The safety of MOVA at high speed junctions

Prepared for Traffic Management Division, Department for Transport

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Executive Summary

Introduction and background

MOVA is a traffic signal control system designed for isolated junctions – i.e. those not part of a linked UTC system (Vincent and Peirce, 1988). The MOVA method has been developed at TRL over many years and has proven to be significantly better than standard Vehicle Actuated (VA) system in terms of capacity and delays. It is estimated that MOVA reduces delays by over 13% compared to junctions under VA control together with significant increases in capacity (Peirce and Webb, 1990).

The original design brief for MOVA was to reduce delays at isolated signal controlled junctions and did not include any requirements to replace existing systems on high-speed roads (i.e. where the 85th percentile speed exceeds 35 mph and D-system Vehicle Actuation (VA) control with Speed Assessment or Speed Discrimination Equipment (SA/SDE) is required).

Early studies at two high-speed sites proved that MOVA can reduce red-running substantially. An improvement in safety was also indicated when four high-speed sites gave a 30% reduction in injury accidents although only statistically significant at the 10% level. This early finding encouraged DfT to require that ‘All new Trunk Road installations shall incorporate MOVA control.’ (TD 35/91).

Additionally, the recently published Traffic Advisory Leaflet for Signal-control at junctions on high-speed roads (TAL 2/03) allows MOVA to be installed as an alternative to VA with SA or SDE on high speed roads.

In 2000 a study was carried out at 31 sites that had been converted to MOVA from the traditional VA with SA/SDE.

The study considered accident data for at least three years before and after the fitment of MOVA. The conclusion was that MOVA was as safe as VA with SA/SDE, but was no better than that. Better was expected, and a new study, which is reported here, was commissioned to consider the reasons for the lack of improvement. The main consideration was whether or not the quality of the MOVA configuration data had an influence on safety.

Safety study

Of the 31 sites studied in 2000, 25 were used in this study. The others had undergone changes that prevented their inclusion. At each, a sample of the data required to configure MOVA was measured.

Cruise speed, saturation flow and stop penalties were measured on four lanes at each site. The measured data was compared with the MOVA data in use at each site and a score was deduced based on the comparison. Assessments were also made of the link-lane structure, flared approach (bonus) data and detector configuration, which were included in the overall score.

Generalised linear modelling was used to determine the statistical significance of differences between the forms of signal control over the 15 year accident period. The analysis was carried out using the GENSTAT computer program (Alvey, et al., 1977).

The overall results for personal injury accident frequency for the 25 junctions (Table A) show that MOVA was slightly worse for the group of all accidents within 100 metres, but better for two-vehicle junction accidents. It should be noted that none of the differences were statistically significant. Thus the result from the original 31 site trial stands, i.e. there was no significant difference overall in safety between VA with SA/SDE and MOVA at the signal junctions studied.

Table A Estimated effect of MOVA compared with VA by total accident group

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents within 100m</td>
<td>1.07</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>1.01</td>
</tr>
<tr>
<td>Two vehicle junction accidents</td>
<td>0.93</td>
</tr>
</tbody>
</table>

In Table A, ‘All accidents’ are defined as personal injury accidents occurring within 100m of the junction; ‘junction accidents’ are those occurring at the junction or within 20m on any of the arms; ‘two-vehicle junction accidents’ are those occurring at the junction or within 20m on any of the arms and involving two or more vehicles.

A group of 8 sites had the highest scores for MOVA configuration, and it was found that they had a lower accident frequency under MOVA than under VA. The difference was statistically significant at the 5% level for junction accidents and for two-vehicle accidents at the junction (Table B). The differences were 19% for all accidents within 100m of the junction, 26% for junction accidents and 29% for two-vehicle accidents.

Table B Estimated effect of MOVA compared with VA for 8 high-scoring sites

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents within 100m</td>
<td>0.81</td>
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<tr>
<td>Junction accidents</td>
<td>0.74*</td>
</tr>
<tr>
<td>Two vehicle junction accidents</td>
<td>0.71*</td>
</tr>
</tbody>
</table>

* Significant at the 5% level.

The modelling results for the remaining group of lower scoring sites showed an increase in accident frequency compared with VA, of 20% for all accidents within 100m of the junction, 15% for junction accidents and 3% for two-vehicle accidents at the junction (Table C). The increase for ‘All accidents’ was statistically significant at the 5% level.

Five of the sites, three of the best sites and two of the worst, were re-visited by MOVA experts to see if factors affecting the safety that were relevant to MOVA could be seen. Issues to do with MOVA were seen, but nothing that could be related to safety in any direct sense could be determined.
Table C Estimated effect of MOVA compared with VA for 17 low-scoring sites

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents within 100m</td>
<td>1.20*</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>1.15</td>
</tr>
<tr>
<td>Two vehicle junction accidents</td>
<td>1.03</td>
</tr>
</tbody>
</table>

* Significant at the 5% level.

Conclusions

As in the previous study, the results again showed no significant difference in personal injury accidents between MOVA and SDE/SA.

The quality of the MOVA configuration data was shown to have a bearing on safety. The sites with better configurations had lower mean accident frequency than with SA/SDE, while sites with poor configurations had a higher mean accident frequency.

It is important to take steps to reduce the incidence of poor MOVA configuration data. This includes dissemination of the results, and the development of configuration aids. Work is already in hand to ease the task of setting up MOVA sites.

References


1 Introduction

1.1 Background

MOVA is a traffic signal control system, originally designed for isolated junctions – i.e. those not part of a linked UTC system (Vincent and Peirce, 1988). The MOVA method has been developed at TRL over many years and has proven to be significantly better than standard Vehicle Actuated (VA) system in terms of efficiency, capacity and delays. It is estimated that MOVA reduces delays by over 13% compared to junctions under VA control. The increase in capacity available with MOVA gives considerable benefits in terms of reducing delays at busy junctions (Peirce and Webb, 1990). The practice of linking two or more adjacent junctions that use MOVA is also increasing. Currently there are estimated to be about 1,000 MOVA sites in the UK with installation rates of at least 100 per year.

When the design of MOVA started in the early 1980s, the brief did not include any requirements to improve safety compared with existing control strategies. This applies in particular to sites where the 85th percentile speed exceeds 35 mph. At these speeds a dilemma zone exists where stopping is uncomfortable, but to not stop risks crossing the stop line during red. Both options have their own accident potential, the first involving shunt accidents and the second both shunt and side collision. Prior to the use of MOVA the traditional control strategy was D-system Vehicle Actuation (VA) combined with Speed Assessment or Speed Discrimination Equipment (SA/SDE) and this strategy is still widely used. The aim of this control strategy is to protect drivers from a change in signal when they are in the dilemma zone.

The main objective of the algorithms in MOVA was to optimise isolated signal controlled junctions in terms of delay and capacity. Nothing was built into MOVA that would specifically avoid presenting amber whilst a driver is in the dilemma zone. However, early studies proved that MOVA can reduce red-running substantially at high speed sites. At two high-speed sites, red-running was reduced by 30% and 50%.

1.2 Previous research

As part of the early work on MOVA, 20 sites throughout the UK were equipped, as reported by Peirce and Webb (1990). The very first research on MOVA safety considered these 20 sites. Overall the 20 sites did not show any benefit or disbenefits when compared with VA. Of these 20 sites, four had 85th percentile speeds in excess of 35 mph, and were thus defined as ‘high-speed’. Taking the four high-speed sites separately, MOVA was associated with a reduction in accident frequency of about 30%, although the statistical significance was only at the 10% level. This early finding encouraged DfT to require that MOVA ‘shall be considered for all new and refurbished trunk-road sites’.

In view of the low level of statistical significance for the original four high speed sites, further work to try and obtain a higher level of confidence was commissioned by the Department of Transport. Therefore, in 2000, TRL carried out the project entitled ‘MOVA accidents on high-speed roads’ The work compared the accident record at 31 high speed sites that used MOVA control but had previously used D-system VA with SA/SDE fitted. These junctions were chosen as having had no other significant changes other than the fitment of MOVA.

The accident data from the 31 sites was reviewed over a 15 year period, including at least three years before and after installation. The result indicated that at the 31 sites in the test, MOVA was as safe as VA with SA/SDE, but failed to provide any evidence that MOVA improved safety. This was unexpected and so the study reported on here, entitled ‘Safety of MOVA Junction Control System’ was commissioned by the Department for Transport to investigate the reasons for the lack of improvement.

