as beneficial."*

The design, implementation and validation of the MOVA changes was commissioned to Pell Frischmann. Three potential design solutions were developed, with each option being tested on site for two days to evaluate the impact and identify a preferred solution to fully implement for the trial. The three options are as follows:

1. Single Priority Extension – a fixed duration extension activated from detection of an HGV at the IN loop
2. Double Priority Extension – shorter fixed duration extensions activated from detection of an HGV at the X or IN loop
3. Ghost Lanes – 'dummy' MOVA links paired up with every normal traffic link using input only from the SVDs allowing alternative values to be used for parameters such as stop penalties

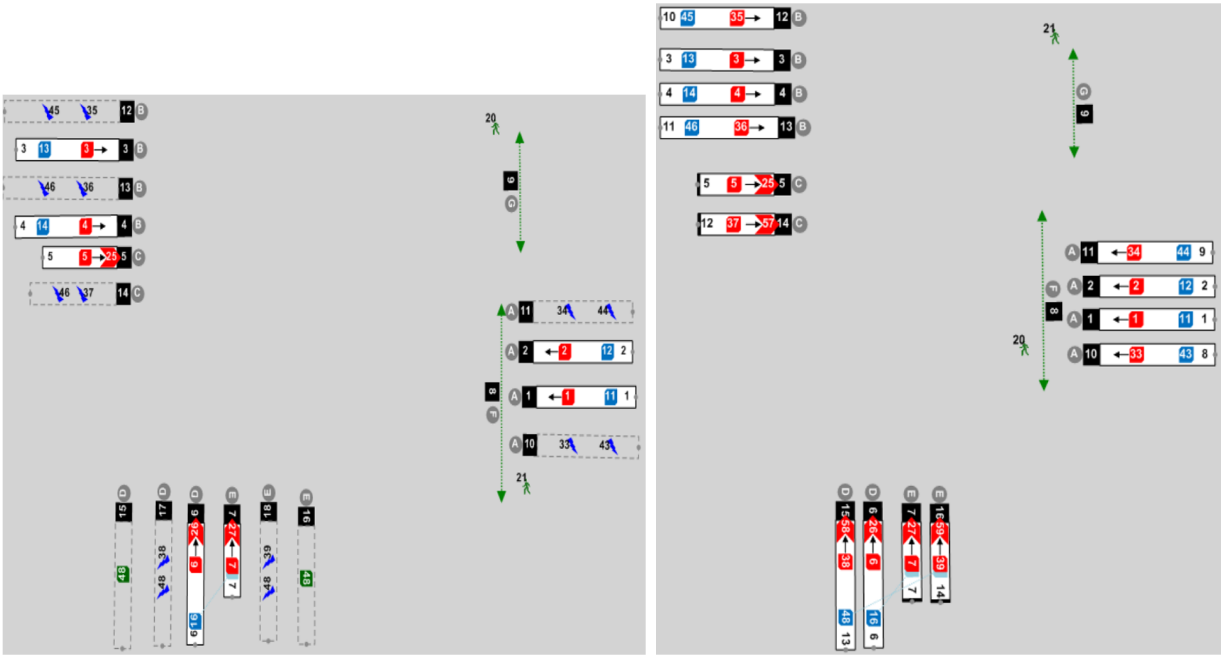

Figure 3 – MOVA Link/Lane diagrams for Options 2 (left) and 3 (right) [Option 1 not shown as nearly identical to Option 2]

Option 3 was dismissed after initial testing as this 'soft' approach was not observed to provide enough discernible benefit to avoiding stopping HGVs. The main reason is believed to be because of the already high stop penalty values assigned to the main MOVA links on the A52 due to the high approach speeds; this is the main parameter to influence the MOVA Benefit Dis-benefit Ratio (BDR) calculation to try and reduce the instances of MOVA changing stage in under-saturated conditions. This option also has no impact during over-saturated conditions as the low number of vehicle inputs on ghost links means they immediately find 'end-sat' and thus do not impact the capacity maximising mode in MOVA. The MOVA Setup and Validation report by Pell Frischmann provides further explanation of the parameters used and explanations as to their effectiveness and can be made available on request.

Both options 1 and 2 were observed to be effective at ensuring that HGVs arriving with the signals on green could clear the junction before a stage change (unless a max-change is forced). With option 1 however, it was not possible to find a suitable single extension value that ensured slightly slower moving HGVs cleared without leading to wasted green after faster HGVs.

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Hence, option 2 emerged as the preferred solution, allowing a variation in the total extension. This is because the IN loop extension is shorter (than in option 1), allowing the HGV to reach the X loop where a second extension to clear the stop-line is triggered. This set-up means that for faster HGVs the second extension is triggered earlier, reducing the total extension applied. Option 2 does not eliminate wasted green from extensions for the fastest HGVs but it does significantly reduce the frequency and extent of these occurrences.

