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Safety evaluation of Compact MOVA Signal Control Strategy – final report

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Transport Research Laboratory

PUBLISHED PROJECT REPORT PPR466

Safety evaluation of Compact MOVA Signal Control Strategy - final report

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Prepared for: Project Record:	**PPRO 04/16/10**
	Safety Evalutaion of Compact MOVA Signal Control Strategy
Client:	**Department for Transport, Traffic Management Division**
	(Suku Phull)

	Name	Date Approved
Project Manager	Mark Crabtree	23/3/2009
Technical Referee	Dave Bretherton	11/8/2009

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Contents Amendment Record

This report has been issued and amended as follows

Version	Date	Description	Editor	Technical Referee

Contents

Executive summary

Introduction

In 2008, MOVA (Microprocessor Optimised Vehicle Activation) was estimated to be in use at approximately 3000 junctions in the UK. MOVA M5 and later releases have a facility to exclude the use of the more distant 'IN' detectors (normally around 8 seconds journey time from the stop line) on some or all of the approaches, thus saving ducting and maintenance cost. Commonly known as 'Compact MOVA', this arrangement can only be used on low speed approaches (where the 85th percentile speed is less than 35mph).

To help DfT fulfil their remit to moderate traffic congestion, smooth traffic flow, improve journey time reliability, and to (where possible) improve safety, they have been proposing to promote and advise on the use of Compact MOVA. To confirm that it is as safe as VA system D the study reported on here was commissioned by DfT to assess the safety performance of Compact MOVA.

The performance of Compact MOVA has previously been found to be better than traditional Vehicle Actuation control, matching standard MOVA in saturated conditions (Henderson, Crabtree and Maxwell, 2005). Studies have also shown that Compact MOVA can significantly reduce pedestrian delay at stand-alone signal controlled pedestrian crossings with negligible effect on vehicular delay when compared with Vehicle Actuation.

Sites Chosen

Five sites were chosen for the trial – two junctions and three stand-alone Puffin crossings. One of the stand-alone crossings was not equipped to do a comparison so was run for two days under MOVA control to see if any evidence of particular characteristics could be deduced.

Conflict Analysis

Conflict analysis is generally a very subjective way of obtaining evidence about safety. There is not only the problem of subjectivity in categorising an observed conflict, but also the need to assume conditions under which the comparisons are made are similar. Similarly it is subjectively difficult to correlate the conflicts with control strategy, although this was attempted. Furthermore, the number of conflicts, particularly those of a more serious nature, is very small in relation to flow. For these reasons no attempt has been made to analyse the results statistically.

The conflict study undertaken in this project did not reveal any concerns, and it was not possible to attribute any of the differences that were observed to either of the signal control strategies. Furthermore, at the Ewell Road site, where conditions were observed to be very similar indeed between the two days, nevertheless a big difference in the number of conflicts was observed. This highlights the variable nature of conflicts.

Pedestrian Delay

Pedestrian delay was analysed from the time that the pedestrian pressed the push button. Where pedestrians did not press the button, or it had already been pressed, the delay was calculated from the arrival time at kerb. If a group of pedestrians arrived and crossed together, then they were treated as a single group rather than as individuals. If they had been counted individually, then the behaviour of a single large group could bias the results.

Previous studies have shown that Compact MOVA reduces pedestrian delay significantly compared with VA, and indeed standard MOVA (Henderson, Crabtree and Maxwell, 2005). However, in this study, pedestrian delay has not been improved, except by a small amount at one site only. At the junctions this unexpected result might be explained partly by the uncontrolled way in which pedestrians crossed the road, and by the fact that the cycle times were similar – probably due to being constrained to be of similar values for both strategies. It was not clear why the pedestrian delay was not reduced under Compact MOVA at the stand-alone crossings, although, arguably, the delays observed under VA were perhaps less than expected.

Red Running

The time after the onset of amber at which drivers crossed the stop lines was recorded at all sites. The results are presented as histograms in the main report with the number being divided into discrete half-second intervals. Cyclists have not been included in the results as it was clear many will disobey the red signal if they perceived it as being safe to do so.

Given the low speed of vehicles on the approaches to the junctions and Puffin crossings on trial, and the absence of IN-detectors, there was no expectation that red-running would be any different between the two strategies. However, taking all the sites together revealed that, overall, Compact MOVA did reduce the number of red-runners and this was at a high statistical significance. At Lechlade, red-running was reduced by over 50%; at Hackney Road by Cremer Street, under Compact MOVA only 1 vehicle out of 60 ran the red, whereas under VA it was 15 out of 74. The number of red-runners and the extent of the red-running at the Ewell Road site was also very small. These three sites had the X-detector locations at the distances recommended by TRL – the remaining similarly specified site (Hackney Road by Dawson Street) had very few red-runners under either strategy so any differences between them would not have shown up.

At the Feltham site, the X-detectors were placed closer to the stop line than ideal for this trial. The evidence suggests that such detector placement may have lead to the similar level of red running under MOVA and VA. Results at the other sites suggest Compact MOVA might have reduced red running had the detectors been placed at the slightly more distant location recommended by TRL. However, although there will always be some degree of site specific behaviour which means the benefits may not occur at every site. It has also been observed that, at the Lechlade site, even though red-running was significantly reduced by MOVA, the amount of red-running was still quite high.

Conclusion

Overall there appears to be no reason to doubt the safety performance of Compact MOVA against VA system D and some indication that red-running can be expected to be reduced (which might or might not lead to real safety benefits). That result was not expected.

Reference

Henderson I R, M R Crabtree and A Maxwell (2005). *Development of Compact MOVA.* TRL Published Report TRL648. Crowthorne: TRL Limited.

Abstract

MOVA traffic signal control is used at approximately 3000 junctions in the UK. The recently released MOVA M5 has a facility to exclude the use of the more distance 'IN' detectors (normally around 8 seconds journey time from the stop line) on some or all of the approaches, thus saving ducting and maintenance cost. Commonly known as 'Compact MOVA', it can only be used on low speed approaches (where the 85th percentile speed is less than 35mph).

The performance of Compact MOVA has been found to be better than traditional Vehicle Actuation control, matching standard MOVA in saturated conditions. Studies have also shown that Compact MOVA can significantly reduce pedestrian delay at stand-alone signal controlled pedestrian crossings with negligible effect on vehicular delay when compared with Vehicle Actuation.

Previous risk assessments and a limited safety study indicate that Compact MOVA is as least as safe as Vehicle Actuation. The research in this project, commissioned by the Department for Transport, is necessary to confirm, or otherwise, these findings, and give confidence in the advice given to Local Traffic Authorities. This report describes the study carried out at three stand-alone Puffin crossings and two junctions. The investigation includes conflict analysis and an assessment of pedestrian and driver behaviour.

1 Introduction

MOVA (Microprocessor Optimised Vehicle Actuation) is now a very well established signal control strategy with approaching 3000 MOVA junctions in the UK and an installation rate of at least 250 sites per year. Since the introduction of MOVA version M5 about two years ago, it has been possible to configure low speed approaches to a MOVA junction without the normal IN detectors. This has often been referred to as Compact MOVA, but it is not a separate version of the program, and is included in MOVA M5 and after.

Compact MOVA offers most of the performance advantages of full MOVA but with installation and maintenance costs being similar to Vehicle Actuated (VA) system D. Therefore it has potential widespread application in urban areas and offers significant advantages for isolated junctions, stand-alone crossings and possibly as fall-back to UTC controlled junctions for overnight and other lightly traffic periods.

The Department for Transport (DfT) have a clear remit to moderate traffic congestion, smooth traffic flow, improve journey time reliability, and to improve safety where possible. Because of the potential improvements in signalled junction control that Compact MOVA can offer, they see it as playing an important role in fulfilling their remit. However, whilst there is no known reason to doubt the safety performance of Compact MOVA when installed and configured acceptably, and applied to low speed roads, at the same time there is no evidence that confirms the safety performance.