1.3 Objectives of the new project

The study covered in this report considered the sites included the last project ‘MOVA accidents on high-speed roads’ more closely to find out if there were any reasons for the lack of improvement and if so what they were. The underlying objectives of this project were as follows:

- Assess the quality of the MOVA configuration data at the sites studied in ‘MOVA accidents on high-speed roads’.
- Assess whether there is a link between the quality of the data configured and the accident frequencies.
- Assess whether there are other common factors that explain the accident frequencies.
- Consider the implications of the findings in regards to the advice currently given about the application of MOVA and whether changes are needed or not.

One major difference between the original 20-site trial (Peirce and Webb, 1990) and the more recent investigations was the fact that the 20 sites were configured by TRL. The sites in ‘MOVA accidents on high-speed roads’ were set up by various others including local highway authority staff and consultants. This posed the question of whether the quality of the MOVA configuration data could be a factor in the lack of improvement.

The effects of poor data on junction operation and safety are hard to predict theoretically. In the project ‘MOVA accidents on high-speed roads’ a ‘safety-audit’ type exercise was conducted to consider the potential effects that inaccurate data could have on the efficiency and safety of MOVA control. The report on the exercise, as written up at the time, is presented in Appendix A.

Whilst it was impossible to be certain about the conclusions made in the exercise, it was also clear that there could well be undesirable consequences of poor data. The main safety-related consequence involved the possibility of presenting red to drivers when they are in the dilemma zone (where stopping is uncomfortable and not stopping risks crossing the stopline during red). For example inaccurate speed information means MOVA cannot correctly model vehicles on an approach and may present amber at what should be a ‘safe’ time in theory,
but in practice it is not\(^1\). The efficiency of signal control may also be reduced by poor configuration data and it is possible that particular inefficiencies may affect safety. For example, poor service of an approach may lead to frustration which may impact safety.

The overall conclusion from ‘MOVA accidents on high-speed roads’ was that, at the 31 sites in that study, MOVA had no effect on safety. However, there was still reason to believe that MOVA has the potential to improve safety. Hence the objective of this study was to find out if there is anything common across the 31 sites that could explain the lack of improvement in safety.

The main project tasks were as follows:
- Collate existing data/ request additional data.
- Measure a sample of MOVA data at every site.
- A ‘desk-top’ review of the collected MOVA data, comparing it with the MOVA configuration in use on-site.
- Analysis of STATS19 accident data.
- Visit selected sites by MOVA ‘experts’.
- Ask questions of the six Highway Authorities involved to find out how they design their MOVA sites.
- Conclusions and reporting.

2 Measurement of MOVA data

The first project task was to collate the existing data collected in the last study, review the data requirements for this project, and request further data from highway authorities where required. To this end, each of the local authorities for the sites was sent a letter requesting the information required.

The aim of requesting the data was to try to identify any changes to the sites since the last study. Changes considered included those to the MOVA data set, controller configuration, site layout, speed restrictions, and significant changes in vehicle flow levels due to local developments. Further evidence of any changes was assessed on site by, for instance, inspection of the controller logbook, controller specification and the MOVA data set. The significance of the change, and whether the effect of the change could be incorporated into the analysis, was assessed. Six of the 31 sites had to be excluded from this study due to changes since the time of the previous review.

2.1 Revisit the high-speed sites from the original 20-site trial

Three of the four high-speed sites in the original 20-site trial still existed in a virtually unchanged state as far as can be determined. A review of the accident records of these sites was warranted to see if the original good showing has been maintained or not. Care was needed as changes over the 10 years since the original review were inevitable. A careful review of the possible outside influences on the safety record has been made. Traffic flows will have changed (probably increased) during that time, but apart from that no significant changes were found. The MOVA data sets currently in use were checked against the original TRL data and were found to be unchanged.

2.2 Measurement of MOVA data

To assess the quality of MOVA data, accurate measurement of a sample of data was undertaken at every site by trained TRL staff. An important feature of this task was that it was undertaken without any knowledge of the accident record. This was considered important so as to avoid bias in either the sample or the measurements.

Attempts to link the data quality and the safety record were made later.

The main reason for taking a sample only (as opposed to collecting all the required data for a complete MOVA commission) was to keep costs down to an acceptable level and allow all the sites to be visited. At each site the intention was to take measurements of cruise speed, saturation flow and proportion of heavy vehicles in four lanes chosen at random and including minor lanes. At a number of sites there were an insufficient number of lanes suitable for taking the required measurements. However, it is believed that enough data was collected for a reasonable estimation of the quality of data to be made. Both cruise speed and saturation flow were measured using Personal Data Assistant (PDA) palm top computers loaded with TRL’s ‘Bundle’ (Binning, 2002).

The data measured in more detail were:

- **Cruise speed** – MOVA has as part of its data a value of speed known as ‘Cruise speed’. It is the 15th percentile speed of vehicles arriving after the queue has discharged on each approach lane. From the outset, it was considered that the accuracy of cruise speed could be one of the more important contributory factors to safety performance at MOVA sites. Appendix A suggests the possible consequences of incorrectly specified cruise speed. Essentially, if the cruise speed is inaccurate, it is more likely that the actual position of vehicles on the road and the position estimated by MOVA will not agree and there is a greater chance of a poor stage-change decision in the face of oncoming traffic. The discrepancies between the MOVA model and reality can also reduce efficiency.

- **Saturation flow** – MOVA has as another data item the saturation flow for each lane (MOVA actually uses the inverse of saturation flow in seconds/vehicle – the data item being known as SATINC). This normally needs to be measured on-site. Accurate saturation flow data is possibly most important during capacity maximisation – an incorrect value of SATINC is likely to reduce the efficiency of the capacity maximisation process and lead to longer than necessary delays. At other times MOVA uses SATINC to determine when a queue has fully discharged in order to determine when to start using the delay and stops minimisation process. At this point, a very poor value may result in MOVA switching to delay minimisation mode whilst there are still queuing vehicles.

\(^1\) The mechanisms behind this are complex and beyond the scope of this report.
to discharge; or not switching long after the queue has discharged. In itself this can result in poor stage-change decisions; but SATINC is also used in the calculation of other important configuration data and a poor value may further degrade control. Inefficient control may lead to frustration which does have potential safety implications. Therefore reasonably accurate values of SATINC are essential to optimum junction operation. However, the potential effect on safety of any error in the saturation flow is still, at least in any direct sense, difficult to suggest.

**Proportion of heavy vehicles** – One final key data item, possibly, is the proportion of heavy vehicles, which is used in conjunction with the cruise speed in specifying stop penalties. It is conceivable that poorly set stop penalties (known as ‘STOPEN’ in MOVA) could distort MOVA’s decisions about when to change away from green in the face of approaching traffic and increase the chances of catching drivers in the dilemma zone.

**Geometric data** – In addition to the measurements above, geometric data was also measured, the main ones being the distances to the detectors. The measured distances were usually different from the distances on the site layout diagrams (SLDs), though not usually by much.

### 3 Desktop review of MOVA data

Normally, much of the work needed to produce a MOVA data set is done ‘at the desk’. Before this point, the on-street measurement of MOVA data (especially the items mentioned in the previous section) needs to be carried out. This data, combined with the information from site layout diagrams (SLDs) and the signal controller specification forms (TR2210 or TR0141), are then used to complete the MOVA data for use on site. After installation (during commissioning and validation) adjustments are often required, but a large proportion of the data set creation is done away from site.

For this study, a comparison was made of existing MOVA data with the measured data, SLDs, and TR0141 forms, although this stopped short of re-creating the MOVA data for any of the sites. The results from this were compared with the data in use at each site. The main purpose of making the comparison was so that the accuracy of the data could be included as a parameter in the accident analysis. By doing this, the effect that the poorer quality MOVA data had on accidents was revealed (see Section 4).

#### 3.1 Data quality

The quality of data set configuration has been assessed by comparing the sampled measurements with those in each of the MOVA configuration data files as follows:

##### 3.1.1 Cruise speed

The cruise speed measurement was converted into two separate values for each lane: namely the times taken for a vehicle travelling at cruise speed to reach the stopline from the IN detector and the X detector, known as ‘CRUSIN’ and ‘CRUSX’ respectively. CRUSIN and CRUSX are both values of time that are derived from the speed and the distance to the respective detectors. Hence the error between measure and ‘in-use’ values are not only subject to incorrect speed measurements, but also due to the incorrect detector distances. Values for CRUSIN and CRUSX were calculated from both the cruise speeds and the detector distances measured on street. These were compared directly with the CRUSIN and CRUSX times in the MOVA data. CRUSX and CRUSIN were compared separately.

