TECHNICAL REPORT

Speed Amelioration in Swindon: implementation and results

PREPARED FOR: JCT Signals Symposium 2016

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1.0 Introduction

Following on from my colleague Bruce Slattery's 2010 Symposium paper 'Speed Amelioration using traffic signals and ITS', which won that year's prize for the most controversial presentation and prompted by Graham Muspratt's 2015 paper 'A78 Fairlie, an innovative approach to encouraging speed compliance using traffic signals', this paper relates CH2M's experiences in trialling ITS technology to influence speed compliance. It relates the technological challenges encountered, summarises the data collected and outlines the statistical findings from using a group of strategy tools at two MOVA controlled junctions in Swindon.

2.0 Background

It has often been said that travel broadens the mind and this appears to be true in the case of those in the traffic signal industry. Time spent in France and Spain by a number of individuals appears to have prompted thoughts on using traffic signal control equipment to influence the speed of vehicles. The desired outcome of these has been to inconvenience a motorist exceeding the local speed limit by detecting their transgression and bringing the downstream signals to red. Some of the continental sites have been on strategic corridors in a city, whilst others have been on roads passing through villages.

In the UK, the measures employed to acknowledge and manage the hazards associated with safely halting traffic on high-speed roads are covered in Traffic Advisory Leaflet TAL 2/03 'Signal-control at Junctions on High-speed Roads'. The Speed Discrimination/ Speed Assessment loop options concentrate on ensuring a vehicle either has sufficient green extensions for it to safely cross the stop line, or extending the subsequent intergreen if the relevant maximum green time has expired so the 'high-speed' vehicle thus in the dilemma zone can safely clear the junction. Within TAL 2/03, the other option is to use Microprocessor Optimised Vehicle Actuation (MOVA), which has the flexibility to identify gaps within approaching traffic and reduce the incidence of drivers being placed in the dilemma zone.

Swindon Borough Council had recently installed a Cloud Amber Argonaut UTMC system and work was carried out to identify sites for a trial of a suite of equipment and technologies that, when combined, would seek to influence the behaviour of drivers as they approached the junctions. The impact of the trial would be examined by comparing baseline data with results following use of the strategy.

3.0 The Trial Sites

The two junctions chosen for the trial implementation in Swindon were:

Site 1 –Queens Drive/ Whitbourne Avenue

The strategy was applied to the northbound approach.

Site 2 –Thamesdown Drive/ Queen Elizabeth Drive

For this site, the strategy was applied to the eastbound approach.

Both of the treated approaches have a speed limit of 40mph, are subject to significant numbers of speeding vehicles and for the approaches monitored, did not have controlled pedestrian facilities immediately beyond the stop line. The normal mode of operation for each junction is MOVA.

In both cases, a new signal control stage was introduced to the controller configuration whereby a red signal is given to the relevant approach (i.e. northbound and eastbound respectively to Queens Drive and Thamesdown Drive), with the opposite approach (i.e. southbound and westbound respectively) begin given a green signal on this stage, and the minor roads also being on a red signal.

4.0 The System

4.1 Overview

The System comprises a number of subsystems, some with multiple functions, as described below:

- **Vehicle Speed Detection (VSD) subsystem** - detects vehicle speeds in advance of the junction using above-ground radar units; of particular interest are those speeds exceeding a threshold value;
- **Automatic Number Plate (ANPR) subsystem** - identifies any vehicles permitted to drive at excessive speed (i.e. emergency services) to ensure that they are not given a red signal;
- **ANPR and Traffic Signal Control (TSC) subsystems** - detects whether there is queuing at the junction, when it would not be safe or appropriate to give a red signal to an oncoming speeding vehicle and/or where it may result in even more queuing;
- **Communications subsystem** - provides wired and wireless communications between site and office where the central control system is located;
- **UTMC Control Computer** - processes the above detection data centrally to assess if it is suitable to request a red signal; also collates trial data for post-trial analysis and reporting; and
- **TSC subsystem** - controls the traffic signals, in particular to provide a red signal on the selected approach where appropriate.

A **red light compliance (RLC) subsystem** was also installed to monitor any changes in the number of vehicles driving through a red signal ("red light running") before and after activation of the System.

CCTV cameras were also installed at each trial junction to provide a visual context to the data collected, primarily in case of any unexpected events, e.g. accidents, where the cause needed to be examined.

Figure 1, below, illustrates the physical architecture of the system.