Hence DfT commissioned the Transport Research Laboratory to evaluate the safety performance of Compact MOVA in comparison with VA control using Microwave Vehicle Detection (MVD). At the start of the project, if the evaluation showed no areas of concern, the intention was for DfT to issue a Traffic Advisory Leaflet giving guidance on the use of Compact MOVA at isolated signal controlled junctions and stand-alone crossings on low speed roads.

2 Study method

2.1 Background

MOVA achieves some of its efficacy compared with traditional VA systems by the use of more distant ‘IN’–detectors, normally placed between 80 and 150 metres from the stop line, depending on the speeds experienced on a particular lane. In the vast majority of cases, inductive loop type detectors are utilised, since MOVA was designed to use them. MOVA also makes use of ‘X’-detectors placed closer to the stop line (typically 35 to 45 metres away).

Compact MOVA is a relatively new variation of the MOVA signal control strategy which has been designed for low speed approaches (where the 85th percentile approach speed is less than 35 mph). It is based upon standard MOVA, but without requiring the more distant IN-detectors. It has been developed by the Transport Research Laboratory and the DfT. Compact MOVA has been released as an integral part of MOVA Version M5. The switch from a standard MOVA approach to a Compact MOVA approach is achieved through the configuration data.

The reason for the development is to reduce installation costs so that implementation of MOVA can be more widespread. The cost of installation is increased because the more distant IN-detectors require ducting for the feeder cable. Another reason why standard MOVA may not always be appropriate is when the approaches are not free flowing which is more likely on an urban approach. Doing away with the IN-detectors can reduce the distance over which traffic needs to be free-flowing.

Because of the low speeds involved, detection requirements may not be so stringent, and alternatives to the traditional inductive loop are becoming available. Indeed, above ground detection has been used at two of the puffin sites in this trial to provide the X-detector functionality.

Studies in earlier projects (Henderson, Crabtree and Maxwell, 2005) have shown that Compact MOVA can significantly reduce pedestrian delay at stand alone signal controlled pedestrian crossings (in the order of 20 to 40% depending on the time of day and site) with negligible effect on vehicular delay when compared with Vehicle Actuation. At junctions, Compact MOVA was shown to reduce vehicle delay by an average of 7% and generally run shorter cycle times than Vehicle Actuation, thus also reducing pedestrian delay. Results from simulation showed pedestrian delay to be reduced by between 0 and 10% depending on the junction and assessment period. In congested periods, Compact MOVA virtually equalled the performance of standard MOVA.

On the basis of the encouraging results prior to this study, the DfT would have liked to have been able to promote and advise on the use of Compact MOVA in a Traffic Advisory Leaflet. However, prior to this project, a full safety evaluation had not been undertaken. Risk assessments and a limited safety study indicated that Compact MOVA was at least as safe as VA. The research in this project was carried out to confirm, or otherwise, these findings, and give confidence in the proposed advice given to Local Highway Authorities.

Of particular interest is the safety performance of Compact MOVA at stand-alone signal controlled pedestrian crossings, where the operation of Compact MOVA differs notably from Vehicle Actuation control. The widespread implementation of Compact MOVA at such crossings is likely to significantly reduce pedestrian waiting delay compared with Vehicle Actuation control. It is also probable that Compact MOVA’s better vehicle gap finding strategy will reduce the number of pedestrians crossing against the red man.

Transport for London (TfL) has installed Compact MOVA at a number of sites and they provided one junction and three Puffins equipped for trial sites. The junction and two of the Puffin crossings were fitted with both Vehicle Actuation control and Compact MOVA control for the purpose of the survey required by this study. A further Puffin was provided by TfL, but was not equipped with MVDs. A further junction was provided by Gloucestershire County Council.

The study compared Vehicle Actuation control with Compact MOVA control in terms of:

- Safety
- Pedestrian behaviour
- Driver behaviour
- Pedestrian delay

2.2 Methodology

Assessments have been undertaken at three stand-alone signal controlled pedestrian crossings and two junctions (two approaches per junction). The original requirement was for sites to be equipped with both Vehicle Actuation (using MVD's, which is the likely control strategy at most isolated low-speed urban sites) and Compact MOVA control. The Pedestrian signal timings were checked against the DfT guidance.

The assessment was undertaken by analysis of video recordings of activity at the trial sites. Four of the sites had video recordings taken for one full day running Vehicle Actuation and one full day running Compact MOVA, and the resulting recordings were analysed as described below. One site (Ewell Road / Oak Hill Crescent) was a last-minute substitute site and was videoed for two days under MOVA control.

2.3 Site selection

TfL suggested a number of potential sites to TRL and TRL personnel visited them to select the preferred sites. The selection criteria were:

- Potential for conflicts (e.g. sufficient pedestrian and vehicle flows; stage orders at the junctions)
- Available video survey equipment mounting positions
- Having a sample of sites that have a range of characteristics
- MVDs present for VA control
- Factors affecting timescales for installation of MVDs
- Equipment function and configuration

The junction in Feltham just south of the High St with the exit from Tesco was chosen as one of the junctions. A further junction, Lechlade in Warwickshire was selected. Other junctions were rejected largely due to low pedestrian demand, and even a lack of pedestrian facilities.

Two sets of Puffin sites were offered: 3 Puffins on Ewell Road, Surbiton and five on Hackney Road, Tower Hamlets. Of the sites on Ewell Road, the one by Oak Hill Crescent was eventually used as it was the only one ready in time (and even then it was not possible to equip it with MVDs in time).

Of the sites on Hackney Road, the one near to Cremer Street and Diss Street appeared to have a reasonable pedestrian flow and is outside a small parade of shops with a residential area opposite. The Puffin adjacent to Dawson Street is outside a bingo hall and was seen to be busy at the end of a session. There is also a School nearby so the site was surveyed during school term. These two crossings were selected as the most likely to show appreciable pedestrian activity. All the selected sites had suitable video survey equipment mounting positions. The chosen sites are shown in Figure 1 to Figure 5.

Figure 1: High St / Tesco entrance, Feltham

Figure 2: Lechlade

Figure 3: Ewell Road / Oak Hill Crescent Puffin

Figure 4: Hackney Road near Cremer Road

Figure 5: Hackney Road near Dawson Street

2.4 Review of control

The operation of the chosen sites was reviewed. In particular, the Compact MOVA data set-up was assessed with regards to the recommendations given in the published 'Draft advice for users of Compact MOVA'. In addition the VA control parameters were checked to confirm that they were in line with the DfT advice, particularly the PUFFIN crossing operation.

At the Hackney Road sites, the detection was provided by range-finding radar detectors that detect at a point along the road in an attempt to mimic inductive loop detectors. The detection points were again set in accordance with TRL advice. The performance of the detectors was reviewed and whilst they were found to be sufficiently good for the purposes of the survey, they were not good enough at the time to warrant a recommendation for widespread use. There are issues in particular where the detector believes that there is a queue of vehicles present when there isn't, which is not often too much of an issue at stand alone crossings, but would be at junctions. The manufacturers are aware of the comments and are working to improve operation.

The detectors at the Feltham junction were placed a little closer to the stop lines than ideal, but it was considered that, if anything, it would make the identification of any dangerous characteristics of Compact MOVA more likely. The location of detectors at the Lechlade site was in accordance with TRL advice, as were those at the Ewell Road/Oak Hill Crescent site – the latter was a late swap for another site and wasn't equipped with suitable VA detectors.

2.5 Survey and analysis

2.5.1 Conflict analysis

A formal study plan was produced, and agreed with both DfT and TfL. The conflict analysis is in line with previous published TfL studies.