##### 3.1.2 Saturation flow

For saturation flow data, the values measured on-street were converted to ‘SATINC’ (the name used in MOVA for the inverse of saturation flow which is in seconds/vehicle) and compared with the values in the MOVA data.

##### 3.1.3 Stop penalty

The stop penalty value, ‘STOPEN’, is derived from the cruise speed and the proportion of HGVs by reference to a lookup table contained in the ‘Guide to MOVA data set-up and use (Crabtree et al., 2004). The proportion of HGVs was measured on the same lanes as for cruise speeds, and a revised value obtained from the table.

##### 3.1.4 Scoring system for comparing data quality

To indicate the quality of MOVA data, a scoring system was set up that gave each site an overall ‘mark out of 10’ for the quality of data (see below). This overall mark was obtained from individual marks for each site for CRUSIN and CRUSX, SATINC, STOPEN and also a score for the qualitative assessment of the link-lane structure and other data issues (such as use of combination detectors and bonus data).

The scores for CRUSIN, CRUSX and saturation flow were themselves calculated as the sum of the scores from the following two-part assessment:

- **Part 1 = worst error in percent (of up to four measured) × 1 (if the error was on a side road) or 2 (if the error was on the main road).**
- **Part 2 = average percentage error over up to four measurements.**

Each of the two parts was converted to a score of between 0 and 5 representing increments of 5% as follows:

<table>
<thead>
<tr>
<th>Percentage error</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 4.9</td>
<td>5</td>
</tr>
<tr>
<td>5.0 – 9.9</td>
<td>4</td>
</tr>
<tr>
<td>10.0 – 14.9</td>
<td>3</td>
</tr>
<tr>
<td>15.0 – 19.9</td>
<td>2</td>
</tr>
<tr>
<td>20.0 – 24.9</td>
<td>1</td>
</tr>
<tr>
<td>25.0 and more</td>
<td>0</td>
</tr>
</tbody>
</table>

With the scores from the two parts added together, the score then becomes a value of between 0 and 10.

The final score for any individual site was the average of all the individual scores, rounded up to the next whole number. Table 1 shows the scores obtained.
Using the system above, the scores for all the sites ranged between 2 and 6, suggesting that at even the ‘best’ junctions, agreement between TRL measured values and those in the MOVA data might not be especially good! Note, however, that the scoring system was arbitrary and possibly quite stringent.

Looking at the individual measured data items, it is clear that there are some large errors. STOPEN values look particularly poor, but these are deduced from two measured values, namely the proportion of heavies and cruise speed. So the error is cumulative and likely to be more noticeable when the constituent parts are themselves in error. In any case, the stop penalty is of less importance than delay in the stop and delay optimisation and it will have a noticeable effect only on very few occasions.

Aside from the specific errors between the measured and ‘in-use’ data, the general quality of the data was also assessed. In practice this mainly involved consideration of the BONUS2 data, the use of combination detectors and the link–lane structure. A score out of 5 was applied to each site depending on the assessment.

The link–lane structure appeared to be wrong in just one case with three other cases where it was unlikely to have been correct. In most other cases, alternative structures could have been appropriate, but there was not enough information to decide whether they may have been better than the one selected or not (and they were not marked down as a result).

The other issues concerned the use of combination detectors and bonus data. The TRL sites were largely satisfactory from this point of view, but no site outside greater London had any ‘BONCUTs’3 set, suggesting many users have not understood bonus data and how it can be used. It was judged that some sites may well have operated more effectively if bonus data was included, with BONCUTs specified, to control short cycling as appropriate.

Combination detectors4 were often not specified when they should have been and IN-sink detectors also were often missing. There were a number of cases where either one or the other should have been present. This could result in significant compromises in the way MOVA operates because the sometimes crucial bonus data is

<table>
<thead>
<tr>
<th>Site reference</th>
<th>VA</th>
<th>MOVA</th>
<th>Ratio score</th>
<th>Sat flow score</th>
<th>CRUSX score</th>
<th>CRUSIN score</th>
<th>STOPEN score</th>
<th>Link lane score</th>
<th>Overall score</th>
<th>IN-sink</th>
<th>Link struct</th>
<th>Bonus data</th>
<th>Other</th>
</tr>
</thead>
<tbody>
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<td>2.67</td>
<td>1.20</td>
<td>0.45</td>
<td>8</td>
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<td>H016</td>
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<td>1.15</td>
<td>8</td>
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<td>18.22</td>
<td>1.31</td>
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<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

- Poor or incorrect use of the feature
- Feature not relevant
- Feature relevant and correctly used

2 MOVA calculates extra capacity (bonus) due to flared approaches and from this whether short-cycling would be beneficial in congested conditions or not. This is known as BONUS data in MOVA parlance.

3 BONCUTs, another MOVA data item, allow users to specify whether flared approaches should be allowed to dominate the capacity maximisation process or not.

4 Combination detectors are used to help MOVA avoid finding the end of saturated flow prematurely where a single lane with one IN-detector feeds two or more lanes each with an X-detector.
deduced from IN-sink and combination detector information. Bonus data was sometimes absent as a result, even though flares existed.

The local authorities were subsequently contacted and informed of any notable errors in the data or deficiencies in the link-line structure.

4 Analysis of STATS19 accident data

Having completed the desk-top review of the sites and the data collected, the analysis of the accident statistics was conducted. The task was to review the personal injury accident data collected in the previous MOVA Safety project and to collect the accident data for the intervening years where possible. All the information was used firstly to check if there had been any changes since the previous project and, secondly, to compare the accident record before and after the installation of MOVA with the quality of the MOVA configuration data.

4.1 Background

Early on in its life, MOVA was shown to reduce the amount of red-running substantially at two high-speed sites. The main reason for the reduction in red-running is the result of a significant advantage MOVA has compared with D-system VA when the latter is combined with SA/SDE. The drawback with VA is that, in all but the very lightest of traffic intensities, the signals frequently change when a maximum time has been reached, as opposed to finding big enough gap(s) in the traffic in which to change safely. With such arbitrary changes, there is an average chance that vehicles will be caught in the dilemma zone (where stopping is uncomfortable, but continuing can mean crossing the stopline during the early part of the red).

The SA/SDE system provides extensions to ‘fast’ vehicles which allow them to reach the system-D X, Y, Z loops, which give further green extensions to allow vehicles to cross the stopline before changing to amber. The reason for the propensity of the signals to change at maximum is that gaps have to be very big for D-system VA with SA/SDE to change before that. To compound the problem, the gaps need to occur simultaneously on all approaches equipped with SA/SDE that will lose right of way together.

MOVA reduces red-running because, generally speaking, it will change when the traffic intensity on the approaches is below average (but not necessarily zero) meaning the chances of catching drivers in the dilemma zone are also below average. This is helped, in no small part, by the assumption that drivers will treat a certain amount of amber as being effectively green (the amount is a data item in the MOVA configuration and usually varies between 1.5 seconds and 2.5 seconds, depending on site characteristics, an important one being speed). This means that MOVA, although not searching for gaps per se, is, in practice, more likely to succeed in changing the signals when there is a sensible gap in arrivals, as opposed to regularly reaching a maximum green limit and changing arbitrarily.

Having established that MOVA has the ability to reduce red-running, there was always the question of the extent to which accidents are related to red-running, and whether a reduction in red-running translates into MOVA being inherently safer than traditional systems.

As part of the early work on the original 20-site trial it was found that a reduction in accidents was associated with MOVA at the four high-speed sites in the trial. A reduction of 30% in accidents was recorded and this was statistically significant at the 10% level (90% confidence). Red-running accidents were reduced by 52% (again with 90% confidence). Taking 19 of the 20 sites in the original trial (one site proved unsuitable for MOVA and was switched back to VA), MOVA was no worse than D-system VA. The figures gave good reason to be optimistic about the potential safety benefits offered with MOVA control at other high-speed sites. However, with just four sites and 90% confidence, further work was required to confirm these findings.

This led to the study of 31 sites reported in ‘MOVA accidents on high-speed roads’. However, no statistically significant difference between MOVA and VA control was found. Accordingly, a new study was commissioned in order to investigate this result in more detail. It was anticipated that most of the 31 sites would still be running MOVA and that 3 additional years of accident data would be available. The intention was to determine whether there were any problems in their configuration by comparing the newly measured data with that used at each site as described in the previous section.