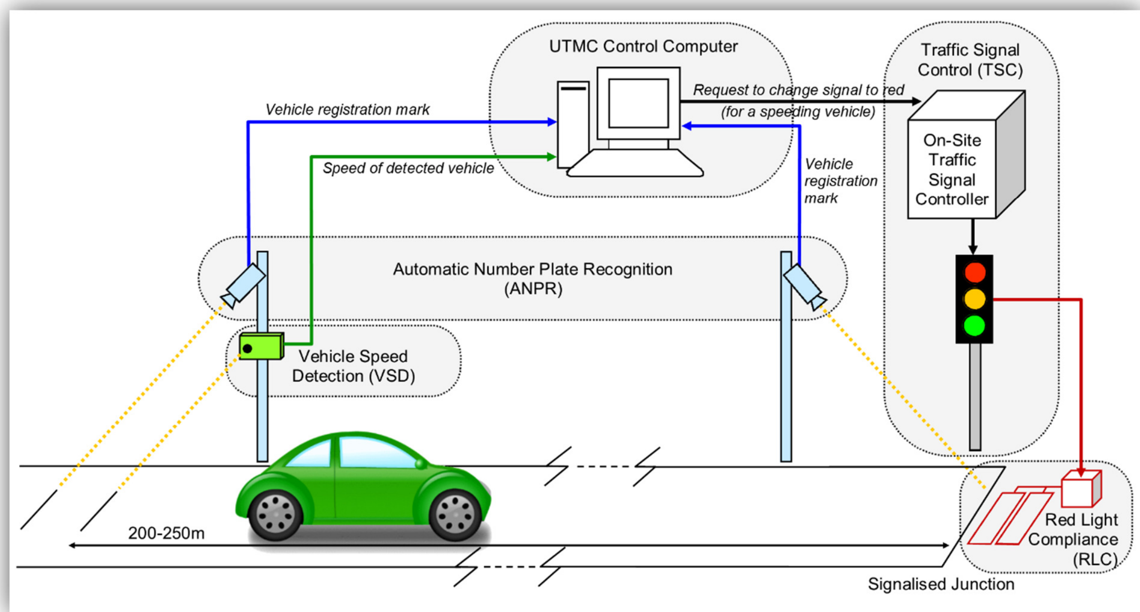


Figure 1: Overview of speed amelioration system

Implementing a red signal for the monitored approach involved a number of parallel processes to determine the following:

- Analysis of speed data from the VSD subsystem to reveal the presence of a vehicle exceeding a pre-determined speed value;

- Matching ANPR subsystem data against the speed data to indicate the presence of a whitelisted speeding vehicle (e.g. emergency services vehicle), in which case the System "stands down" for a defined period of time until that vehicle has cleared the junction;
- Analysis of ANPR subsystem data to determine if the approach is "congested", in which case introducing a red signal may compromise safety and/or increase congestion; in any case, the vehicle is likely to be forced to slow down due to the congestion, thus making implementation of a red signal unnecessary; and
- Analysis of speed data to identify if the vehicle is driving at such a high speed that introducing a red signal at the approach may compromise road safety, with the driver either attempting to abruptly stop or deciding to increase speed further in an attempt to pass through the junction.

With the System in a "non-congestion" state, a non-whitelisted vehicle detected above the "trigger" speed threshold and below the maximum speed threshold will result in a request to the site signal controller for the speed amelioration stage to be immediately activated.

Even when the request has been delivered to the on-site traffic signal controller (i.e. the TSC subsystem), there may be several conditions under which the controller determines that it is not appropriate to make the requested signal stage change. These are:

- Each signal stage has a "minimum green" period representing the minimum time period for which it will stay active once the stage has started. If the current stage is on minimum green when a red signal request is received by the controller then the controller will ignore the request.
- If the signals at the junction are already on a stage that is giving a red signal to the relevant approach then the controller will again ignore the request; nor is the red signal extended for a further period of time.

If the above conditions do not apply then the controller will implement the red signal at the approach.

The red light compliance (RLC) subsystem operates independently from the other subsystems, as does the CCTV subsystem. Both of these subsystems collect data locally for retrieval at a later date.

Figure 2 below, shows the data flow and decision process for implementing a red signal for a vehicle speeding on the monitored approach.

4.2 Implementation of a red signal

At the end of the process shown above, the ultimate outcome is to bring the relevant phase to red for those vehicles exceeding the configured threshold. Instructing signal controllers using add-on or remote systems is a well-established technique when MOVA, Urban Traffic Control and UTMC are considered. However, those systems rely on the controller for compliance with safety-related matters such as minimum greens and intergreens. The purpose of this System is to end green despite the potential for an optimised green to have not been delivered on-street.

Achieving that required a potentially unique combination of already available techniques:

- Special conditioning within the traffic signal configuration includes a 'bit' that is toggled by receipt of the 'Speed' bit from the UTMC system i.e. the UTMC system passes this through to the controller through the UG405 O.T.U.;
- The 'bit' is assigned a MOVA detector number. Receipt of the 'bit' by the 'control' part of the UTC interface causes a 'reply' output that is passed back to the UG405 O.T.U. but this time to the MOVA platform;
- The MOVA detector demands a Priority/ Emergency link within the dataset held on the Siemens Gemini² UG405 Outstation Transmission Unit; and

- This link demands the 'Speed' stage, which at each site is characterised by the ahead traffic being brought to red, whilst traffic proceeding in the opposite direction on the main road continues to receive a green signal.

Note that the available window in which to implement the strategy is relatively short, given that minimum green cannot be violated and MOVA can conceivably identify end of saturation and choose to move to an alternative stage. This proved initially challenging to test due to time lags between staff on site advising remote staff to input a simulated Speed 'bit'.