The data collection was as follows:

Vulnerable road user delay and behaviour

Sample of:

- Arrival time ('ready to cross')
- Time of push button pressed
- Time when start to cross (foot on crossing)
- Green man start time
- Red man start time
- Number of signal cycles
- Traffic signal indication
- Count of users not using the crossing to cross/ partially using the crossing.

Vehicle delay (at stand-alone crossings only)

Sample of:

- Total stationary time and average stationary time
- Number of vehicles that come to a halt.

Since vehicle delay at junctions was comprehensively assessed in an earlier project and the main aim of this project was to evaluate safety, further vehicular junction delay comparisons were not undertaken in this project.

Conflict analysis was undertaken for the entire recorded period (minimum 10 hours per site). Conflict assessment includes vehicle-vehicle conflicts (within the junction or Puffin crossing area and on the approach), and vehicle-pedestrian conflicts.

Type of conflict:

0. Discomfort (close proximity, but no action required to avoid conflict).
1. Precautionary or anticipatory braking or directional change when risk of collision is minimal
2. Controlled braking or directional change to avoid collision (but with ample time for manoeuvre), or equivalent by pedestrians
3. Sudden emergency actions (such as hard braking or turning by vehicles or equivalent by pedestrians) to avoid collision or a near miss
4. Collision.

Action taken by vehicle:

- Proceeded normally
- Precautionary braking or lane change when risk is minimal
- Delayed start of movement

- Rapid deceleration, lane change or stopping to avoid collision, resulting in a near miss
- Emergency braking or violent swerve to avoid collision, resulting in a very near miss situation
- Emergency action followed by collision.

Action taken by pedestrian:

- Proceeded normally
- Stopped (then continued/ returned to kerb)
- Slowed
- Accelerated (walking speed/ ran).

Count of vehicles going through the crossing area when a pedestrian is on the crossing - undertaken for the entire recorded period (12 hours per site / type of crossing) classified by:

- Vehicle crossing behind pedestrian
- Vehicle crossing in front of pedestrian
- Status of traffic signal indication (i.e. red, green etc).

Assessment of driver required decisions and actions at the onset of amber

Sample of:

- Vehicle position relative to stop line
- Vehicle classification
- Stopped (and stopped with hard braking/ closely following vehicle)
- Continued (and time relative to start of amber when crosses the stopline (traffic signal indication i.e. amber/ red etc))
- No vehicle in ‘decision zone’.

General

- The vehicle classification will be noted
- Other driver behaviour of relevance e.g. edging forward.

2.5.2 Pedestrian delay

Previous work has shown that MOVA can substantially reduce pedestrian delay both at junctions and at stand alone junctions. By reducing delay there is the potential to improve compliance with the green man which, in turn, may improve safety. In this project, pedestrian delay was measured from the videos. The following data was recorded about when pedestrians started to cross:

- between 5 and 10 seconds before start of green man;
- between 0 and 5 seconds before green man;
- with the green man;
- within 3 seconds after the end of green man;
- between 3 and 5 seconds after end of green man.

2.6 Review of Compact MOVA advice

The current draft advice on the use of Compact MOVA, especially the X-detector distances, written by TRL, was reviewed and the results from the surveys incorporated into revised advice as appropriate. This revised advice will be delivered to the DfT for use in a Traffic Advisory Leaflet. In addition TRL will take advantage of any opportunities to publish the advice at conferences or in the technical press with the agreement of DfT.

The MOVA documentation and information on the TRL software website has been updated as appropriate.

3 Analysis and results

3.1 Conflict analysis

3.1.1 Introduction

Conflict analysis is generally a very subjective way of obtaining evidence about safety. There is not only the problem of subjectivity in categorising an observed conflict, but also the need to assume conditions under which the comparisons are made are similar. Furthermore, the number of conflicts, particularly those of a more serious nature, is very small in relation to flow. For these reasons no attempt has been made to analyse the results statistically.

Some attempt has been made to subjectively correlate the conflicts with control strategy. Again this is not exact, because ultimately, it is impossible to say categorically whether or not an incident is related to the signal control strategy, even in cases where there seems prima facie to be no reason for there to be any cause-and-effect.

3.1.2 Feltham

There were quite a few conflicts at the Feltham junction, however, the vast majority were in the minor categories as shown in Table 3-1.

Table 3-1: Number of conflicts by category and control strategy; Feltham

Category	VA	MOVA
0	44	34
1	6	4
2	3	2
3	2	0
4	0	0

The two most serious conflicts, category 3, were both associated with the lights turning to green to vehicles. In the first case, two pedestrians started to cross in front of a stationary bus as the lights changed. The driver did not see them and started to move, but then saw the pedestrians and braked sharply. One of the pedestrians jumped back slightly. In the second case, a pedestrian tried to run across as the light changed. The driver of the vehicle in lane 3 delayed its start, but the vehicle in lane 2 pulled away. The pedestrian had to stop abruptly to avoid running into the car. In both these cases, the risky behaviour resulted from the pedestrian starting to cross as the lights changed to green to vehicles. The most likely factor to influence such behaviour is the expectation of the waiting time before the next pedestrian stage. Pedestrians would not know that the control system had been changed on one day for an experiment. Therefore, the expected waiting time will not depend on whether MOVA or VA is controlling the signals at that time, but on a general expectation of waiting time, which may relate to that particular situation or to traffic signals in general.

In total, 33 conflicts under VA control involved pedestrians failing to complete crossing the road before the start of the vehicles stage, including some starting to cross as the vehicle stage started. Under MOVA control, there were only 17 such conflicts. MOVA has been found to reduce the waiting time and should, therefore, reduce the expected delay, but such an effect would not be apparent on two consecutive survey days.

Overall, although there were fewer conflicts under MOVA, it cannot be said that MOVA is definitely safer than VA, but there is no evidence of any reduction in safety either.

3.1.3 Lechlade

The junction at Lechlade was a T-junction. The number of conflicts by category are given in Table 3-2. On the main road, only minor conflicts (category 0) were observed. There was no significant common cause, or difference between the two control strategies. Behaviours observed included:

- Pedestrians delaying start to cross behind vehicle
- Vehicle delaying start to allow pedestrian to cross or finish crossing
- Pedestrians crossing away from the formal crossing
- Pedestrians crossing through stationary vehicles and vehicles in one or both lanes were ready to start
- Pedestrians crossing when turning vehicles approaching
- Large vehicles having difficulty turning

More conflicts were seen on the minor arm. Similar numbers of the conflicts involved vehicles turning into and out of the side road. There were 5 category 1 or 2 conflicts, all of which involved vehicles turning into the side road. It appears that pedestrians were likely to cross the side road when the signals were green to the main road, but this behaviour and resulting conflicts were not obviously related to MOVA or VA signal control, and there was far from enough data to suggest there were any differences between the two strategies.

Table 3-2: Number of conflicts by category and control strategy; Lechlade

Category	VA	MOVA
0	10	19
1	0	2
2	0	3
3	0	0
4	0	0

3.1.4 Ewell Road

During both days of observations at the Ewell Road Puffin it was operating under MOVA control. As can be seen from Table 3-3, there were appreciably more conflicts on the first day, 40, than the second, 5. There were six conflicts rated as category 2, near miss. These involved pedestrians running for part of the crossing to avoid conflict. However, in five of these cases, an alternative interpretation is that the pedestrians chose to cross in a small gap and were happy to run to avoid waiting at the kerb. In the sixth case, the pedestrian may have misjudged the speed of a fast approaching car, which did not slow. The fact that the pedestrian ran may well have been forced rather than voluntary in this case.

Nine of the more minor conflicts involved pedestrians failing to complete crossing before the start of vehicle amber. Of these one involved a person with a walking frame. In all these cases vehicles delayed starting without obvious harassment to the pedestrians. Most of the other conflicts involved pedestrians crossing in gaps and vehicles slowing slightly as a precaution.