The priority extension facility was included for all lanes at the junction for simplicity, the priority extension maximums were set at 11s for the A52 stages and 7s for the side road stages. This represents a maximum extension beyond the normal max sufficient to clear an HGV arriving at the IN loop just as the normal max green would time off.

Data Gathering

Data to evaluate the trial was gathered from several sources to understand the impact of the changes made and evaluate the hypothesis.

MOVA Logs

Data logs from the MOVA control were downloaded weekly, for a period of 8 weeks before and 6 weeks after the trial, to overlap with the traffic survey dates. For each timeperiod (the default MOVA time periods were in use on this site throughout) the MOVA logs record:

- The number of appearances and average duration of each stage
- The average occupancy for all loops on the junction
- The flow in vehicles across each X loop
- The total flow in vehicles summed for all IN loops

The logs gathered in total covered the periods of 27 June to 25 August 2017 and 13 July to 28 August 2018 (the first and last days of each period only includes data for part of the day).

Traffic Survey Data

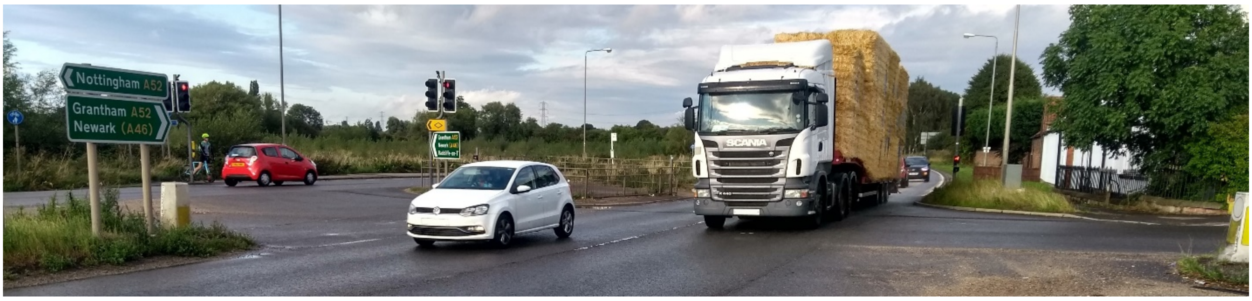
A dataset recording the number of times an HGV stopped, at what time and for how long was created by an external contractor using video footage from cameras installed at the site. This enabled the frequency and duration of stops in the pre-trial period to be compared to the post-trial period. The surveys were taken for both the eastbound and westbound carriageways for the 100m length leading up to each stop-line.

Automatic Number Plate Recognition (ANPR) data was collected for the analysis of journey time change. Several cameras set at a distance back on each arm of the junction enabled the number plate to be matched and the time taken for a vehicle to travel between the points calculated. The average time it took for vehicles to travel across the junction could then be analysed and the two periods compared to see if there were any differences in average journey time.

Automatic Traffic Counters (ATCs) were installed on each arm of the junction to count traffic during the pre-trial and post-trial periods. For each 15-minute period of each day a count of vehicles, separated by vehicle length, was recorded. Vehicle speed was also measured and a count of vehicles by speed bin was included in the data.

These surveys were carried out over the periods of 13-19 July 2017 and 9-15 July 2018.

Further investigation of the ATC data revealed some questionable outputs. The ATC data showed that overall traffic had decreased by 11% eastbound and 15% westbound, but HGV traffic had more than doubled in both directions. Verification using the video footage showed little change in HGV traffic. A possible explanation is the longer queues causing vehicles to move over the sensors more slowly, resulting in the ATCs classifying two smaller vehicles as a single HGV. In light of the issues with the 2018 ATC data, other sources were required to provide an estimate of traffic change between the periods.



Permanent Traffic Count Sites

Inductive loops in the road enable Highways England to count the volume of traffic at locations on their network. Unfortunately, the coverage of these traffic counters is patchy on some sections of the All-Purpose Trunk Road network. The nearest count site to the Stragglethorpe Road junction that has data for the pre- and post-trial periods is approximately 3 miles to the east near to the A46 Bingham Interchange. Whilst this is some distance from the trial site, in the absence of other sources it allows for an estimate of the variation in traffic to be made.

Environmental Data

Air quality data has been obtained from Rushcliffe Borough Council for the monitoring site adjacent to the trial location as well as two nearby sites at similar junctions for use as control sites. All three sites record Nitrogen Dioxide (NO_2) concentrations using diffusion tubes and at Stragglethorpe Road additionally through an automatic sensor. This data was gathered covering the periods of July 2016 to November 2017 and July 2018 to November 2019.

To support analysis of this data, meteorological data covering temperature, wind speed, precipitation cloud cover and relative humidity was obtained for the nearest available location covering the same period.