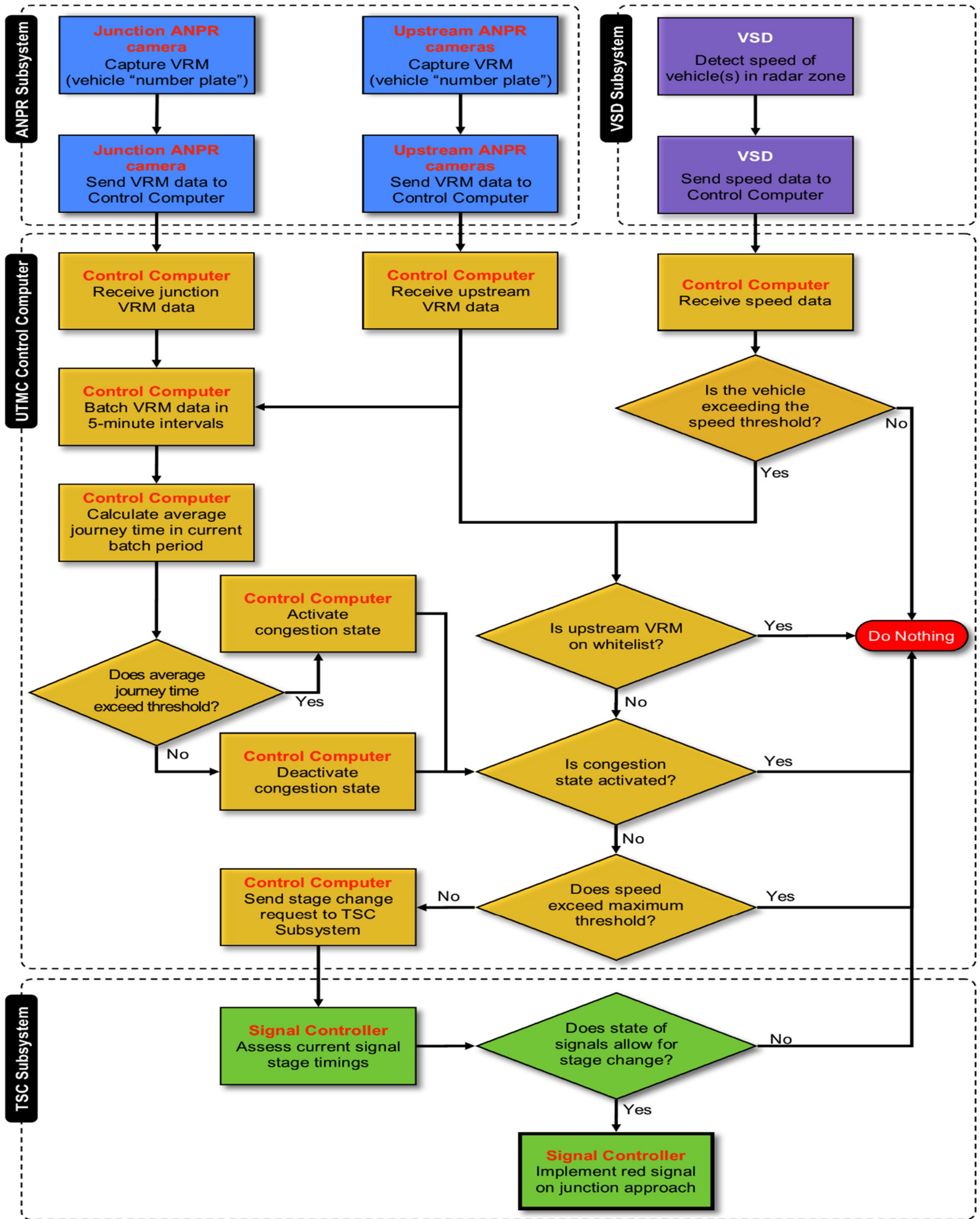


Figure 2: data flow and decision process for implementing a red signal for a vehicle speeding on the monitored approach

4.3 Threshold Values

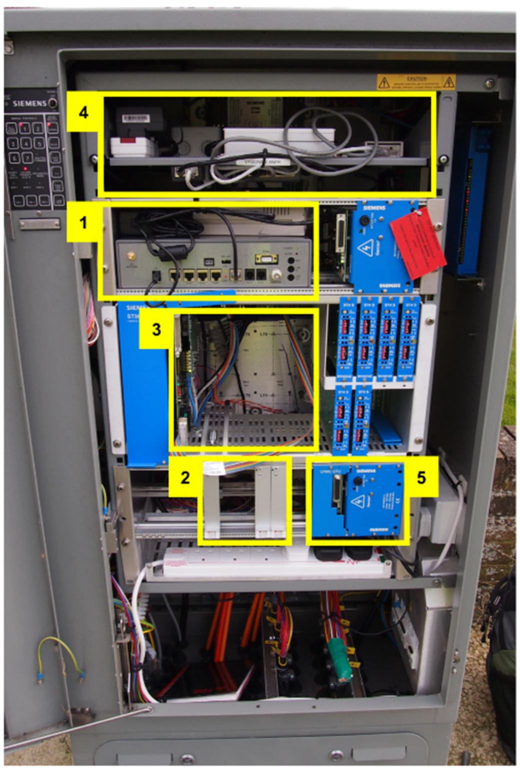
Each trial site has different traffic flow/speed characteristics and thus was given its own parameters for operation of the System. These are illustrated in Table 1 below.

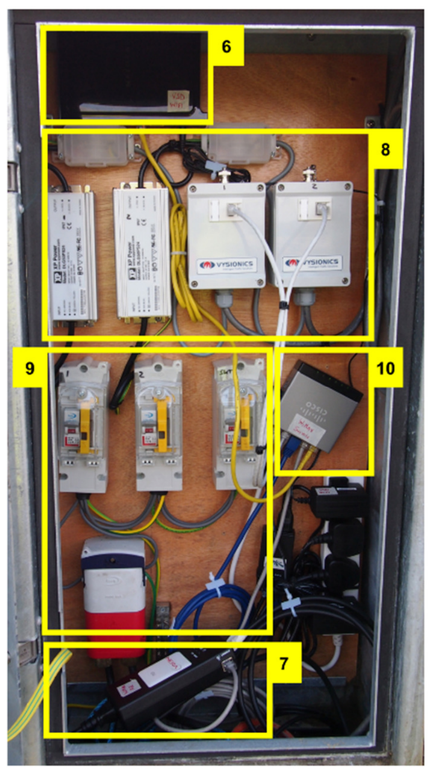
Parameter	Queens Drive	Thamesdown Drive	Comment
Trigger speed	48mph	53mph	Speed above which a red light request is made to the signal controller, subject to other conditions described above.
Maximum speed	70mph	70mph	Speed above which a red light request will not be made, for safety reasons.
Congestion threshold	16s	17s	Average (5-minute aggregated) journey time between upstream and junction ANPR cameras above which a "congested" condition is assumed and the System will not activate under any circumstances.