Table 3-3: Number of conflicts by category and control strategy; Ewell Road by Oak Crescent

Category	29th Aug	30th Aug
0	18	2
1	16	3
2	6	0
3	0	0
4	0	0

Given that the results for pedestrian delay and vehicle red-running were very consistent between the two days, the difference in the number of conflicts between the two days seems likely to be pure chance, rather than there being a genuine difference.

3.1.5 Hackney Road / Cremer Street

Several conflicts at this crossing involved cyclists riding through the crossing despite being shown a red light. Such incidents are unlikely to be influenced by the control algorithm and have been excluded from the analysis. Of the other conflicts there were noticeably more under MOVA than under VA, see Table 3-4.

Table 3-4: Number of conflicts by category and control strategy; Hackney Road by Cremer Street

Category	VA	MOVA
0	1	5
1	4	8
2	0	5
3	2	1
4	0	0

One of the category 3 conflicts under VA involved a cyclist approaching on green nearly hitting a slow pedestrian. The other was caused by vehicles and a cyclist going round the wrong side of the splitter island. The category 3 under MOVA involved a pedestrian crossing diagonally from the island in front of an LGV. Of the five category 2 conflicts, one involved a cyclist going the wrong side of the island and another was between a vehicle emerging from a side road near the crossing as a pedestrian was crossing on vehicle green. The other conflicts involved pedestrians crossing against the signals causing vehicles to brake.

3.1.6 Hackney Road / Dawson Street

Again there were conflicts involving cyclists proceeding through a red light and these have been omitted from the analysis. The remaining numbers of conflicts are given in Table 3-5.

Table 3-5: Numbers of conflicts by category and control strategy; Hackney Road by Dawson Street

Category	VA	MOVA
0	12	25
1	34	24
2	3	16
3	2	1
4	1	0

The most serious conflict was a collision when operating under VA control. A cyclist squeezed between two light goods vehicles, one turning out from the neighbouring junction whilst the driver was making a phone call and the other on the main road. The collision was at low speed with no apparent injuries. Of the two category 3 conflicts under VA, one involved a heavy goods vehicle turning left from the main road that nearly hit a cyclist approaching the crossing in the same direction. The other involved a cyclist riding the wrong side of the island during the amber. Both incidents would appear to be independent of the signal control strategy.

The category 3 incident under MOVA control involved a motorcycle overtaking a car that had stopped, on green, to allow pedestrians to cross. The motorcyclist had to brake hard and swerve round the pedestrians. Obedience to the zigzag markings would have prevented the incident as would have continuing when signals were green. A second similar incident was judged to be category 2. It is noticeable that there were more category 2 conflicts under MOVA than VA. One of these involved a van that jumped the red light at speed and had to brake hard to allow the crossing pedestrians to reach the refuge. The remaining category 2 conflicts involved pedestrians (children in 6 incidents) crossing against the signals and with approaching vehicles or through slow moving vehicles.

3.1.7 Summary and conclusions

There were differences in the number of conflicts at the sites under MOVA and VA, although the daily rates (Table 3.6) appear very similar, apart from category 2 (due entirely to higher numbers at the two Hackney Road sites). However, the conflicts did not appear to be directly associated with inappropriate signal changes away from vehicle priority causing drivers to run the red. It is not considered that the conflict analysis demonstrated any difference in safety between operating under VA or MOVA control. Indeed, the results from Ewell Road showed that there can be a large difference in the number of conflicts between days even when using the same control strategy and all other circumstances appear similar.

Signal control strategies that reduce pedestrian waiting time would be expected to reduce the occurrence of pedestrians crossing against the signals, which was involved in many of the conflicts. Queuing through crossings can cause problems, some drivers are willing to allow pedestrians to cross when they see a queue ahead, but others travelling in the same, or opposite, direction may not be so considerate leading to potentially hazardous conditions. Such queues are unlikely to be influenced by the control at the crossing, but a strategy to change to the pedestrian stage more readily in congested conditions may be worth investigating.

Table 3-6: Number of conflicts by category and control strategy; overall daily rates

Category	VA	MOVA
0	16.75	17.2
1	11	9.5
2	1.25	5.33
3	1.25	0.17
4	0.25	0

3.2 Pedestrian delay

From a safety point-of-view it is thought that pedestrian compliance with the green man is desirable. It is also thought that reducing pedestrian delay encourages compliance. The pedestrian delay part of the study has therefore concentrated on these aspects, hence the need to consider in detail when pedestrians arrived, if/when the demand button was pressed, and when they started to cross in relation to the green man.

Pedestrian delay was analysed from the time that the pedestrian pressed the push button. Where pedestrians did not press the button, or it had already been pressed, the delay was calculated from the arrival time at kerb. If a group of pedestrians arrived and crossed together, then they were treated as a single group rather than as n individuals. If they had been counted individually, then the behaviour of a single large group could bias the results.

Pedestrians that either cross with the green man or cross up to 3 seconds before the start of the green man are likely to be reacting to the change in right of way – 3 seconds prior to the green man the amber period will at least be well underway and traffic starting to react to it. At 5 seconds before the green man and with a 2 second all-red period, the amber will have just started and any actions are more likely to be in anticipation of the signals changing rather than direct reactions.

3.2.1 Feltham

The junction has staging that allows traffic phases to run with (non-conflicting) pedestrian phases (walk-with-traffic). The crossing point across the main road included a centre reserve, but was covered with one phase. The crossing distance was therefore quite long and required a very long intergreen between the pedestrian phase ending and the main road traffic phase starting.

An additional characteristic was that pedestrian activity was particularly non-compliant at this site, possibly because of the many opportunities to cross single traffic streams which the layout presents.

A summary of the pedestrian waiting times is given in Table 3-7.

Table 3-7: Summary of pedestrian waiting times at Feltham.

Control strategy		Average (s)	Standard Deviation (s)	Sample size
VA	Waiting time at kerb	11	40	248
	Waiting time at central reserve	12	12	62
MOVA	Waiting time at kerb	9	13	240
	Waiting time at central reserve	13	15	74

VA	Proportion, from kerb	Average delay (s)	Proportion, from central reserve	Average delay (s)
Started to cross in green man	26%	12	27%	4
In first 3s of blackout	4%	0	0%	0
3 to 5s of blackout	5%	0	0%	0
Up to 5s before green man	19%	12	13%	12
Between 5 and 10s before green man	11%	9	15%	3
Other	34%	17	44%	23

MOVA	Proportion, from kerb	Average delay (s)	Proportion, from central reserve	Average delay (s)
Started to cross in green man	25%	14	2%	6
In first 3s of blackout	5%	0	4%	21
3 to 5s of blackout	2%	1	2%	29
Up to 5s before green man	17%	16	20%	08
Between 5 and 10s before green man	15%	5	20%	03
Other	36%	11	52%	29

The delay to pedestrians was broadly similar between the two strategies, especially in the category 'started to cross in green man' which is most relevant to the signal control strategy. From this it is fair to conclude that the differences between the two strategies are most likely due to natural variation between the two days. There is unlikely to be any difference due to the signal control strategy. There is too much effectively uncontrolled pedestrian activity at this site for the signal control strategy to make a noticeable difference.

3.2.2 Lechlade

Lechlade had an all-red pedestrian stage to cater for pedestrians. As with many signal controlled junctions the pedestrian compliance is low. Table 3-8 gives a summary of the pedestrian waiting times.

Table 3-8: Summary of pedestrian waiting times at Lechlade.