On re-examination, 25 of the 31 sites in the ‘MOVA accidents on high-speed roads’ study were found to be still running MOVA and were physically unchanged, with no reason to believe that traffic patterns had changed significantly. In this study, the original analysis period was extended to include personal injury accident data from 2000 to 2002, giving 15 years in total.

4.2 STATS19 data

Details of personal injury accidents at the junctions from 1988 to 2002 were obtained from the STATS19 database. The accidents obtained were all those occurring within 100m of the junction (on the basis that accidents even quite remote from the junction could be influenced by the signal control). Their locations were determined from Ordnance Survey grid references. The total number of accidents obtained was 2195, giving an average accident frequency of 5.85 accidents per junction-year (regardless of the method of signal control, which could be VA, MOVA or ‘other/unknown’).

4.3 Plain language descriptions

Plain language descriptions of the accidents were obtained from the appropriate local authorities. The information was used to identify accident types in more detail and to clarify accident locations. Where the numbers of accidents supplied by the local authorities differed from those obtained from STATS19, all those occurring within 100m of the junction were included.
### 4.4 Accident groups

Three main personal injury accident groups were defined as:

- All accidents occurring within 100m of the junction.
- Junction accidents (i.e. those occurring at the junction or within 20m on any of the arms).
- ‘Two-vehicle’ junction accidents (i.e. those occurring at the junction or within 20m on any of the arms and involving two or more vehicles).

The total numbers of accidents in each of these groups and their severity are shown in Table 2.

### Table 2 Numbers of accidents and severity for total accident groups under all methods of signal control

<table>
<thead>
<tr>
<th>Description</th>
<th>Number of accidents</th>
<th>Severity (% serious &amp; fatal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight &amp; fatal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All accidents</td>
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<td>2195</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>1226</td>
<td>1422</td>
</tr>
<tr>
<td>Two vehicle junction accidents</td>
<td>1106</td>
<td>1244</td>
</tr>
</tbody>
</table>

### 4.5 Accident modelling

Generalised linear modelling was used to determine the statistical significance of differences between the forms of signal control over the 15 year accident period. The analysis was carried out using the GENSTAT computer program (Alvey et al., 1977).

Accident modelling was undertaken for all accidents within 100m of the junction, all junction accidents and all two-vehicle junction accidents, and for subgroups of each of these, comprising serious & fatal and slight accidents. The model included the following factors:

- Changes over time at individual sites.
- Trends over the 15 year period being considered.
- Seasonality factors.

Table 3 gives the breakdown of accident numbers and frequency by form of signal control. For example, accident frequency under MOVA control was calculated from:

\[
A = \frac{\text{Accidents under MOVA}}{\text{Junction years under MOVA control}}
\]

Overall, accident frequency under MOVA was very similar to that under VA.

By contrast, accident frequency under ‘other/unknown’ control was rather higher than under either MOVA or VA.

### Table 3 Accident frequency by form of signal control

<table>
<thead>
<tr>
<th>Description</th>
<th>VA</th>
<th>MOVA</th>
<th>Other/unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction years</td>
<td>124.0</td>
<td>156.25</td>
<td>94.75</td>
<td>375.0</td>
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<tr>
<td>All accidents</td>
<td>628</td>
<td>777</td>
<td>790</td>
<td>2195</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>97</td>
<td>110</td>
<td>116</td>
<td>323</td>
</tr>
<tr>
<td>Slight</td>
<td>531</td>
<td>667</td>
<td>674</td>
<td>1872</td>
</tr>
<tr>
<td>Severity (% fatal or serious)</td>
<td>15.4%</td>
<td>14.2%</td>
<td>14.7%</td>
<td>14.7%</td>
</tr>
<tr>
<td>All accidents / year</td>
<td>5.06</td>
<td>4.97</td>
<td>8.34</td>
<td>5.85</td>
</tr>
<tr>
<td>Serious &amp; fatal accs/yr</td>
<td>0.78</td>
<td>0.70</td>
<td>1.22</td>
<td>0.86</td>
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<tr>
<td>Slight accs/yr</td>
<td>4.28</td>
<td>4.27</td>
<td>7.11</td>
<td>4.99</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>391</td>
<td>504</td>
<td>527</td>
<td>1422</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>55</td>
<td>74</td>
<td>67</td>
<td>190</td>
</tr>
<tr>
<td>Slight</td>
<td>336</td>
<td>430</td>
<td>460</td>
<td>1226</td>
</tr>
<tr>
<td>Severity (% fatal or serious)</td>
<td>14.1%</td>
<td>14.7%</td>
<td>12.7%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Junction accidents / year</td>
<td>3.15</td>
<td>3.23</td>
<td>5.56</td>
<td>3.79</td>
</tr>
<tr>
<td>Serious &amp; fatal accs/yr</td>
<td>0.44</td>
<td>0.47</td>
<td>0.71</td>
<td>0.52</td>
</tr>
<tr>
<td>Slight accs/yr</td>
<td>2.71</td>
<td>2.75</td>
<td>4.85</td>
<td>3.27</td>
</tr>
<tr>
<td>Two-vehicle jn accidents</td>
<td>365</td>
<td>456</td>
<td>423</td>
<td>1244</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>40</td>
<td>54</td>
<td>44</td>
<td>138</td>
</tr>
<tr>
<td>Slight</td>
<td>325</td>
<td>402</td>
<td>379</td>
<td>1106</td>
</tr>
<tr>
<td>Severity (% fatal or serious)</td>
<td>11.0%</td>
<td>11.8%</td>
<td>10.4%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Two-vehicle jn accs / year</td>
<td>2.94</td>
<td>2.92</td>
<td>4.46</td>
<td>3.32</td>
</tr>
<tr>
<td>Serious &amp; fatal accs/yr</td>
<td>0.32</td>
<td>0.35</td>
<td>0.46</td>
<td>0.37</td>
</tr>
<tr>
<td>Slight accs/yr</td>
<td>2.62</td>
<td>2.57</td>
<td>4.00</td>
<td>2.95</td>
</tr>
</tbody>
</table>

Table 4 Estimated effect of MOVA compared with VA by total accident group

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>1.07</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>1.12</td>
</tr>
<tr>
<td>Slight</td>
<td>1.06</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>1.01</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>1.15</td>
</tr>
<tr>
<td>Slight</td>
<td>0.99</td>
</tr>
<tr>
<td>Two vehicle junction accidents</td>
<td>0.93</td>
</tr>
<tr>
<td>Serious &amp; fatal</td>
<td>1.07</td>
</tr>
<tr>
<td>Slight</td>
<td>0.91</td>
</tr>
</tbody>
</table>

1 Estimates unreliable due to small numbers of accidents.

In the study carried out in 2000 on the 31 high speed sites, no significant difference overall in the personal injury accident frequency was found between the VA and MOVA control. This finding has been confirmed at the 25 signal junctions (six fewer sites than in the earlier study) included in this study. MOVA was associated with a 7% higher accident frequency within 100m of the junction and a 1% higher accident frequency at the junction itself, but a 7% lower frequency for two vehicle accidents, compared with VA. It is important to note, however, that none of the results were statistically significant.

### 4.6 Effect of MOVA configuration

#### 4.6.1 Higher-scoring sites

Modelling was undertaken on the subset of 8 sites with...
higher scores (of 4, 5 or 6) for MOVA configuration. Models for total accident groups showed a lower accident frequency under MOVA than under VA and the difference was statistically significant at the 5% level for junction accidents and for two-vehicle accidents at the junction. The differences were 19% for all accidents within 100m of the junction, 26% for junction accidents and 29% for two-vehicle accidents (Table 5). The result for junction accident frequency is similar to the 30% lower accident frequency under MOVA obtained at the four high speed sites that were included in the original 20 site trial. The 95% confidence limits for the ratios were from 0.57 to 0.97 for junction accidents and 0.53 to 0.95 for two vehicle junction accidents.

Table 5 Estimated effect of MOVA compared with VA for 8 higher-scoring sites

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>0.81</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>0.74*</td>
</tr>
<tr>
<td>Two vehicle junction</td>
<td>0.71*</td>
</tr>
</tbody>
</table>

* Significant at the 5% level.

4.6.2 Low-scoring sites

By contrast, the modelling results for the remaining low scoring sites showed an increase in accident frequency compared with VA (Table 6), of 20% for all accidents within 100m of the junction, 15% for junction accidents and 3% for two-vehicle accidents at the junction. The increase for all accidents was statistically significant at the 5% level.