Estimated background air quality data was also obtained from the Department for Environment, Food & Rural Affairs Local Air Quality Management website for 2017, 2018 and 2019 for the 1km^2 grid covering the trial location. This data provides estimated annual average background concentrations of nitrogen oxides (NO_x), NO_2 and particulate matter (PM_{10} and $PM_{2.5}$).

Customer Survey

Three questions relating to the trial site were included in Highways England's monthly customer survey 'HighView' for January, February, March and May 2020 seeking customer views on the changes to the site and whether they had perceived any impact

 Author: Mark Roxburgh / Andrew Hartley 10/08/20 on journey times or frequency of stops. Unfortunately, there were only 22 responses to these questions giving a sample size that is too small to form any robust conclusions.

Results and Analysis

This section presents the key findings from the data analysis to inform the conclusions for the study, full details of the analyses is presented in separate reports.

Traffic Volumes

Doubts over the accuracy of the ATC data meant that other data sources were required to estimate the change in traffic. Sample counts were taken from the video footage. Whilst the ATC data on the day sampled suggested that westbound HGV traffic had increased by 80%, the sample counts showed a 5% increase. Eastbound HGV traffic supposedly increased by 86% on the day sampled, however, the sample counts showed a 3% reduction. It’s difficult to categorise HGVs from the video footage and it’s not feasible to do counts for every day, therefore these changes are only an estimation.

The Highways England data obtained from inductive loops approximately 3 miles away wasn’t available for the exact dates of the trial but indicated a general change in HGV traffic of +5% westbound and +10% eastbound, which differs significantly from the video sample counts. MOVA is also a source of traffic count data, however, it doesn’t distinguish by vehicle type. This data showed a reduction of 8% for westbound traffic and a reduction of 2% for eastbound traffic on the day that video sample counts were taken.

Given the limitations of the data available and the variations in results these give the change in traffic volumes cannot be reliably estimated. The best correlations in the data available indicate only small changes in the region of ±5%. The rest of the analysis assumes that there has been no substantive change in flow volumes between the before and after data.

Cycle time and Occupancy

Evidence from the MOVA data shows that the overall cycle times for the junction have increased during the trial. Increases to average stage times are evident on all four main stages (stage 4 being the exception as this is a fixed length stage for the pedestrian crossing). Increases in the stage times occur for these stages in nearly every time-period.

A review of the junction occupancy data, plotted against the total junction flow for each time interval, shows – as expected – a general trend of increasing occupancy with flow and at an increasing rate as the junction reaches capacity. Comparison of the before and after data also shows an upwards shift in the typical occupancy values, most likely due to the increased cycle times resulting in longer queues on red.