Table 1: Threshold values for operation of the System

4.4 Equipment

In Cabinets

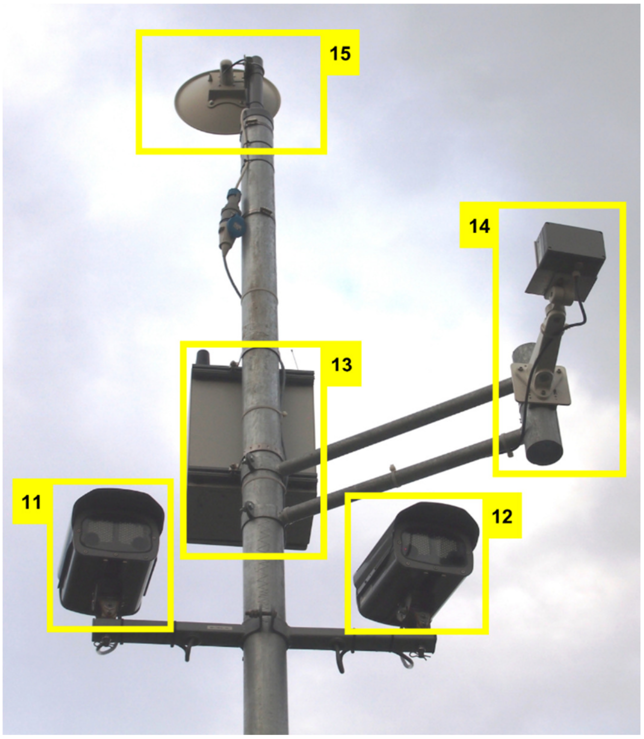




ST900 Signal controller cabinet Upstream equipment cabinet

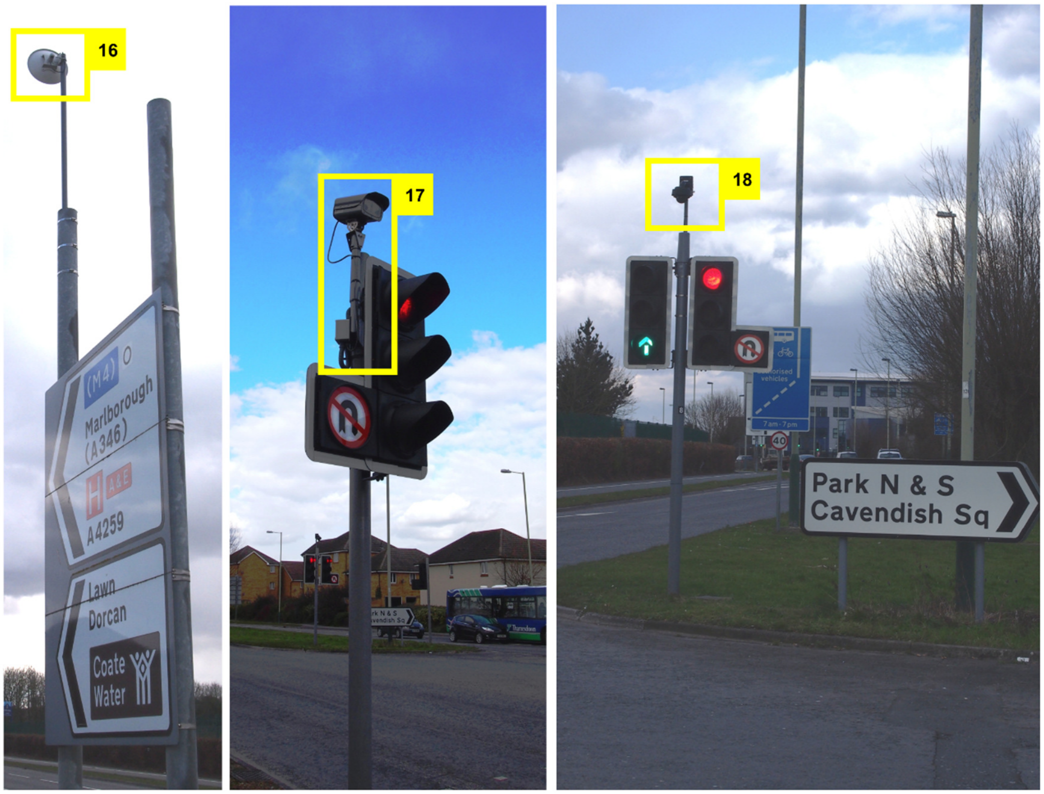
1. CCTV recording unit
2. RLC equipment
3. LAN router for CCTV subsystem
4. Power and communications equipment for junction ANPR camera
5. UTMC OTU
6. LAN router for VSD subsystem
7. ODU ("Outdoor Unit") for WiMax subsystem
8. Power and communications equipment for upstream ANPR cameras
9. Mains power supplies
10. LAN switch for WiMax subsystem

Pole-Mounted Equipment at Upstream Position



11. Lane 1 ANPR camera
12. Lane 2 ANPR camera
13. VSD processing unit
14. VSD radar speed detector
15. "Local" directional WiFi link (connects site equipment between upstream and junction)

Pole-mounted at Junction



16. “Local” directional WiFi link (between junction and upstream positions)
17. Lane 2 ANPR camera
18. CCTV camera

5.0 Data Collection

5.1 Queens Drive Trial Evaluation

For this junction, the System became operationally active, i.e. requesting a red signal in response to detection of excessive speed, at 1130 on June 25th 2014. It remained in this active state for 30 days until July 25th.