Table 6 Model parameters for MOVA compared with VA for 17 low-scoring sites

<table>
<thead>
<tr>
<th>Accident group</th>
<th>Ratio of effect of MOVA to effect of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>1.20*</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>1.15</td>
</tr>
<tr>
<td>Two vehicle junction</td>
<td>1.03</td>
</tr>
</tbody>
</table>

* Significant at the 5% level.

4.6.3 Further investigation

Further investigation was undertaken to try to identify the elements of the site configuration that were most important. The stop penalty and the link/lane structure showed little correlation with high scoring sites. Sites with good estimates of saturation flows tended to have high scores, but the correlation was only about 27%.

Cruise speeds showed the highest correlation with overall score, about 70%. However, they did not offer any better discriminatory power than the overall configuration score, with values as low as 2 out of 10 for cruise speed alone constituting a ‘good’ score. It did not prove possible to say whether under or overestimating the cruise speed was better, since only 3 of the sites included in the accident analysis had speeds underestimated compared with the measured data.

4.6.4 Overall finding

Overall, the finding from the modelling of the 8 high scoring sites and the other 17 lower scoring sites was that the quality of MOVA data has a bearing on the safety of the junction. There was some (but inconclusive) indication that cruise speed data has the greatest effect on safety, but it was not possible to distinguish between overestimating and underestimating speeds in that respect.

4.7 Further site visits

To investigate the findings of the accident analysis further, visits were made to five of the sites by MOVA experts: two sites that had been found to have an improved safety record under MOVA and three for which the opposite was the case. It was hoped to identify junction characteristics that have an influence on safety and to gain an understanding as to why some sites had an improved safety record under MOVA and others had not. Section 5 describes the results of those visits.

4.8 ‘Original’ high-speed MOVA sites

A check was also made of the original 4 high-speed sites that had led to the earlier tentative conclusion that MOVA was safer than VA at high-speed sites. One of the sites had changed and was therefore not considered further. The remaining three were all in London. Details of accidents at or within 20m of the junctions were obtained from STATS19 for the period from 1990 to 2002. Figure 1 of accident frequency as a function of time shows a very slight upward trend over the period, which was not statistically significant. It is likely that traffic flows have increased substantially over the same period and therefore accident rates will have fallen. However, it is not clear to what extent the presumed decrease in the accident rate compares with the long term downward trend in accident rates in the UK, or the trend in accident rates at signal-controlled junctions.

In this study, only accident frequency post 1990 was considered. The results for pre-1990 accidents were available from previous work but some accidents had been filtered out invalidating the comparison. Firstly, some accidents that were considered to be unrelated to the operation of the signals were omitted from the earlier study; this could not be done in this study because plain language data was not available. Secondly, at one of the three sites, a change was made to the junction during the original study which meant that accidents involving right turning vehicles from one approach had to be excluded.

However, it seems reasonable to suggest (if not conclude) that the original good showing (30% reduction) at these sites looks to have been approximately maintained since those original trials.

5 Visits to site by MOVA experts

5.1 Procedure

As a final component of the project, a selection of MOVA sites was re-visited by two senior TRL staff who between
them have had about 35 years experience with MOVA. Five of the sites were visited, three that had a poorer safety record under MOVA and two with a better record. The hope was that some indication as to why the accident records were different would be observed.

Prior to visiting the sites, a review of the information available for each of them was undertaken, including the accident record. The following checklist was used both before the site visit and on-site to help gather the information required:

- Location and details of the site to be visited.
- Conditions at the time of the visit.
- The version of MOVA in use.
- Accident record under VA and MOVA.
- Amount of delay optimisation observed.
- Fault record.
- General efficiency (Bonuses, Link structure, Lost time, Phasing complexity).
- Other issues.
- Geometry (Phase lags, Speed limits and speeds in general).

Reports on each of the site visits can be found in Appendix B.

5.2 Findings from site visits

All the sites visited were running acceptably with MOVA and, at the more heavily trafficked London sites at least, looked to be running very efficiently. However, at each site there were various issues to do with the way MOVA had been set up and operating.

Overall, it proved impossible to identify particular safety issues at any of the sites that could be attributed to a different signal control strategy. That is not to say that there were none; just that it was difficult to spot any.

Various observations were made which were not considered to impact safety, at least not directly. The more significant ones follow.

At two of the sites, S023 and S024, two exits (one at each) were restricted in width by parked vehicles (which appeared to be residents of houses on those arms in both cases). This meant that exiting vehicles were crossing the MOVA detectors which, in turn, affected the calculated minimum green (the time needed to clear vehicles queuing between the stop line and the X detector) for the next time those approaches received green. This would often cause a maximum-minimum (known as MAXMIN) green to run, which was often much longer than necessary. Occasionally the stage itself ran unnecessarily as exiting vehicles put in demands without any vehicles waiting at the stop line. This obviously affects operational efficiency, but it ought not to have any noticeable effect on safety, except by introducing the occasional unnecessary stage change and perhaps adding to frustration. If this same problem was to occur under VA the stage would run unnecessarily but would not run longer than necessary. This might well be a common problem, and uni-directional detectors have been used in some cases to provide a solution. Their use perhaps ought to be more widespread.

All of the sites had a similar characteristic on at least one of the approaches whereby vehicles could queue side-by-side close to the stopline but well downstream of the X-detector. What was observed at most of the sites was that at low flows, the calculated minimum could be longer than necessary, possibly reaching MOVA’s MAXMIN (typically about 15s) when perhaps only half that value was really needed. There are two possible ways of dealing with this: the first is to have a reduced start-up lost time (STLOST, possibly using a negative value) or the second would be to have an X-sink detector to count out the doubled-up vehicles. Both should result in a more appropriate calculated minimum. Unfortunately, neither method is appropriate if lane usage is such that side-by-side queuing does not occur most of the time - the calculated minimum may be too short on the occasions when queuing occurred in a single lane. Once again, such operational inefficiencies ought not to impact safety, except by causing visually obvious unnecessary delay, hence frustration possibly.

At the site S023 it was obvious that changes to the layout had been made at some point in the recent past (new signal heads, including pedestrian aspects, and lane markings that looked fresh). Subsequent enquiries revealed that changes occurred about a year after MOVA was installed and also...
that MOVA had not operated satisfactorily for long periods during that first year. Because of this the site has been excluded from the analysis.

5.3 Cruise speed measurement consistency

The one single MOVA data item that, on the face of it, could have the most direct impact on exactly when MOVA changes stages in the face of oncoming traffic is cruise speed (see section 2.2). This raises the questions of how easy it is to measure and how consistent the results might be.

To gain some idea of this, several measurements were taken at a single location as follows:

i Single person measuring six separate sets of data over a period of about two hours (Table 7).

ii Three observers taking measurements at the same time, over the same distance, but free to decide for themselves which vehicles to measure (Table 8).

iii As for ii but all three observers measuring the same vehicles (Table 8).

Table 7 Six separate cruise speed measurements

<table>
<thead>
<tr>
<th>Survey</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
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<td>19</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Mean speed (mph)</td>
<td>32.10</td>
<td>37.60</td>
<td>35.20</td>
<td>39.80</td>
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<td>37.90</td>
</tr>
<tr>
<td>Cruise Speed (ms⁻¹)</td>
<td>12.59</td>
<td>12.18</td>
<td>13.37</td>
<td>15.12</td>
<td>14.25</td>
<td>14.40</td>
</tr>
<tr>
<td>Cruise Speed error</td>
<td>± 0.4</td>
<td>± 0.7</td>
<td>± 0.5</td>
<td>± 0.5</td>
<td>± 0.5</td>
<td>± 0.8</td>
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</table>

Table 8 Cruise speed measurements with three surveyors

<table>
<thead>
<tr>
<th>Surveyor 1</th>
<th>Surveyor 2</th>
<th>Surveyor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Mean</td>
<td>31.30</td>
<td>34.70</td>
</tr>
<tr>
<td>Cruise Speed (ms⁻¹)</td>
<td>12.59</td>
<td>13.18</td>
</tr>
<tr>
<td>Cruise Speed error</td>
<td>± 0.4</td>
<td>± 0.4</td>
</tr>
</tbody>
</table>

Table 8 Cruise speed measurements with three surveyors

<table>
<thead>
<tr>
<th>Survey</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>15</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Mean speed (mph)</td>
<td>31.30</td>
<td>31.60</td>
<td>32.00</td>
</tr>
<tr>
<td>Cruise Speed (ms⁻¹)</td>
<td>12.59</td>
<td>12.71</td>
<td>12.88</td>
</tr>
<tr>
<td>Cruise Speed error</td>
<td>± 0.3</td>
<td>± 0.4</td>
<td>± 0.3</td>
</tr>
</tbody>
</table>

‘MOVA Speed’ on a Personal Data Assistant (PDA) was used in all.