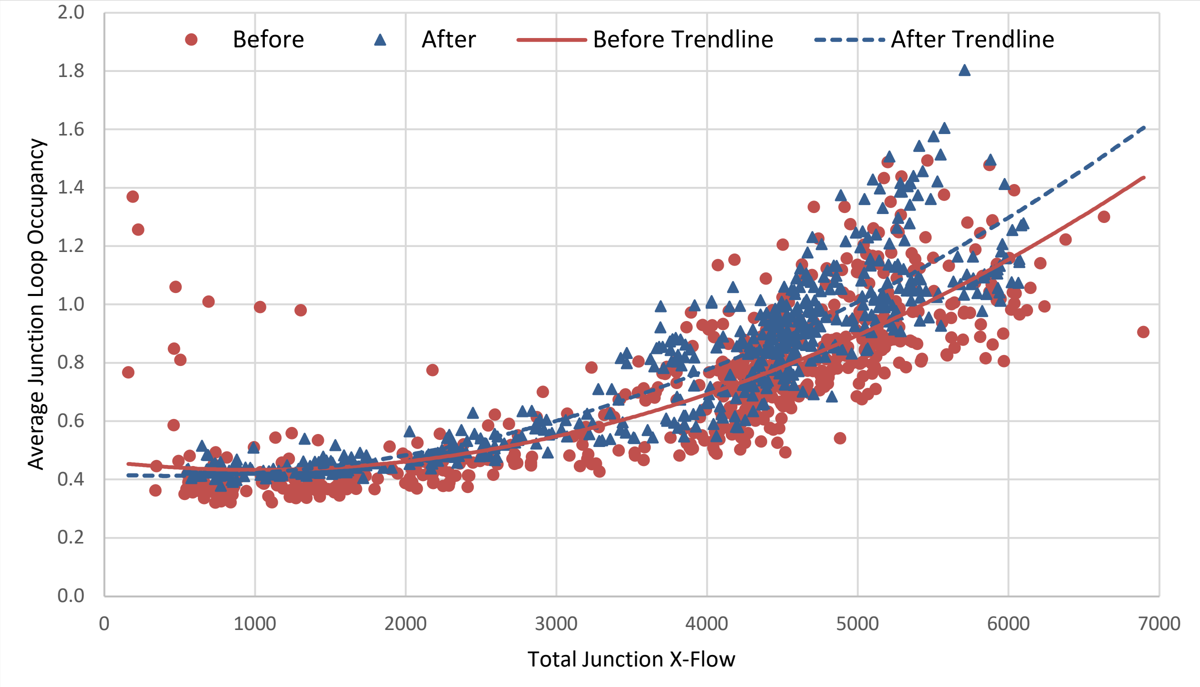


Figure 4 – Junction occupancy vs junction traffic flow, Mon-Fri

A52 Westbound Weekday

During the working week there was a significant increase in HGV stops on the westbound approach of 32%, while there were increases seen for all hours of the day these were most significant between 9am and 4pm. The average duration for an HGV stop increased slightly from 23s to 27s, however more significant increases were observed between 8-9am (25s to 50s) and between 6-7pm (22s to 46s).

Figure 5 – Total HGV stops, Mon-Fri, Westbound, by hour of the day

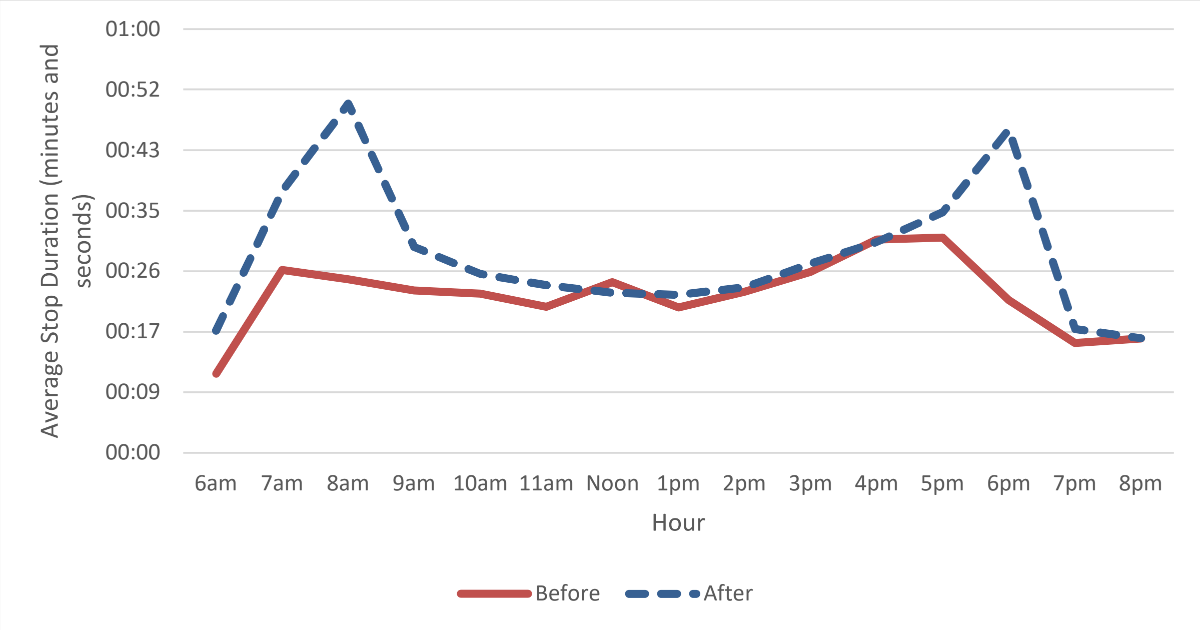


Figure 6 – Average HGV stop duration, Mon-Fri, Westbound, by hour of the day

Despite the increase in the number and duration of HGV stops, the average journey time for westbound traffic through the junction reduced by an average of 11s on weekdays during the trial.

Analysis of the MOVA data shows that there was an increase in the average duration of all four main traffic stages during the trial. For most hours of the day this change has had a greater proportional impact on the red time than on the green time on the westbound approach which is believed to be the primary cause of the increased number and duration of stops. To further note, the increased cycle time means that the demand dependent stages are skipped slightly less frequently, again disproportionately affecting the red time for the main stage.

It is also possible that roadworks at the upstream junction (A52 / Nottingham Road) during the before period was slightly gating traffic or affecting the platooning of flows arriving at the Stragglethorpe junction. This could be a slight factor in the changes seen in HGV stop frequency and delay but does not account for the level of change observed.

A52 Eastbound Ahead Weekday

In the Eastbound direction, the number of HGV stops for the ahead movement on weekdays reduced by 13% during the trial period. However, the roadworks present at the downstream junction was observed to cause queueing in the evening peak (4-5pm) back through Stragglethorpe Junction, artificially inflating the number of stops in the before data. Notwithstanding this the overall impact on HGV stops for the eastbound ahead flows is slightly positive during the day but slightly negative overnight.

The impacts on journey time and HGV stop duration overall are relatively low, with increases of 3s and 6s (excluding data from 4-5pm).