Data was collected and analysed both ‘pre’ and ‘post’ System activation to provide ‘Baseline’ and ‘Trial’ datasets. Due to technical issues with the data collection systems there were some differences in the date ranges of data available for the various data types. Table 2 below summarises the data sources used in the assessment.

Data Source	Data Type	Baseline Dates	Trial Dates
Permanent inductive loop[1]	Traffic volume	10.4.14 – 8.6.14	30.6.14 – 25.7.14
Permanent inductive loop[1]	Upstream speed		
ANPR subsystem	Approach speed[2]	23.4.14 – 24.4.14	26.6.14 – 24.7.14
UTMC control computer	No. of requests for red signal	N/A	26.6.14 – 25.7.14
MOVA message logs	No. of activations of red signal	26.5.14 – 25.6.14	25.6.14 – 11.7.14, 15.7.14 – 25.7.14
MOVA assessment logs	MOVA occupancy		
MOVA assessment logs	Traffic volume		
RLC subsystem	Red light running data	26.5.14 – 25.6.14	25.6.14 – 25.7.14

Table 2: Data sources for Queens Drive trial

Notes:
[1] A permanent induction loop detection point is located upstream of the VSD point, providing traffic volume and speed data. Speed data from this location is termed ‘upstream’ speed.

[2] Average speed to the junction is calculated between the upstream and junction ANPR cameras. This is termed 'approach' speed.

It should be noted that there were no public announcements made immediately prior to the start of the trial period. The system had been publicised earlier, but before it was operational. The sensitivity of the proposal and its gestation period meant that the Council adopted a lower profile start to the implementation trial. Consequently, there were no signs or other publicity advising of the trial period.

5.2 Thamesdown Drive Trial Evaluation

The System became operationally active, i.e. requesting a red signal in response to detection of excessive speed, on 2nd March 2015 and remained in this state until 10th May. However, there was a system 'outage' between 6th March and 12th March that meant the System was not active between those dates. The Easter school break was between 30th March and 12th April.

Data was collected and analysed both 'pre' and 'post' system activation to provide 'Baseline' and 'Trial' datasets. There were some technical issues with the data collection systems that meant not all data was available for the full baseline and trial date ranges, as outlined below.

Table below summarises the data sources used in the assessment.

Data Source	Data Type	Baseline Dates	Trial Dates
Permanent inductive loop[1,2]	Traffic volume	19.1.15 – 15.3.15	2.3.15 – 10.5.15
Permanent inductive loop[1,2]	Upstream speed		
ANPR subsystem	Approach speed[3]		
UTMC control computer	No. of requests for red signal	N/A	2.3.15 – 5.3.15, 13.3.15 – 10.5.15
MOVA message logs	No. of activations of red signal	N/A	13.3.15 – 16.3.15, 24.3.15 – 10.5.15
MOVA assessment logs	MOVA occupancy	19.1.15 – 15.3.15	2.3.15 – 10.5.15
MOVA assessment logs	Traffic volume		

Table 3: Data sources for Thamesdown Drive trial

Notes:

[1] A permanent induction loop detection point (referred to below as the 'ATC site') is located upstream of the VSD point providing traffic volume and speed data. Speed data from this location is termed 'upstream' speed.

[2] It should be noted that the ATC site appears to not have detected all vehicles as the vehicle counts analysed were low compared to other sources of volume data, such as MOVA loops, in both the baseline and trial periods. Hence the MOVA loop data was used for traffic volumes for this analysis. The upstream speed data from the ATC loop was used but was viewed with caution due to the under-representation of trips.

[3] Average speed to the junction was calculated between the upstream and junction ANPR cameras. This is termed 'approach' speed.

A range of data was available within the trial period described above. It was decided to analyse trial data for two weeks between 16th and 29th March before the Easter break. A full four weeks of data was not available due to the system outage between 6th and 12th March. School holidays were avoided since different traffic patterns could potentially affect trial results. Further data was collected later in April / May after Easter. However, this was not used since there were technical issues with the MOVA data that meant the data could not be considered as reliable. It also increased the possibility that obtaining data later in the year would introduce other factors to affect the results such as increased hours of daylight and fewer nights with below zero temperatures.

6.0 Specific Analyses

The impacts of implementing Speed Amelioration were analysed through a comparison of baseline and trial data. The types are listed below, with some representations shown to illustrate how they were plotted. Unless otherwise stated, the figures shown are for the Queens Drive trial.