Over several measurements (Table 7) there was some variation in cruise speed values, but nothing too significant. The time difference in a stage change decision made by MOVA due to a 2 ms⁻¹ difference in cruise speed at about 14 ms⁻¹ would be about 1 second. This is judged to be acceptable, any greater than that probably would not.

From the above, it would seem that differences between observers are acceptable (Table 8) and not an issue. Obviously, a reasonable standard of observations is necessary to obtain this consistency across different persons.

During the early stages of the development of MOVA it was found that, once the queue has discharged, the speed of vehicles tended to be quite consistent for a given approach. In MOVA this speed is know as the ‘cruise speed’ and it is used in calculating key data within the site configuration. During MOVA’s stop and delay optimisation process, the cruise speed is used to estimate the approximate positions of each vehicle on each approach that is currently green. With these estimates and knowledge of the number of vehicles waiting on red, MOVA is able to judge when to change the signals for optimum junction performance. If the cruise speed is significantly in error, MOVA may decide that the signals can change ‘now’ possibly asking a driver to make an awkward decision about whether to stop or continue. However, there is quite a large degree of tolerance to errors in the cruise speed and there should not normally cause any real problem in the stops and delay optimisation process unless the errors are large.

In taking a sample of the MOVA data at the 25 sites in this study there is evidence that measuring cruise speed to an acceptable level of accuracy might be a problem. However, all the sites investigated were commissioned relatively early on in MOVA’s life and, at the time, cruise speeds did tend to be overestimated, although it is not clear why. However, experience from the early days, and the observed effects of having cruise speeds too high, has resulted, it is thought, in more realistic speeds being used since then.

5.4 Questionnaire of local authorities involved

Each of the five local highway authorities (LA) having responsibility for the sites in this study was sent a questionnaire. The questions posed are given in Appendix C. The purpose of this exercise was to find out something about how the sites were set up and how they are set up now. Four of the authorities responded. The following is a summary of the responses:

- Only one of the respondents had used someone outside the LA to set up a MOVA site, and then only once.
- A mixture of senior and junior graded staff were used now, but mostly senior at the time the junctions under consideration were installed.
- All those who had set up MOVA had been trained.
- When asked how cruise speeds and saturation flows were measured, a variety of answers were given. Cruise speeds were often measured upstream, with speed guns or with observers being highly visible (and likely to affect speeds). Very occasionally, speeds were determined by ‘educated guesswork’. Saturation flows were usually estimated using RR67 (Kimber et al., 1986).
- Three respondents said MOVA was never installed for safety reasons, although MOVA was used where SA/SDE would otherwise have been used. (However, it is thought that some authorities do use the benefits of MOVA to allow fully signalled right turns and/or add pedestrian facilities for example while maintaining junction capacity).
Concerns were expressed mainly about the collection of data, which is known to be an issue at many junctions. Others reported that, whilst configuring the more straightforward sites was easily achieved by experienced practitioners, more complex sites did pose problems.

6 Summary and conclusions

1 The original design brief for MOVA was to reduce delays at isolated signal controlled junctions and did not include any requirements to replace existing D-system Vehicle Actuation (VA) control with Speed Assessment or Speed Discrimination Equipment (SA/SDE) control on high-speed sites. However, early studies at two high-speed sites proved that MOVA can reduce red-running substantially.

2 As part of the first 20-site MOVA trial (Peirce and Webb, 1990) four of the high-speed sites hinted that MOVA improved safety substantially (reducing accident frequency by about 30%), although the statistical significance was only at the 10% level. This early finding encouraged DfT to require that ‘All new Trunk Road installations shall incorporate MOVA control.’ (TD 35/91).

3 A later study entitled ‘MOVA accidents on high-speed roads’ was carried out at 31 sites in which the safety of MOVA was compared with traditional VA that also had SA/SDE fitted. The result was that MOVA was found to be as safe as VA with SA/SDE, but was no better than that. The study considered the reasons for the lack of improvement under MOVA. The main question was whether or not the quality of the MOVA configuration data had an influence on safety.

4 Of the 31 sites studied in ‘MOVA accidents on high-speed roads’ 25 were used in this study. The others had undergone changes that prevented their further inclusion. At each, a sample of the data required to configure MOVA was collected. ‘Cruise speed’, saturation flow and stop penalties were measured on up to four randomly chosen lanes at each site. The sample data was compared with the MOVA data in use at each site and a score was deduced base on the comparison. Further assessments were made of the MOVA data to look at link-lane structure, bonus data and detector configuration. The overall junction scores ranged between 1 and 6 out of 10 with eight sites having scores of 4, 5 or 6. Whilst the scoring system was quite stringent, the scores do indicate that even the ‘better’ sites tended only to be adequately configured compared with TRL’s measured values and assessments. The scores for stop-penalty data (known as ‘STOPEN’ in MOVA) were notably different from TRL’s recommended values, and there was a tendency for the cruise speeds to be overestimated. Additionally, there appears to be a particular misunderstanding of the use of the configuration data associated with flared approaches.

5 Generalised linear modelling was used to determine the statistical significance of differences between the forms of signal control over the 15 year accident period.

6 For all the sites, MOVA was 7% worse for the group all accidents within 100m of the junction, 1% worse for junction accidents but 7% better for two-vehicle accidents. None of these results were statistically significant. See Table 4. Thus the results of the original 31 site trial stand, that is that there is no significant difference overall in the personal injury accident frequency between VA with SA/SDE and MOVA at the signal junctions studied.

7 For the group of 8 sites with high scores for MOVA configuration, a lower accident frequency was found under MOVA compared with VA and the difference was statistically significant at the 5% level for junction accidents and for two-vehicle accidents at the junction. The differences were 19% for all accidents within 100m of the junction, 26% for junction accidents and 29% for two-vehicle accidents (Table 5).

8 By contrast, the modelling results for the remaining low scoring sites showed an increase in accident frequency compared with VA (Table 6) of 20% for all accidents within 100m of the junction, 15% for junction accidents and 3% for two-vehicle accidents at the junction. The increase for the ‘all-accidents’ category was statistically significant at the 5% level.

9 A check on the accuracy was made to see which, if any, of the MOVA data items had the greatest bearing on the safety record. Cruise speed had the strongest bearing, but had no better discriminatory power then the overall score.

10 A check was also made of the original 4 high-speed sites that had led to the earlier tentative conclusion that MOVA was safer than VA. From the 3 sites found to exist in a virtually unchanged state a slight upward trend in accident frequency was found. However, it seems reasonable to suggest (if not conclude) that the original good showing has been largely maintained.

11 Overall, the findings from the modelling of the 8 higher scoring sites and the other 17 lower scoring sites was that the quality of MOVA data has a bearing on the safety of the junction.

12 An exercise was undertaken to consider the variability in the measurement of cruise speed. At the same site, on the same day, over approximately a 2-hour period it was found that some variability existed (the lowest value being 12.9ms⁻¹ and the highest 15.1 ms⁻¹) but that the consequences of the variability were acceptably small. Any greater variability and the consequences might be less acceptable. However, there was little variability between measurements made by three different people at the same time which suggests that the actual measuring of the speeds can be carried out with acceptable consistency.

13 In answer to a brief questionnaire, the local highway authorities responsible for the sites included in the study said that they had nearly always used in-house staff originally, mainly at senior level for the sites in question. Some used junior staff now. All those
involved had received training of some kind. A variety of answers were given when asked how cruise speeds and saturation flows were derived. MOVA was not installed for any direct safety benefits (although some junctions were signalised or changed for that reason).

14 The sites considered in this study represent the earlier MOVA installations. Current practice in configuring and setting up MOVA sites could well be such that there are fewer ‘poor’ installations now. It is especially noticeable that the industry has adopted the view that cruise speeds need to be realistic, but to err on the low side. Therefore, it could be the case that, apart from the early MOVA sites, the majority have a reasonable standard of configuration data. However, it is acknowledged that there is scope for improving the ease with which the MOVA configuration data is specified.

7 Recommendations

This study has shown that, for the sites included at least, the safety record of high-speed MOVA sites is sensitive to the quality of the MOVA configuration data. Since the 31 sites considered in this study, and previously in the project ‘MOVA accidents on high-speed roads’ were installed relatively soon after MOVA became commercially available, it is possible that the poorer quality of configuration was due to inexperience on the part of the personnel involved at the time. Therefore, because of the experience gained, much of the improvement needed in MOVA configuration may be occurring already. However, this is an assumption which would be very difficult to confirm. In any case, it is acknowledged that MOVA is difficult for the inexperienced to set-up and that the current (assumed) high standard of configuration is achieved mainly because there are a handful of experienced people who carry out the majority of installations (including some in the authorities that look after the sites included in this study).