The difference in the outcomes for the Eastbound and Westbound ahead traffic is likely due to the Eastbound ahead flow receiving green in both Stage 1 and 2. As a result for the Eastbound ahead movement the increase in green time is proportionally slightly higher than the increase in red time.

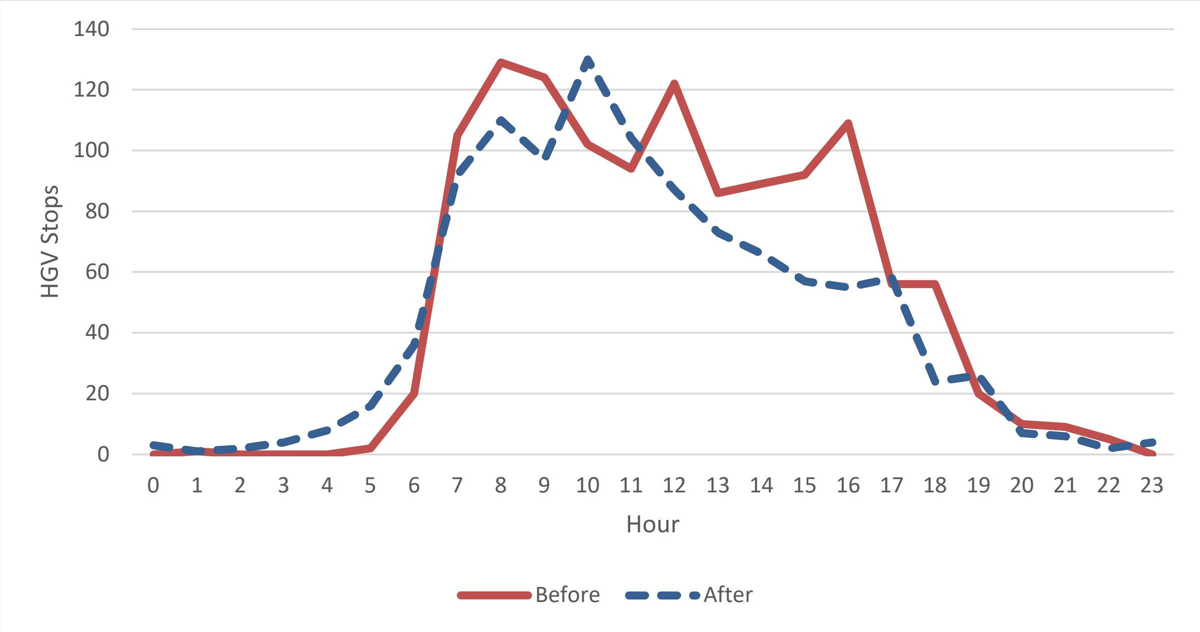


Figure 7 – Total HGV stops, Mon-Fri, Eastbound ahead, by hour of the day

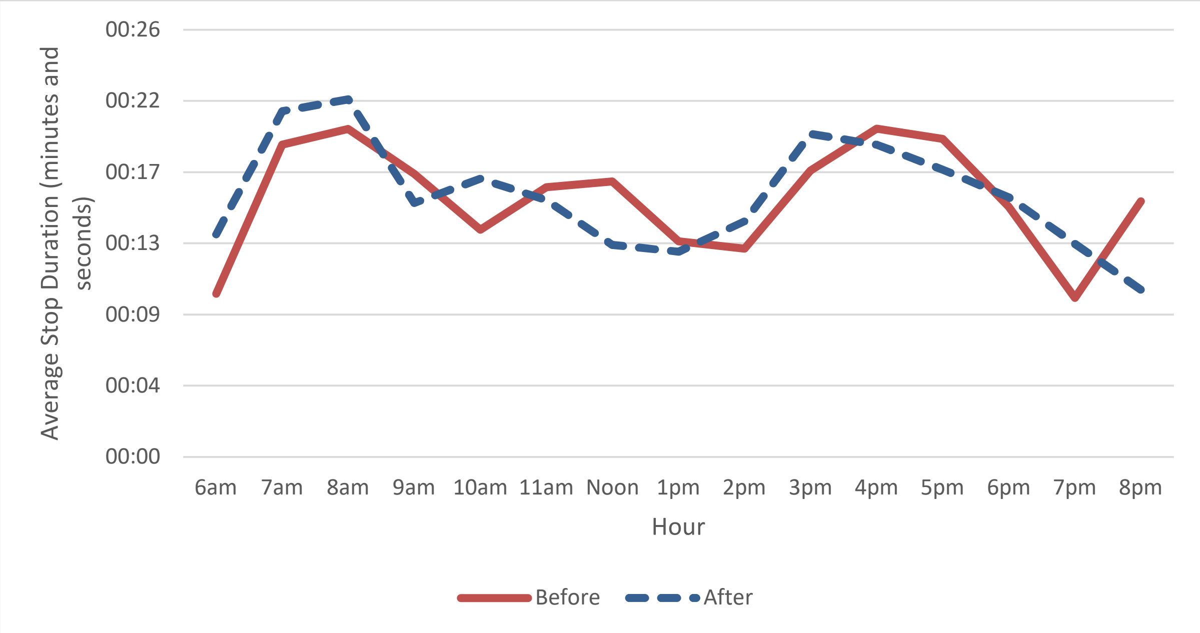


Figure 8 – Average HGV stop duration, Mon-Fri, Eastbound ahead, by hour of the day