VA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	11	17	34	29
7 – 9s from start of green man	0	0	-	-
9 – 11s from start of green man	1	2	2	-
Up to 5s before green man	1	2	11	-
Between 5 and 10s before green man	1	2	16	-
Other	47	77	9	12
All	61	100	14	17

MOVA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	12	14	44*	28
7 – 9s from start of green man	1	1	1	-
9 – 11s from start of green man	0	0	-	-
Up to 5s before green man	4	4	8	10
Between 5 and 10s before green man	4	4	31	29
Other	92	77	9	13
All	118	100	14	21

* *Included a group of 6 pedestrians, all waiting 1 minute 6 seconds. Excluding all but one of this group brought the average down to 34 seconds*

Activity appears to be much higher on the MOVA data. However, problems with the video mean the difference has been exaggerated. As with the Feltham site, the delay to pedestrians was broadly similar between the two strategies. Again from this it is fair to conclude that the differences between the two days in most likely due natural variation between the two days. There is unlikely to be any difference due to the signal control strategy, especially with similar average cycle times (61 seconds under MOVA, 56 under VA). There is too much effectively uncontrolled pedestrian activity at this site for the signal control strategy to make much difference, as is evident in the number of pedestrians in the ‘other’ category, and with the cycle time being relatively low already.

3.2.3 Ewell Road

The Ewell Road site is a Puffin crossing on a wide road with three lanes in total, and a centre refuge. Shopping, hence parking, was prevalent on the two lane approach, effectively making the crossing one-lane for much of the time.

Due to difficulties with this site, MOVA was the control strategy used for both survey days. Table 3-9 provides a summary.

Table 3-9: Summary of pedestrian waiting times at Ewell Road Site.

MOVA day 1	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	254	46	11	10
7 – 9s from start of green man	8	1	0	1
9 – 11s from start of green man	4	1	0	0
Up to 5s before green man	116	21	11	9
Between 5 and 10s before green man	34	6	9	8
Other	133	25	6	10
All	549	100	9	10

MOVA day 2	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	216	41	11	10
7 – 9s from start of green man	6	1	1	3
9 – 11s from start of green man	4	1	0	0
Up to 5s before green man	93	18	9	7
Between 5 and 10s before green man	45	9	6	8
Other	157	30	4	7
All	521	100	8	9

The figures in the tables indicate a high level of consistency between the two days, both in terms of total number of pedestrians observed, and the delay experienced. Unfortunately it is not possible to conclude whether MOVA would have been more effective at minimising pedestrian delay than VA at this site.

3.2.4 Hackney Road, by Cremer Street

Hackney Road is a busy main road in the East End of London. The pedestrian activity was not particularly high, but use of the crossing was steady. This crossing had one lane in each direction, with a centre reserve. The results are shown in table Table 3-10

Table 3-10: Summary of pedestrian waiting times on Hackney Road by Cremer Street.

VA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	64	17	12	10
7 – 9s from start of green man	4	1	4	4
9 – 11s from start of green man	6	1	3	3
Up to 5s before green man	33	9	12	11
Between 5 and 10s before green man	31	8	8	6
Other	231	64	3	14
All	367	100	6	13

MOVA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	22	13	10	6
7 – 9s from start of green man	2	1	-	-
9 – 11s from start of green man	0	0	-	-
Up to 5s before green man	26	15	12	7
Between 5 and 10s before green man	14	8	7	6
Other	108	63	5	8
All	172	100	7	8

At this site, there was more activity on the VA day. However, when the proportion of pedestrians column is considered, then the pedestrian behaviour is similar and there is little difference between the two strategies.

3.2.5 Hackney Road by Dawson Street

This Puffin crossing was located within ½km of the one by Cremer Street. Pedestrian activity was much higher at this site as compared with Cremer Street. The results are shown in table Table 3-11

Table 3-11: Summary of pedestrian waiting times on Hackney Road by Dawson Street.

VA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	229	48	9	10
7 – 9s from start of green man	15	3	2	5
9 – 11s from start of green man	0	0	-	-
Up to 5s before green man	87	18	9	9
Between 5 and 10s before green man	72	16	8	6
Other	68	15	5	5
All	471	100	7	5

MOVA	Number	Proportion (%)	Average delay (s)	Standard deviation
Started to cross in green man	113	41	9	10
7 – 9s from start of green man	3	1	0	0
9 – 11s from start of green man	1	1	0	0
Up to 5s before green man	69	25	7	9
Between 5 and 10s before green man	49	18	6	6
Other	37	14	4	9
All	272	100	7	9

At this site there is little to choose between the two signal control strategies, with MOVA performing slightly better in the 'up to 5s before green man' (ie where pedestrians are starting to cross during the intergreen).

3.2.6 Summary and Conclusions

Previous results for MOVA and particularly Compact MOVA have shown that pedestrians can benefit significantly from their use. However, in this study, there is no real evidence of Compact MOVA giving any benefit. In the case of the two junctions, there are many pedestrians who simply cross as soon as they can rather than wait for the green man. Also at the two junctions the cycle times were not much different between VA and MOVA, probably because both strategies were effectively capped to similar values to be reasonable for pedestrians.

At the two Puffin crossings where a comparison between VA and Compact MOVA was made, there was no real evidence that MOVA was better. It is not understood why this was the case (there was not the time to investigate). However, VA appears to have performed better than expected in this study.

3.3 Compliance of drivers to red signal

The time after the onset of amber at which drivers crossed the stop lines was recorded at all sites. The results are presented as histograms with the number being divided into discrete half-second intervals. Cyclists have not been included in the results as it was clear many will disobey the red signal if they perceived it as being safe to do so.

3.3.1 Feltham

The time that drivers crossed the stop line after the onset of amber at the Feltham site is given in Chart 3.1, and the distance from the stop line at start of amber in Chart 3.2

Chart 3.1. Time drivers crossed the stop line after the onset of amber at Feltham site

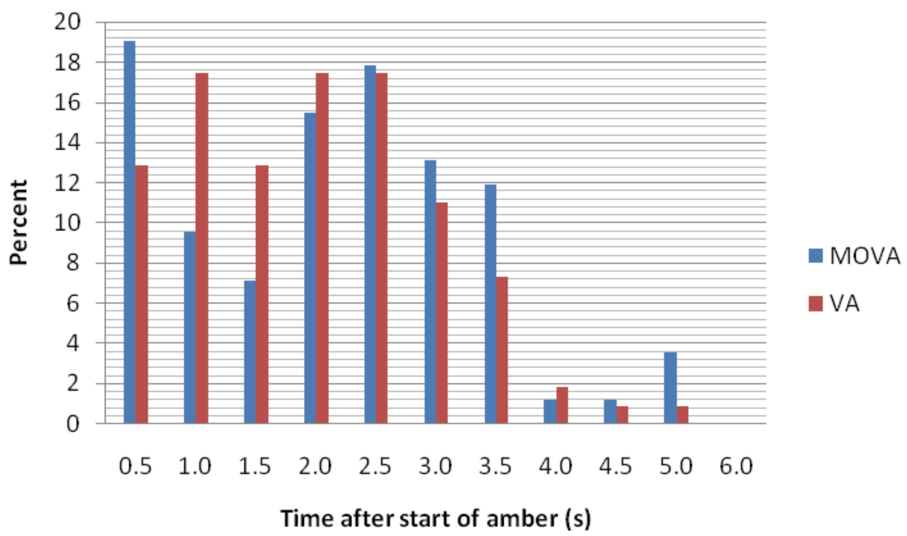
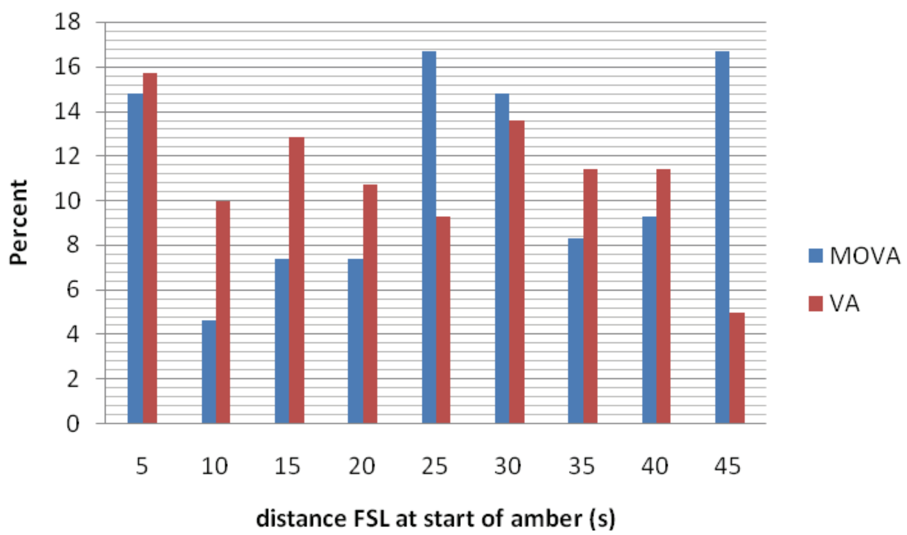