Steps need to be taken to help ensure that MOVA is not poorly configured in the future. The following might help in achieving this aim:

- Dissemination of the results through this TRL published report and through presentations of papers at conferences
- Dissemination of the results through revisions to:
  - TAL 03/97 The MOVA Signal Control System.
  - TAL 02/03 Signal Control at junctions on high speed roads.
  - TD35 All Purpose Trunk Roads MOVA System of Traffic Control at Signals.
  - MCH1542 Installation Guide for MOVA.
  - TRL MOVA Application Guides.
- Recommend that the configuration of MOVA sites on high-speed roads should be checked e.g. through the Traffic Control User Group (TCUG).
- Push the development of the online measuring facilities for saturation flow and cruise speed

Much work is being undertaken as part of the MOVA Development Group and as part of ongoing MOVA maintenance and upgrades. Not all the work is designed to improve safety, although it is always hoped that improved safety will be a beneficial side effect. These are the features that have recently been considered and are planned to be included in forthcoming versions of MOVA:

- Automatic on-line measurement of saturation flow.
- Configurable priority reaction to pedestrian demands.
- Automatic on-line cruise speed measurement.
- Improvements to ‘MOVA Setup’, the MOVA configuration data creation program.
- Improved handling of plan changes (which will allow more appropriate data to be used by time-of-day for example).

All these features have been planned for introduction into MOVA. However, their accuracy and effectiveness (especially the on-line measuring functions) will only be confirmed or otherwise once in use. Completing this work is likely to take a number of years.

Improving MOVA Setup could be key to making the configuration of MOVA sites easier and, therefore, better. However, this is not the only component in the installation and use of MOVA that causes problems. Assessing how well MOVA is working is not easy, even for the experienced. Easier interpretation of the MOVA output and better tools for assessing performance are needed to improve the situation.

Training is another key issue. Courses are available and many in the industry have undergone training. However, the training available is not subject to any review process nor is there a requirement for those designing MOVA installations to have undergone training. There may be some benefit if all MOVA configuration data was at least audited or reviewed by trained people.

There are other research strands that could help. Suggested future research includes:

- Simulation studies to consider the effect of various parameters including cruise speed, stop penalties etc.
- Investigation into the variability of cruise speeds in relation to traffic density, junction configuration, and by time of day.
- Re-configure the 17 poorly configured sites and see how accident frequencies change.
- Investigate the safety record of a large number of randomly selected sites before and after MOVA installation.

8 Acknowledgements

TRL are grateful for the assistance of the local highway authorities involved and Transport for London.
9 References


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<tr>
<th><strong>10 Glossary</strong></th>
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<tr>
<td><strong>Accident</strong></td>
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<td><strong>Bonus Cut Marker (BONCUT)</strong></td>
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<td><strong>Bonus green</strong></td>
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<td><strong>Combination X-detector (COMBX)</strong></td>
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<td><strong>Control strategy</strong></td>
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<td><strong>Cruise Speed (CRUISE)</strong></td>
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<td><strong>D system VA</strong></td>
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<td><strong>IN-sink detector</strong></td>
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<td><strong>Lane (short and long)</strong></td>
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<td><strong>Speed Discrimination Equipment (SDE)</strong></td>
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<tr>
<td><strong>Stage</strong></td>
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<td><strong>Stop penalty (STOPEN)</strong></td>
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**Stopline detector**
A detector installed immediately before the stopline to provide a demand in case vehicles turn into the detector approach without crossing the X detector.

**Start-up lost time (STLOST)**
For each lane i.e. the time from the start of green to when saturation flow commences. The default value is 1.3 seconds. (See lost time, which is distinct from start-up lost time).

**UTC**
‘Urban Traffic Control’. A traffic control system which links the timings of traffic signals within a network using a central computer.

**VA**
Vehicle Actuation; see ‘D’ system.

**Vehicle detector**
For MOVA these are most commonly loops of wire cut into the road in each lane which act as inductive sensors. These are connected to special electronic equipment that detects the change in inductance as a vehicle passes over the loop (usually by detecting a frequency shift), and changes the level of an output which is held ‘on’ when the vehicle is over the loop.

**X detector**
The detector located in each lane so as (ideally) to give a 3.5 second cruise time from detector to stopline. This detector is often sited at about 40m before the stopline in urban areas, and is therefore called the ‘X’ detector by analogy with the similarly placed D-system detector.

**X-sink detector**
A detector which counts traffic leaving a lane after it has crossed and been counted by the X detector (and the IN detector if there is one on the lane). The X sink detector is used particularly to count traffic making unsignalled free left turns.
Appendix A: Assessment of MOVA’s behaviours when cruise speeds are inaccurate

Below is an excerpt from the unpublished report on the study in 2000 on 31 high speed sites.

A.1 Possible effects of inaccurate cruise speeds

A qualitative assessment on the effects of the use of incorrect cruise speed data has been made by the study team and other MOVA experts at TRL. On the face of it, inaccurate cruise speed data could theoretically affect safety and the number of red-runners.

The cruise speed used in MOVA is approximately the 15th percentile, i.e., the speed exceeded by 85 percent of vehicles. This data is used only when MOVA is in its delay optimising phase, which occurs only after all lanes on green have ceased running at saturation flow (and MOVA is not attempting to maximise capacity because the junction is overloaded). During the delay optimising phase, vehicles will be travelling at cruise-speed towards the junction whilst previously queued traffic is still present, but is moving. Thus MOVA’s cruise speed is somewhat lower than the average speed that would be achieved in the absence of vehicles still accelerating after having queued. It has been found to vary little from vehicle-to-vehicle at any given site.

Whilst in its delay-optimising mode, MOVA is balancing the delay of vehicles currently on green with those waiting on red. The cost of stopping a vehicle also enters into the equation and this alone tends to mean a single vehicle on any approach will hold the green. MOVA would be expected to change when the last vehicle that it is holding green for is 1.5 seconds (at cruise speed) away from the stopline; that vehicle would not normally be expected to stop.

Given that the cruise speed should be slightly lower than the free-running speed, and that it is the 15th percentile speed, very few vehicles will be travelling slower than cruise speed when free running. The few that do travel slower than cruise speed may get trapped in the dilemma zone as they will be further from the stopline than MOVA thinks they are. However, overall the chances of being trapped should be much lower with MOVA than in the case of D-system VA with SA/SDE when it frequently changes phase, vehicles will be travelling at cruise-speed towards the junction whilst previously queued traffic is still present, but is moving. Thus MOVA’s cruise speed is somewhat lower than the average speed that would be achieved in the absence of vehicles still accelerating after having queued. It has been found to vary little from vehicle-to-vehicle at any given site.

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A.2 Overestimated cruise speed

When the cruise speed used in MOVA is higher than would be correct, the IN-detectors will be placed further back than they should be and vehicles will be travelling slower than MOVA expects. The problem this may cause is that a vehicle travelling below the (optimistic) cruise speed may drop out of MOVA’s model before it gets to the X-detector (which it will do later than MOVA thinks it should have). MOVA may choose to change stage at this point, which could put a vehicle right in the middle of the dilemma zone. Theoretically, this could mean the number of vehicles being trapped could be average, or even greater than average. However, the error in cruise speed would have to be quite substantial for this to be a significant problem (small errors are thought to be easily tolerated).

A.3 Pessimistic cruise speed

When the cruise speed in MOVA is pessimistic, problems of a rather different nature could occur. As with optimistic cruise speeds, there is the general problem that MOVA is not aware of the actual position of vehicles on approaches. In the majority of circumstances, MOVA would normally hold on to green for a vehicle that has crossed the IN-detector, irrespective of what is waiting at red, but this is not a hard-and-fast rule. This is because MOVA is seeking to change the signals when the benefits of doing so outweigh the disadvantages. Therefore changing against single vehicles may occur. If that vehicle is closer to the stopline than MOVA thinks it is, it could get trapped in the dilemma zone. On the other hand, when MOVA holds green for single vehicles, they will be further advanced than MOVA thinks they are. This not only means there is some wasted time (because MOVA could have safely changed earlier than it did), it also effectively means MOVA is searching for a bigger gap in which to change the signals than is necessary. MOVA may operate inefficiently as a result, which might lead to more vehicles being caught in the dilemma zone.