A52 Eastbound Right-Turn Weekday

On weekdays, the number of HGV stops on the right turn into Stragglethorpe Road reduced by 9%, with the reduction largely being during the interpeak period. There was little overall change in the duration of HGV stops on this movement except during the morning and evening peaks when the average stop duration notably increased.

Looking in more detail at multiple stops, where an HGV had to stop more than once prior to clearing the junction, there was a slight increase for this right turn movement during the trial, increasing from 21 to 23. Further analysis of these events however shows that between 7-9am the number of HGVs having multiple stops increased from 8 to 16. Outside of these hours the number of multiple stops reduced from 13 to 7.

There was also an increase in the journey time for this movement of 12s during the weekdays, with the increase largely being in the morning peak, when the opposing ahead flow is highest. This data clearly shows that the longer cycle times resulted in cycles during the morning peak where the right turn movement was oversaturated and not all vehicles in the queue cleared on the first green phase.

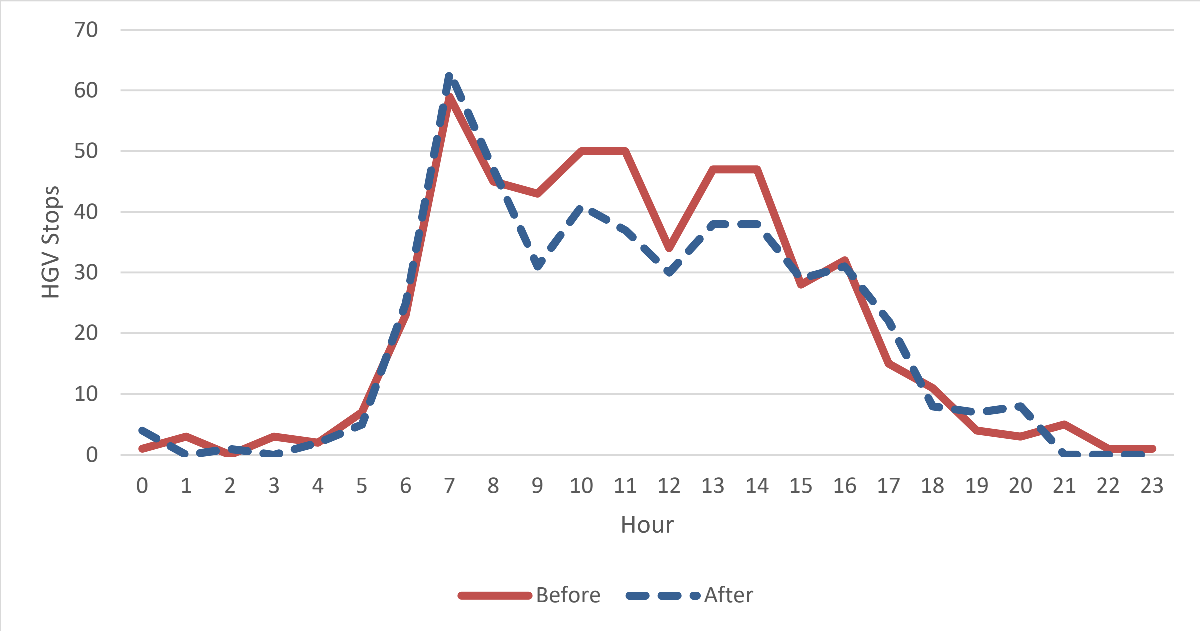


Figure 9 – Total HGV stops, Mon-Fri, Eastbound right-turn on to Stragglethorpe Road, by hour of the day