Chart 3.2. Distance from stop line at start of amber at Feltham site

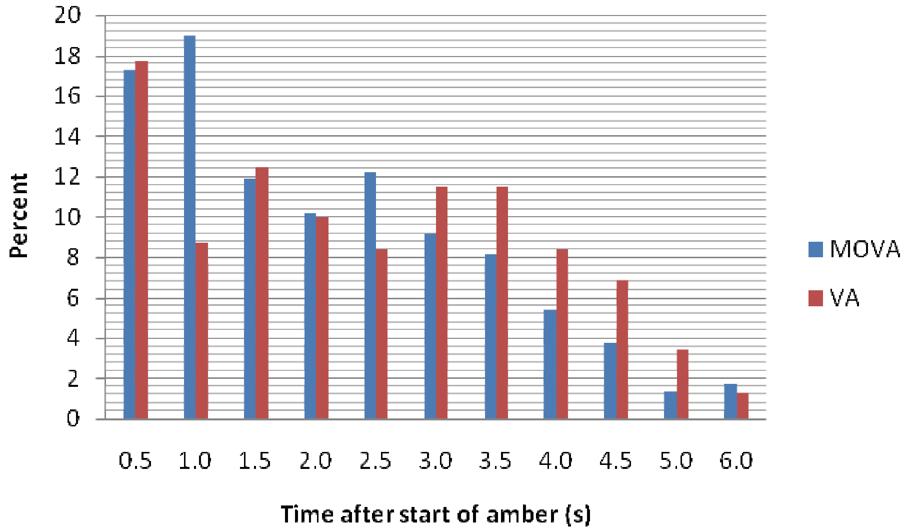


In terms of red-runners there were slightly fewer under VA, although the result is not statistically significant. One reason for this is because the X-detectors were closer to the stop line than the distances recommended thus hampering the operation of MOVA at the site. There would have been few, if any, vehicles that were included in the stop and delay optimisation part of the MOVA process.

3.3.2 Lechlade

The time that drivers crossed the stop line after the onset of amber at the Lechlade site is given in Chart 3.3

Chart 3.3. Time drivers crossed the stop line after the onset of amber at Lechlade site



With the X-detectors placed in accordance with advice, there was much more stop and delay optimisation at this site. As a result, the number of red-runners under MOVA were notably fewer than under VA. The result was statistically significant at 99 percent. The fact that there were a significant number of red-runners under either control strategy is likely to be because of the nature of the site – it is tight with narrow roads, yet is a main route toward Swindon containing a relatively high proportion of HGVs, and there does seem to be a reluctance to fully obey the red signal.

It was not possible to analyse the position of vehicles at the onset of amber due to restrictions with camera locations.

3.3.3 *Ewell Road*

For the Ewell Road site the time that drivers crossed the stop line after the onset of amber is given in Chart 3.4, and the distance from the stop line at the start of amber, is given in Chart 3.5.

Chart 3.4. Time drivers crossed the stop line after the onset of amber at Ewell Road Puffin

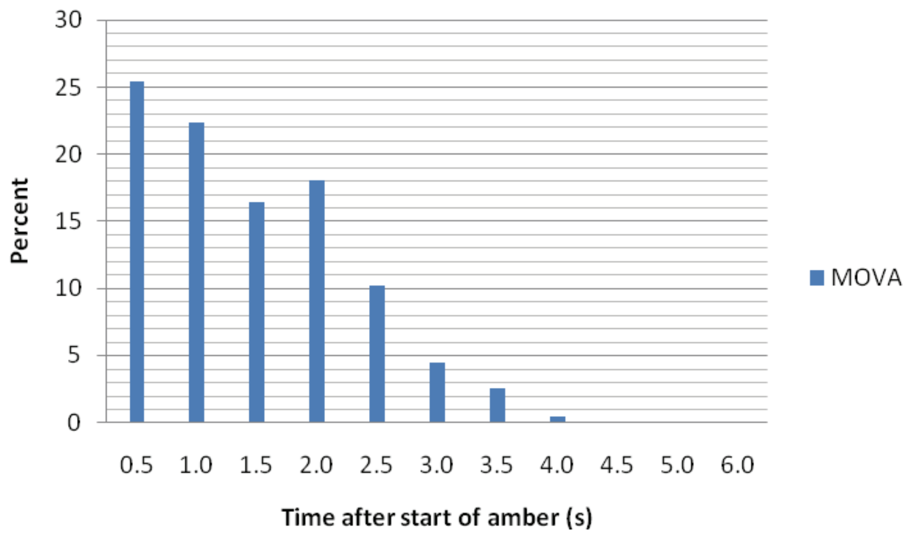
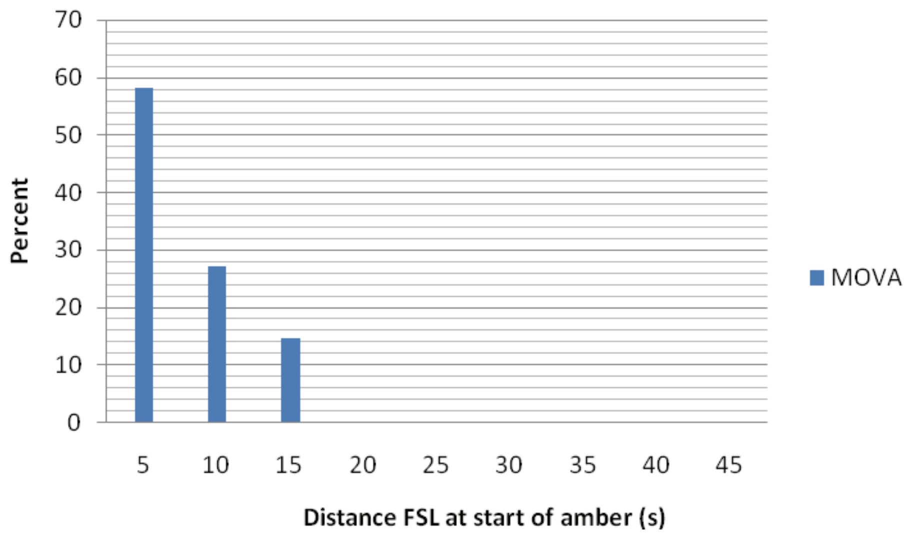


Chart 3.5. Distance from stop line at start of amber at Ewell Road Puffin



The data presented in Charts 3.4 and 3.5 are for MOVA only because, as previously mentioned, it was not possible to run VA at this site. Only 13 vehicles out of the 421 that crossed after the start of amber actually crossed after the start of red. All but two of those crossed within the first half-second of red.

The position at which vehicles were on the approach when amber was presented looks to have been very consistent and MOVA does not appear to have presented any drivers with an awkward decision about whether to stop or continue (15m is easily covered within the 3 seconds of amber even at very low approach speeds).

Once again this site had the X-detectors placed in accordance with TRL advice and again the resulting stop and delay optimisation appears to have been very effective in minimising the amount of red-running.