6.1 Upstream Speed

The following data were plotted to examine the upstream speed situation:

- Upstream Speed versus Time of Day
- Average Upstream Speed versus Hourly Traffic Volume
- Number of Vehicles Exceeding 50mph Upstream Speed per hour versus Hourly Traffic Volume

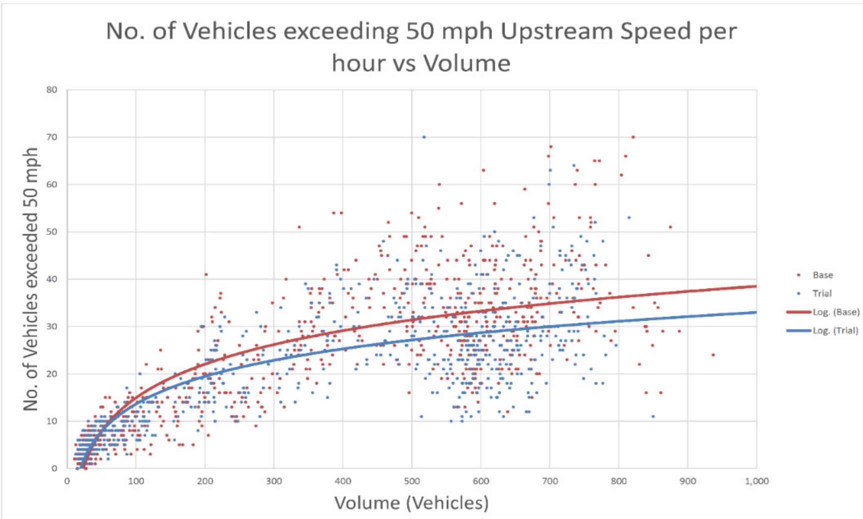


Figure 3: Number of Vehicles exceeding 50 mph Upstream per hour versus Volume

This indicates that there was some reduction in average upstream vehicle speeds during the trial period. It also indicates a decrease in the number of vehicles with an upstream speed greater than 50mph.

6.1.1 Significance

A statistical test was undertaken to determine whether the reduction in upstream speed was statistically significant. This used the statistical theory that a sample proportion (p_s) follows a Normal distribution, as follows:

$p_s \sim N(p , pq/n)$

where:

p is the proportion of the population with a given characteristic,

$q = 1 – p$, and

n is the sample size.

To test for the difference between sample proportions (p_1 and p_2) the test statistic Z can be used, as follows:

$Z = (p_1 – p_2) / \sqrt{p'q'(1/n_1 + 1/n_2)}$, where $Z \sim N(0 , 1)$

for unknown p, where $p' = (n_1p_1 + n_2p_2) / (n_1 + n_2)$ and $q' = 1 – p'$.

It is possible that the number of days with lower than average traffic volumes (e.g. weekends) in the dataset could bias the sample results since one may expect a higher proportion of speeding vehicles when volumes are low. Hence the test was undertaken firstly on the whole dataset and secondly on weekdays only, excluding bank holidays.

Table 4 below shows the results of the statistical tests for the Queens Drive trial.

Test	Base			Trial			Results	
	Vol (n_1)	No. over 50 mph	p_1	Vol (n_2)	No. over 50 mph	p_2	p'	Z
All days	282,370	17,949	6.4%	243,213	13,440	5.5%	6.0%	12.67
Weekdays	195,745	11,498	5.9%	189,299	10,018	5.3%	5.6%	7.86

Table 4: Statistical test for change in proportion of vehicles over 50mph upstream speed

The high 'Z' values indicate that across the whole dataset there is statistical evidence that the proportion of vehicles with upstream speed over 50 mph reduced during the trial period, with a high level of confidence. When only (non-bank holiday) weekdays are considered, the degree of statistical significance is slightly reduced but the result is still statistically significant at a high level of confidence.

It should be noted that for the Thamesdown Drive trial, the data indicated that observed upstream speeds were slightly higher for the trial period than in the baseline period. The reason for this is not known. However, this conclusion should only be viewed as indicative due to the under-representation of vehicles in the ATC loop upstream speed data. It should also be noted that, as for the Queens Drive trial, there was no specific publicity relating to the trial and no publication of trial dates.

6.2 Approach Speed

The following data were plotted:

- Approach Speed versus Time of Day
- Approach Speed versus hourly Traffic Volume
- Average Upstream Speed versus Average Approach Speed

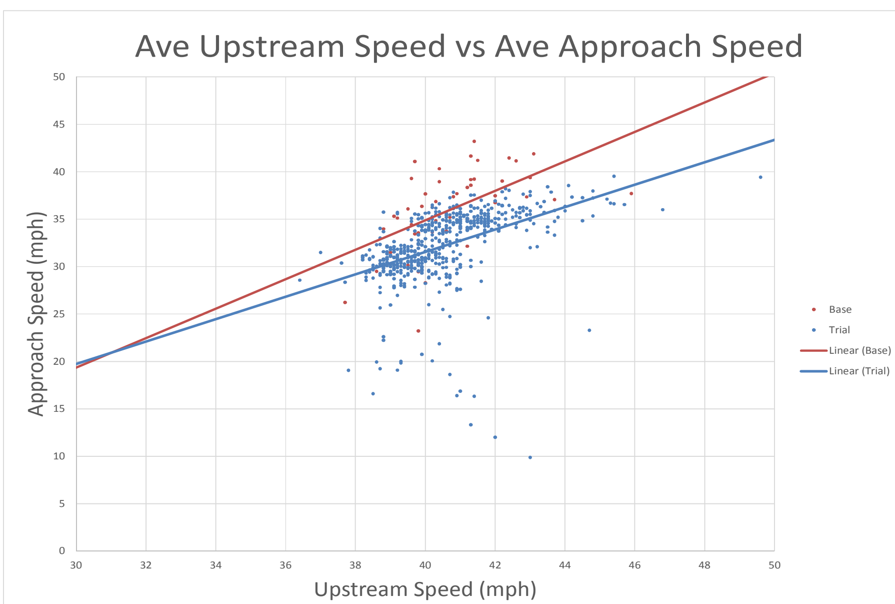


Figure 4: Average Upstream Speed versus Average Approach Speed

This indicates that average approach speeds were lower during the trial. When plotted against upstream speed the data shows for a given upstream speed, the associated approach speed was generally lower during the trial.