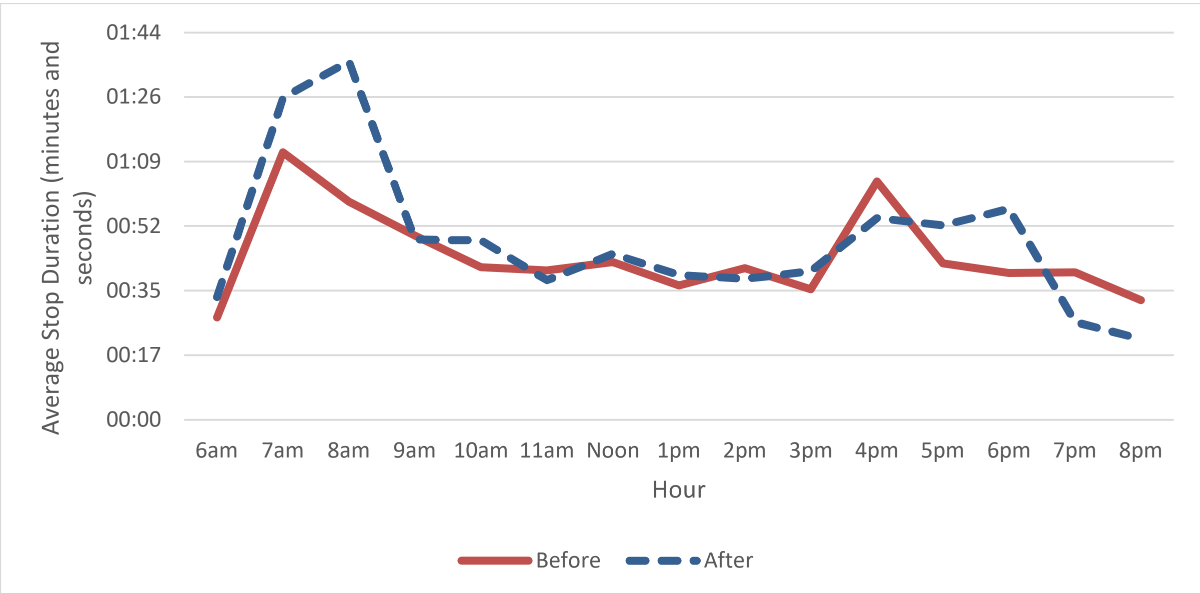


Figure 10 – Average HGV stop duration, Mon-Fri, Eastbound right turn on to Stragglethorpe Road, by hour of the day

Customer reports during the trial noted increased right turn queues for this movement, blocking back into the ahead lane during some peak periods. This is consistent with the above data and is likely linked to the increased cycle time and time on red. However, the data does also show that the priority facility here does provide a benefit in ensuring HGVs are more likely to get through when the right turn is not oversaturated.

Stragglethorpe Road Weekday

No HGV stops data was collected for Stragglethorpe Road due to the very low proportion of HGVs using this route. Weekday journey times on this approach increased during the trial with an average increase of 9s for the left turn and 3s for the right turn. This is consistent with data for the other approaches and is likely due to the longer cycle times.

It is possible that HGV stops may have reduced on this approach, consistent with the right turn in, due to the similar flow composition, turn geometry and green times.

Weekends

In the westbound direction at weekends there was an overall reduction in the number of HGV stops, reducing by 32% on Saturday and 27% on Sunday. Weekend data for the Eastbound data only covers Saturday, during which the number of HGV stops on the ahead movement reduced by 39% during the trial. Similarly, the number of stops for HGVs making the right turn into Stragglethorpe Road on Saturday reduced by 30%.

The improved performance during weekend is likely linked to the reduced HGV proportions in the overall flow.

Air Quality Impact

The NO_2 data from the monitoring site adjacent to the trial shows a slight reduction in concentrations during the trial when compared to the before data. However, similar reductions are also evident in the control sites as well as in the estimated annual average concentrations.

As such it can be concluded that the trial has had no measurable impact, positive or negative, on the concentrations of harmful NO_x concentrations. It is also probable that there has been either a neutral or slight increase in particulate matter concentrations due to the increase in the frequency of HGV stops.

Evaluating the Hypothesis

The starting hypothesis can be broken down into a few elements which can be evaluated individually to inform the overall evaluation.

We can now retrofit equipment to the controller on an existing MOVA site to provide selective detection of large vehicles

The installation of the Selective Vehicle Detection (SVD) at this site was undertaken without the need for any traffic management, although the increased sensitivity of the system did highlight that one of the loops was failing and needed to be re-cut under normal maintenance processes.

This trial has clearly shown that SVD can be readily retrofitted to existing MOVA sites, at least where lane discipline over the loops is good. There are also several other sites known to have installed similar systems, although typically using rectangular loops – either existing or new.

There is still scope for the technology to be developed, particularly in terms of the software and configuration to improve reliability when using diamond loops.

Thereby modify the MOVA control

This was already known to be true from previous implementations of SVD systems. This trial looked at two alternative methods (fixed priority extensions and dummy ‘HGV only’ links) of using the SVD input to alter the behaviour of MOVA both of which worked to differing degrees.

To reduce stops for large vehicles

Overall the data shows that the effect of the trial has been to increase the number of HGV stops, even accounting for a slight increase in HGV numbers. However, there is also evidence of benefit on the right turn movement from the A52 into Stragglethorpe Road.