3.3.4 Hackney Road Puffin by Cremer Street

For the Hackney Road Puffin by Cremer Street the time that drivers crossed the stop line after the onset of amber is given in Chart 3.6, and the distance from the stop line at the start of amber, is given in Chart 3.7.

Chart 3.6. Time drivers crossed the stop line after the onset of amber at Hackney Road Puffin by Cremer Street

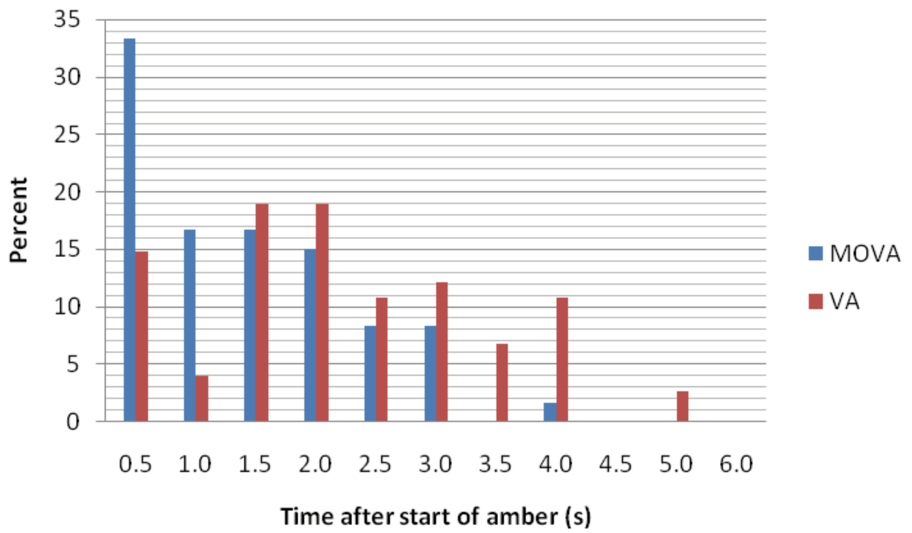
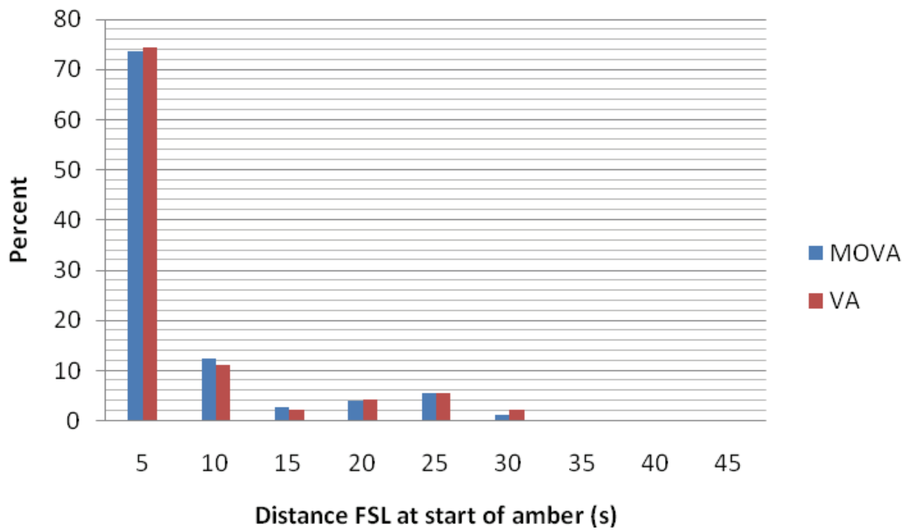


Chart 3.7. Distance from stop line at start of amber at Hackney Road Puffin by Cremer Street



At this site the MOVA X-detection was provided by range-finding above-ground radar detectors. The distance from the stop line that the detection point was set to was again in accordance with TRL advice. There were some issues with detection, but despite this the amount of red-running was again less under MOVA than under VA – statistically significantly so at 99 percent.

3.3.5 Hackney Road Puffin by Dawson Street

For the Hackney Road Puffin by Dawson Street the time that drivers crossed the stop line after the onset of amber is given in Chart 3.8, and the distance from the stop line at the start of amber, is given in Chart 3.9.

Chart 3.8. Time drivers crossed the stop line after the onset of amber at Hackney Road Puffin by Dawson Street

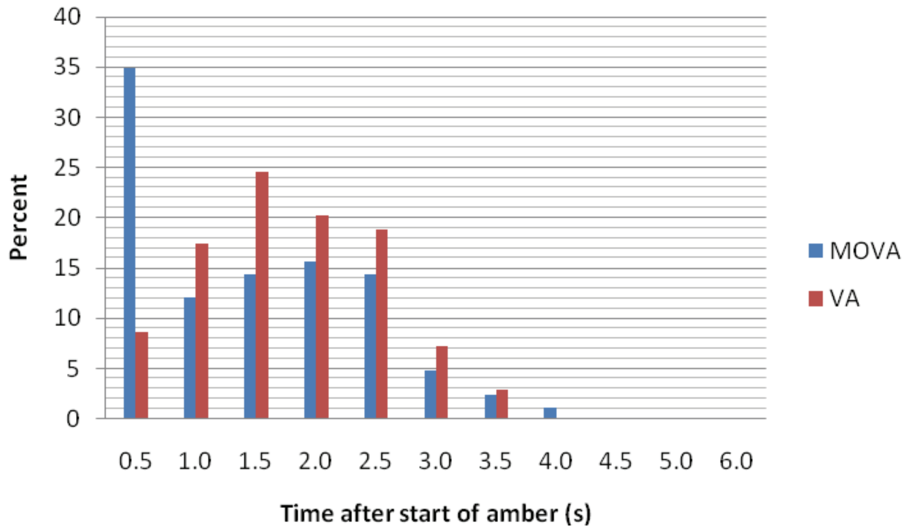
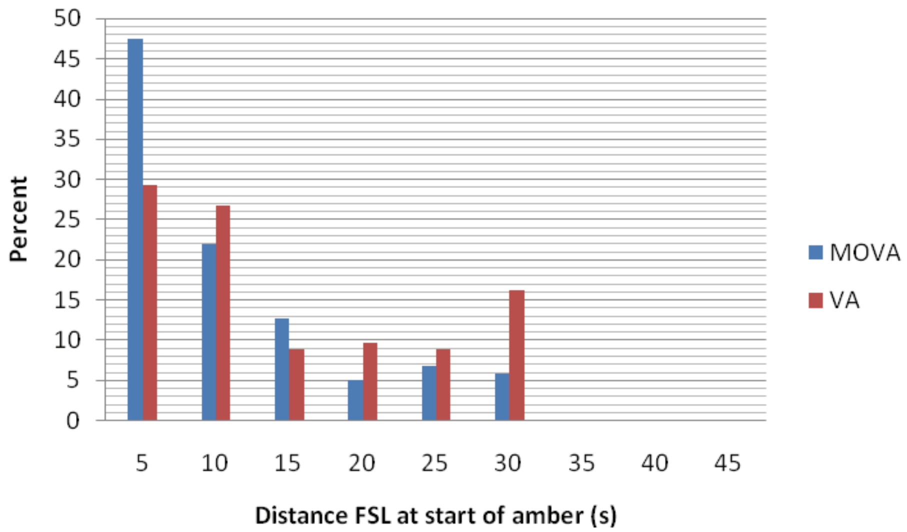


Chart 3.9. Distance from stop line at start of amber at Hackney Road Puffin by Dawson Street