However, this conclusion should only be viewed as indicative due to the relatively small sample size for the baseline approach speed data.

A similar outcome was noted for the Thamesdown Drive trial and this was subjected to a test for statistical significance.

Table below shows the results of the statistical tests for the Thamesdown Drive trial.

Base			Trial			Results	
Vol (n_1)	No. over 40 mph	p_1	Vol (n_2)	No. over 40 mph	p_2	p'	Z
13,384	2,678	20.0%	6,147	1,167	19.0%	19.7%	1.67

Table 5: Statistical test for change in proportion of vehicles over 40mph upstream speed

The test results show evidence at the 5% significance level that the proportion of five-minute intervals with average speeds over 40mph reduced in the trial period.

The data indicates that observed upstream speeds were slightly higher for the trial period than in the baseline period. The reason for this is not known. However, this conclusion should only be viewed as indicative due to the under-representation of vehicles in the ATC loop upstream speed data, as described above.

6.3 Junction Capacity

MOVA occupancy data was reviewed to determine potential System impacts on junction capacity. This is an established technique as used in other studies, on the basis that average occupancy per vehicle over MOVA detectors is a good proxy for delay per vehicle (for example Wood et al, 2007[1]). This technique was undertaken on the basis that average MOVA occupancy values can be used as a proxy measure for junction delay i.e. the lower the MOVA occupancy the lower the vehicle delay.

The following data were plotted to examine the capacity situation:

- MOVA occupancy versus Traffic Flow (2 hour periods)

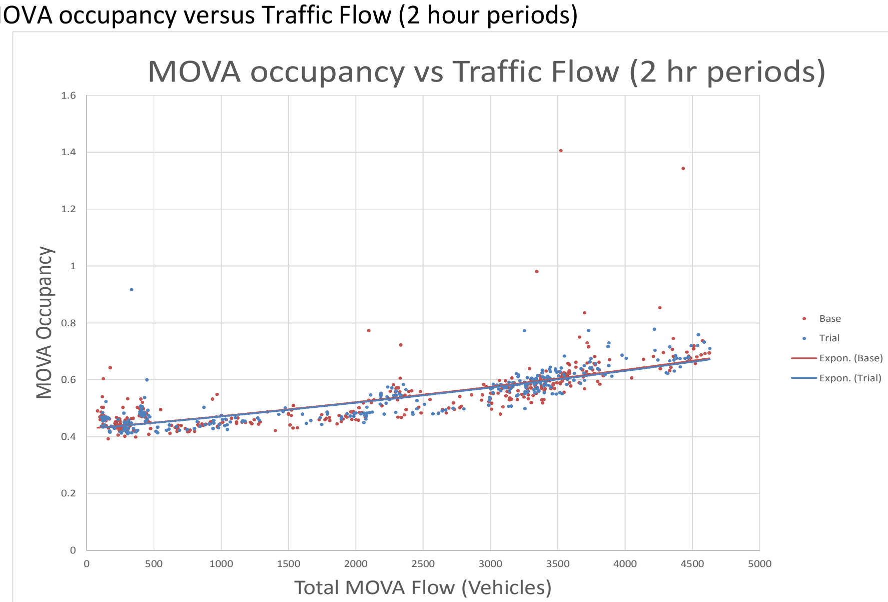


Figure 5: MOVA occupancy versus Traffic Flow

[1] K Wood, M Crabtree, A Kirkham, A Maxwell and R Robbins (TRL Limited) (2007). SURVEY OF MOVA AND SCOOT OPERATION AT M42 JUNCTION 6. TRL Limited PPR252.

Figure 5 shows average MOVA occupancy versus total junction vehicle throughput in two-hourly time 'bins'. (Hourly data was not available over each 24-hour period due to the limitations of the MOVA assessment log configuration in MOVA 6). This shows a virtually identical relationship between traffic flow and average MOVA occupancy in the baseline and trial periods, indicating that System operation had no impact on junction capacity.

- MOVA occupancy versus Traffic Flow (over 3000 vehicles/ 2hour)

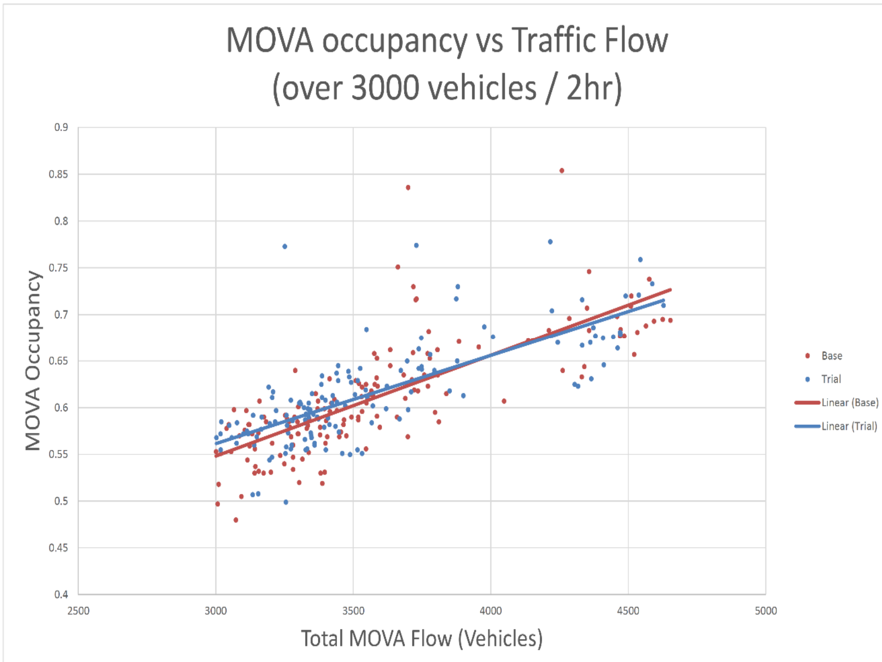


Figure 6: MOVA occupancy versus Traffic Flow (over 3000 vehicles per 2 hour period)