Observations on site confirmed that the changes were ensuring that the SVD input was extending the green phase to allow HGVs to clear where otherwise MOVA would be likely to end green, thus preventing that HGV from having to stop. This is supported by the clear increase in average stage times showing that the revised control strategy was consistently extending beyond the previous MOVA control setup. While these extensions have allowed the vehicle on green to clear, the resulting red time increase on competing approaches has resulted overall in more HGV stops.

The net result is that the previous operation of MOVA was giving a better balance, maintaining overall junction efficiency, at the cost of occasionally stopping HGVs approaching on green. Conversely, the blanket approach taken has removed the ability of MOVA to take a more wholistic view, extending green for as little as one HGV without any regard to the traffic build up on other approaches.

Despite the disappointing overall result, the reductions in HGV stops seen in the right turn movement from the A52 into Stragglethorpe Road does prove that such systems can provide a benefit. The key difference with the right turn movement is that large vehicles slow down more than small vehicles when approaching the junction turn due to the tight radius. This creates a gap in the platoon which MOVA will often see as inefficient and instigate a stage change. Over time this becomes self-reinforcing as regular users, bus drivers for example, expect not to clear on the current green if too far back in the queue and thus accelerate even more slowly resulting in larger gaps.

As the platoon is then not cleared, MOVA is almost immediately presented with a fresh demand for the right turn stage, encouraging shorter greens on other stages to cycle round and subsequently a worse saturation flow on the next green as the heavy vehicle is at the front of the platoon.

Notably in the case of this site, there is a bus stop a short way into the side road and if a bus is at the front of a platoon of right turning vehicles and makes a stop, the rest of the platoon queues back into the junction creating further adverse effects.

Improving emissions and air quality

The environmental data obtained did not show any clearly identifiable change in local air quality resulting from the trial. This is particularly noteworthy as the movement with the largest impact on stops, albeit negative, is the one closest to the monitoring station.

We know that an HGV stopping and starting results in greater tail pipe emissions as well as generating particulate matter from brakes and tyre friction, however, even with the measurable increase in the number of stops, the net impact was shown to be too small to detect within the wider variations.

Thus, while the link between HGV stops and air quality is known and proven, the level of impact that is likely to be achieved from an HGV priority system at an individual junction is too small to be claimed as an air quality scheme. Implementation over a wider area, such as an urban network with multiple signal sites, may provide greater benefits, however, this needs further research to evidence.

Improving junction throughput

There is no evidence from the study evaluation that the junction throughput has increased due to the trial. The longer cycle times may have indirectly improved the capacity; however, the extended greens result from prioritising HGVs clearing the junction after the main platoons have cleared potentially resulting in a loss of efficiency.

The general trend of increased journey times on most movements evidences an overall reduction in efficiency, most likely due to the priority extensions overriding the optimisations within MOVA.

Reducing fuel consumption

Overall the trial has been shown to increase stops and journey times, likely leading to a slight increase rather than decrease in fuel consumption. However, if the dis-benefits can be designed out and the benefits identified to the right turn movement retained then it is probable that this would lead to a slight overall improvement in fuel consumption.

Summary and Conclusions

The trial has shown that selective vehicle detection of HGVs can be used to provide a benefit in MOVA control, however, it is not universally beneficial and careful thought is required when implementing it.

The greatest benefits have been gained on movements where there is a clear speed differential between large and small vehicles, for example on a tight turn radius. In these cases, MOVA may tend to make a stage change due to a gap in the platoon which it assumes to be an inefficiency. The use of selective detection can override this where the gap is caused by a large vehicle moving slowly and ensure that the signals are kept green to allow the vehicle to clear and not be stopped at the front of the platoon.

On more free-flowing movements or on phases with generally high green times the use of a priority extension from selective detection of HGVs may be less efficient than allowing the junction to cycle. Evidence from the trial shows clearly that, even with a relatively simple (5-stage) junction these holds result in a net detriment to the junction operation.

In such cases, use of the softer ghost links approach will allow MOVA to continue to optimise but nudge the optimiser towards allowing the HGV to clear. As such, where traffic is built up on other approaches MOVA will not look to extend but will extend if traffic is much lighter. Such an approach however is not likely to effect significant changes where stop penalty values are already high.

The benefits of such an approach however are relatively small and the trial has not been able to provide sufficient data to clearly evidence the magnitude of benefits due to the dis-benefits also present. Prior to any future implementation it is recommended that further desktop analysis or traffic modelling is undertaken to evaluate the value for money case.

At Stragglethorpe Road a future scheme to ban the U-turn movement and overlap stages 2 and 3 is now planned. As such an immediate change has been initiated to remove all the priority links except the one on the right turn from the A52 into Stragglethorpe Road. A further review looking to implement priority extensions for traffic approaching on Stragglethorpe Road and ghost links for the A52 ahead movements is proposed to be included in the forthcoming scheme.

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