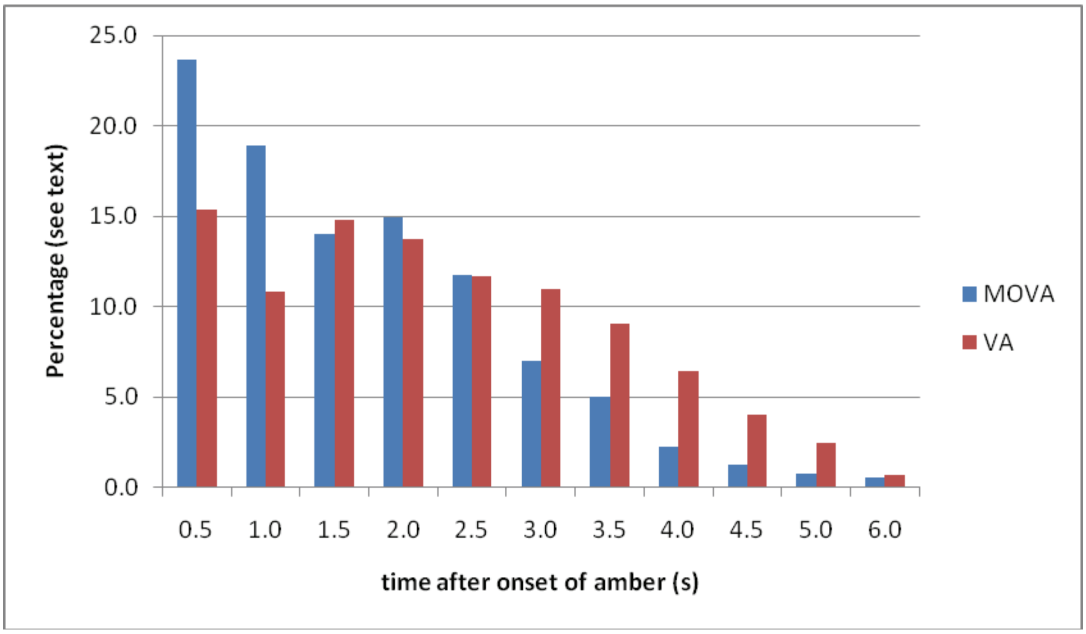
As with the other Hackney Road site, the MOVA X-detection was provided by range-finding above-ground radar detectors. Again the distance from the stop line that the detection point was set to was in accordance with TRL advice.

Despite being an identical type of crossing just a few hundred metres away from the one by Cremer Street, the number of red-runners is noticably lower at this site, under both MOVA and VA. MOVA again can be seen to have reduced the number of red runners, though due to the smaller numbers the result is not statistically significant in this case.

3.3.6 Summary and Conclusions.

In terms of the number of red-runners, Compact MOVA has shown clear signs that it can reduce their number compared with VA. Taking all the sites together (Chart 3.10) shows that, overall, Compact MOVA did reduce the number of red-runners and this was at a high statistical significance. At Lechlade, red-running was reduced by over 50%; at Hackney Road by Cremer Street, under Compact MOVA only 1 vehicle out of 60 ran the red, whereas under VA it was 15 out of 74. The number of red-runners and the extent of the red-running at the Ewell Road site was also very small. These three sites had the X-detector locations at the distances recommended by TRL – the remaining similarly specified site (Hackney Road by Dawson Street) had very few red-runners under either strategy so any differences between them would not have shown up.

Chart 3.10: Overall vehicle stopping behaviour



At the Feltham site, the X-detectors were placed closer to the stop line than ideal for this trial. The evidence suggests that such detector placement may have lead to a similar level of red running under MOVA and VA, where as the other sites suggest Compact MOVA might have given an improvement had the detectors been placed at the slightly more distant location recommended by TRL, although there will always be some degree of site specific behaviour which means the benefits may not occur at every site. It has also been observed that, at the Lechlade site, even though red-running was significantly reduced by MOVA, the amount of red-running was still quite high.

4 Conclusion

To help DfT fulfil their remit to moderate traffic congestion, smooth traffic flow, improve journey time reliability, and to (where possible) improve safety, DfT have been proposing to promote and advise on the use of Compact MOVA. The use of Compact MOVA for stand-alone crossings and as backup for UTC junctions during quiet periods as well as for the more likely isolated junctions ought to help provide more effective signal control in many cases. The study commissioned by DfT and reported here is to assess the safety performance of Compact MOVA. The premise was that if safety was found to be at least as good as standard MVD controlled VA, DfT plan to offer improved advice on the use of Compact MOVA.

Previous work has shown that Compact MOVA can provide benefits at both junctions and stand-alone crossings (Henderson, Crabtree and Maxwell, 2005).

The conflict study undertaken in this project did not reveal any concerns, although it was thought to be rather subjective and it was not possible to attribute any differences to the signal control strategies. Furthermore, at the Ewell Road site, where MOVA ran on both days and conditions were observed to be very similar indeed between the two days; nevertheless a big difference in the number of conflicts was observed. This highlights the variable nature of conflicts.

Previously Compact MOVA has reduced pedestrian delay significantly compared with VA, and indeed standard MOVA. However, in this study, pedestrian delay has not been improved, except by a small amount at one site only. At the junctions this unexpected result might be explained partly by the uncontrolled way in which pedestrians crossed the road, and by the fact that the cycle times were similar – probably due to being constrained to be of similar values for both strategies. It was not clear why the pedestrian delay was not reduced under Compact MOVA at the stand-alone crossings, although, arguably, the delays observed under VA were perhaps less than expected.

Given the low speed of vehicles on the approaches to the junctions on trial, and the absence of IN-detectors, there was no expectation that red-running would be any different between the two strategies. However, at three of the sites, a reduction was observed under MOVA control, and the results were statistically significant overall at 99%. Placement of the X-detectors in accordance with TRL advice appears to have been important in this (or at least not placing the X-detector too close to the stop line).

Overall there appears to be no reason to doubt the safety performance of Compact MOVA against VA system D and some indication that red-running can be expected to be better (which might or might not lead to real safety benefits). That result was not expected.

5 Acknowledgements

We would like to thank DfT (Suku Phull) for commissioning the project, TfL for nominating and preparing sites for study, especially Nigel Pompilis and his team for their efforts and Warwickshire County Council, especially Sue Woodward and her team for preparing the Lechlade site.

6 References

Henderson I R, M R Crabtree and A Maxwell (2005). *Development of Compact MOVA.* TRL Published Report TRL648. Crowthorne: TRL Limited.

Safety evaluation of Compact MOVA Signal Control Strategy – final report

MOVA traffic signal control is used at approximately 3000 junctions in the UK. The recently released MOVA M5 has a facility to exclude the use of the more distance 'IN' detectors (normally around 8 seconds journey time from the stop line) on some or all of the approaches, thus saving ducting and maintenance cost. Commonly known as 'Compact MOVA', it can only be used on low speed approaches (where the 85th percentile speed is less than 35mph).

The performance of Compact MOVA has been found to be better than traditional Vehicle Actuation control, matching standard MOVA in saturated conditions. Studies have also shown that Compact MOVA can significantly reduce pedestrian delay at stand-alone signal controlled pedestrian crossings with negligible effect on vehicular delay when compared with Vehicle Actuation.

Previous risk assessments and a limited safety study indicate that Compact MOVA is as least as safe as Vehicle Actuation. The research in this project, commissioned by the Department for Transport, is necessary to confirm, or otherwise, these findings, and give confidence in the advice given to Local Traffic Authorities. This report describes the study carried out at three stand-alone Puffin crossings and two junctions. The investigation includes conflict analysis and an assessment of pedestrian and driver behaviour.

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ISSN 0968-4093

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Published by

IHS
Willoughby Road, Bracknell
Berkshire RG12 8FB
United Kingdom
T: +44 (0) 1344 328038
F: +44 (0) 1344 328005
E: trl@ihs.com
W: http://emeastore.ihs.com

ISBN 978-1-84608-860-5

9 781846 088605

PPR466