To determine the effects at higher traffic volumes, a further comparison of average MOVA occupancy versus total junction vehicle throughput is provided in **Error! Reference source not found.**, which is restricted to volumes over 3,000 vehicles per two-hour period. A linear trend line is shown to compare baseline and trial junction performance. The three 'outlying' high occupancy values over 0.9 were removed from the baseline dataset as they may be anomalous and adversely affect the apparent baseline junction performance. This shows a slightly lower gradient of the regression line for the trial versus the baseline dataset indicating that System operation did not reduce junction capacity.

6.4 Safety Considerations

One safety concern with the trial was the possibility of increased levels of red light violation (i.e. "red light running"). RLC subsystem data was analysed to identify the proportion of red light violations in the baseline and trial scenarios. Since the RLC subsystem just provided duration of vehicles over the detection point during a red signal phase and was thus not a direct identification of red light violation, some degree of judgement was required to gauge whether a vehicle appeared to have violated a red signal. As such the data was analysed using two different criteria to identify red light violation, as follows:

- any vehicle estimated to be travelling over the detection point at a speed exceeding 5mph during a red signal phase i.e. a vehicle on the loop for 3.1 seconds or less; and
- any vehicle estimated to be travelling over the detection point at a speed exceeding 2mph during a red signal phase i.e. a vehicle on the loop for 7.6 seconds or less.

The data indicated that during the trial there were a greater proportion of hours with no red light violations in both the 2mph and 5mph assessments.

Table below provides the total number of estimated red light violations, according to both the 2mph and 5mph criteria, and the violation rates for the base and trial periods. This shows a slight reduction in red light violation rates with the operation of the System. Whilst a test for statistical significance was not undertaken, it is clear that the results do not suggest an increase in the number of red light violations.

Period	Total no. of Vehicles	2 mph		5 mph	
		No. of violations	% of violations	No. of violations	% of violations
Baseline	280,162	608	0.22%	402	0.143%
Trial	282,302	601	0.21%	387	0.137%

Table 6: Red light violations at the Queens Drive site

Red light violation data was not available for the Thamesdown Drive site due to a data capture malfunction. Thus no analysis of System activation upon red light running was possible.

7.0 Conclusions

The results of the Speed Amelioration trial for **Queens Drive** indicate that:

- the System operates as expected in terms of higher incidence of System requests and activation with higher vehicle speeds;
- there is a statistically significant reduction of upstream vehicle speeds;
- there is a likely reduction of approach speeds in relation to upstream speeds;
- there is no adverse impact on junction capacity; and
- there is no adverse impact on red light violations.

The results of the trial for **Thamesdown Drive** indicate that:

- the System operates as expected in terms of higher incidence of System requests and activation with higher vehicle speeds;
- a potential small increase in upstream speeds was observed but this data source did not capture all vehicles and hence this observation cannot be considered as conclusive;
- there is a statistically significant reduction of approach speeds; and
- there is no adverse impact on junction capacity.

This indicates that the initial trial objectives were achieved at both sites in terms of demonstrating that the System can operate as intended with detection of speeding vehicles and a corresponding adjustment of signal control. The results also indicate a reduction in approach speeds and potential reduction in upstream speeds without loss of junction capacity or adverse safety implications.

8.0 Recommendations from the Trial Evaluation

The trial evaluation report included recommendations to carry out further testing to prove the effectiveness of the system, with consideration for the following:

- more comprehensive baseline and trial data coverage due to some data gaps in the trial as reported herein, such as limited baseline ‘approach’ speed data for Queens Drive, no red light running data for Thamesdown Drive, etc.;
- a potential alternative measurement method for red light violations, since the data source available for this trial required an element of inference rather than providing a means of direct detection. Implementation of inductive loops on the downstream side of the junction stop line at each site would allow for such ‘direct’ measurement of red light violation; and
- whilst there was some publicity prior to trial implementation, different approaches to publicity may influence the effectiveness of the system. For example, a higher level of public awareness may lead to a more significant change in driving behaviour. This could include additional press coverage of the system and/or static signing in advance of the trial junctions to inform drivers that the system is operating.

9.0 Acknowledgements

9.1 Swindon Borough Council

Philip Martlew, who took over the project when Mohammad Shafie left

Andrew Parfitt – Traffic Signal Manager

9.2 CH2M Colleagues

Stephen Alexander - System design and project management

Lee Templeman – Original modelling, TR2500 specification changes and MOVA datasets

Chris Bushell for the statistical analysis and comprehensive trial report

9.3 Suppliers

Cloud Amber – UTMC system, algorithms, remote testing

Capita– Communications system infrastructure

Nexus Alpha – Speed detection (VSD) subsystem

Vysionics – ANPR subsystem

JAH Traffic – Initial O.T.U. configuration work

Paul Rouse Signals Limited - Controller configurations

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