A.4 Other considerations

There are other possible reasons why poor set up could cause MOVA to operate less than optimally which could conceivably lead to a reduction in safety benefits. Consideration of all possibilities would be complicated, and it would still leave the problem that it is very difficult to translate the anticipated behaviour of MOVA into any real safety risk analysis.

One effect that MOVA will often have when it is installed in place of VA (especially with SA/SDE) is a reduction in average cycle times. This means more signal changes per unit time. The reduction in red-running found in the earlier work still holds true, but the increased opportunity to red-run may have some influence on the results and it may lead to other types of accident being affected adversely. This effect was considered in the earlier work (the original 20-site trial), but the information needed to analyse it in this study was not available. This could be a factor in the failure to improve safety at the 31 junctions. However, even if this proved to be the case, it should not automatically follow that one should advise in a general sense to lengthen cycle times without first considering the disadvantages of doing so.

There are possibilities outside the direct influence of MOVA. An important one that has been suggested is that red-running may have, as a trend, increased over the last ten years or so, possibly affecting the results. There is no particular evidence to support this, but it could be a factor nevertheless.
It should be emphasised that the above is very much conjecture at this stage. The true effects of incorrect MOVA data in general, and cruise speed data in particular, are not known. Nor is it known how sensitive MOVA might be to inaccuracies and what can be tolerated and what cannot.

Even if the result observed for the 31 junctions in this study applies generally and that, underlying all this, is the fact that MOVA really is no safer than VA with SA/SDE, it should still be possible to use MOVA to improve the safety of many junctions by sacrificing some of the delay benefits and making other changes that improve safety. Changes such as the introduction of early cut-off stages, or even doing away with opposed right-turn movements altogether (by separately signalling them) may become possible by using MOVA. Many authorities already take this approach.
Appendix B: Expert site visits

B.1 Expert site visit to site H016

Site visited

Conditions
Weather was fine and dry, dry roads, about 8°C.

MOVA version
M2.9A. Monitron. (Could not open controller).

Accident record under VA and MOVA
Plain language descriptions for accidents early in the trial were rather vague and did not reveal much. There were a couple of accidents involving vehicles coming from the north and turning right off the main road being hit by vehicles going ahead from S to N. In any case, one was MOVA, the other VA.

Safety issues
There were very few accidents from which to take any views about safety issues at this site. The divide error (see ‘Fault record’) may have caused MOVA to shorten delay optimised stages on occasion which is not satisfactory and may have encouraged red-running.

Amount of delay optimisation
The site seems quite willing to go into delay optimisation when appropriate with a lengthy spell (at least 20 seconds) observed during the visit and in the PM peak. Most cycles during the peak were, however, terminated on end sat decisions.

Fault record
It is difficult to say how faulty the site is because the dates recorded in the error log were haphazard. However, there were 9 records of code 50 error suggesting divide errors were occurring. One cycle was observed where the signals changed early when it seemed obvious they should not have. (It is thought that code 50 errors indicate that ‘stagos’ is going negative on occasions, which it shouldn’t, and the divide error occurs when stagos and the remaining parts of the divisor in the offending equation just happen to add to zero).

General efficiency
Bonuses
A small bonus due to a short bay is present on link 4 but has not been included in the data. It is thought that including it might improve efficiency slightly in conjunction with bonus due to the X-sink on link 3.

Link structure
Correct.

B.2 Expert site visit to site S023

Site visit

Conditions
Weather was fine, mostly dry with snow showers, mainly dry roads, about 4°C.

MOVA version
M4.1 [std]. Monitron Rack mounted.

Accident record under VA and MOVA
This junction had ‘other’ as the form of junction control from 1999 onwards, which is thought to be because of changes to stopline positions and additional pedestrian facilities.

Safety issues
As is now common in some parts of the country, this site had separately signalled right-turns off the main road without any dividing island. The right turns run immediately prior to the straight ahead movements. What can happen is that the straight ahead traffic incorrectly

Lost time
Not assessed, but unlikely to be incorrect. Long intergreen from S3 of 15 seconds, possibly to allow for pedestrians.

Phasing complexity
Not an issue.

Other issues
None.

Geometry
The junction has a long LR stagger, and the RTs off the main road are opposed. Seems to work ok in practice.

Phase lags
Not thought to be any, but could not easily determine since we could not open the controller.

Speed limits and speeds in general
Speed limit is thought to be 30mph on all approaches. Actual speeds were not that high on any approach and the site is almost certainly no longer high speed (if it ever was).
anticipates the start of their green from the starting amber of the right turn. They may have gone by the time the RTIA has appeared (or not appreciate that it is an RTIA and not a full green). One instance of this was observed, and another where a foreign truck driver hooted the person in front because they thought they should be going.

The approach from the east was downhill towards the junction. At the time of observation, speeds were generally not particularly fast. However, some looked to be at the 40mph (18ms⁻¹) limit – the cruise speed was 13ms⁻¹. A couple may have been higher still, which suggests speeds during quieter periods may be high enough to warrant special consideration. (This is a general issue, possibly for all MOVA sites).

Amount of delay optimisation
A fair proportion of changes from stage 1 were delay optimised changes, although this tended to be in busier periods only. At quiet times, changes occurred at end-sat or at calculated minimum, because of the lack of traffic.

Fault record
There were a large number of ‘code 50’ errors (possibly divide errors) although the date for all of them was the same. This was probably an isolated problem on one day.

There are a large number of assessment lines with zero occupancy. This is likely to be due to a problem with detectors, although the error log does not have many reports of detector malfunction (which are put there after 24 hours). This suggests repeated but temporary problems with detectors.

General efficiency
Bonuses
A small bonus due to a short bay is present on link 6 but has not been included in the data. It is thought that including it might improve efficiency slightly in conjunction with bonus due to the X-sink on link 3. Reducing STLOST would help reduce the calculated minimum which can be longer than necessary because of side-by-side queuing that MOVA thinks is single lane queuing.

Lost time
Not assessed, but unlikely to be incorrect. The intergreen from S1 to S2 and S2 to S3 is 8s, and the movements also have all-red extension detectors. There may be scope for improving efficiency depending on whether the interstage times have been set to minimum of maximum expected values in the MOVA data. LOSTIM is set to 24s for all links; should be 23s.

Phasing complexity
Not a big issue, but with four stages the junction may not be particularly efficient when busy.

Other issues
None.

Geometry
Phase lags
None.

Speed limits and speeds in general
At the time of observation, speeds were generally not particularly fast. However, as already stated, some looked to be at the 40mph (18ms⁻¹) limit when conditions made higher speeds possible – the cruise speed was set in MOVA data at 13ms⁻¹. Cruise speeds where measured during the site visit and were about 10.5ms⁻¹ during a period when it was quite busy.

B.3 Expert site visit to site S024
Site visit

Conditions
Weather was fine, mostly dry with snow showers, mainly dry roads, about 4°C.

MOVA version
M2.10. Monitron Integrated.

Accident record under VA and MOVA
There was a very bad year in 1998, just after MOVA installed, but it has been much better since then. Main accident types are (a) vehicles turning right being hit by vehicles from the opposite direction going ahead and (b) rear shunts / lane changes.

Safety issues
Casual observation showed why the right-turn accidents were one of the main types. There is a long RT+SA lane (about 5 cars) and no early cut-off or separate stage. The right-turners cannot see any signals. In the opposing direction, there is a short left turn slip, and anyone making that manoeuvre has to give way to the right-turners. There were a number of occasions where RTs made risky-looking manoeuvres in front of approaching vehicles. It looked as if they may be turning right in anticipation that opposing vehicles were making the left turn. Sometimes they didn’t.

Lane-change and shunt accidents could well be due to straight-on traffic having to cut back from the RT+SA lane because of RTs not signalling. One incidence of this was observed, although the driver waited until it was clearly safe to ‘cut back’. The RT from the other direction is banned, although one vehicle was observed to make this manoeuvre. (RTs can make a ‘loop-back’ after turning left to make this manoeuvre).

Neither of these safety issues is likely to have been affected by MOVA operation in any direct sense.
Amount of delay optimisation
MOVA delay-optimised reasonably well and was not observed to make poor decisions in the face of oncoming traffic.

Fault record
The fault record was clear apart from the noting of one faulty detector, No 4, which was still faulty.

One fault (not to do with MOVA) was that the overhead signal for the southbound approach was a full green and not a SA arrow.

Another observed fault was that the all-red back to stage 1 was sometimes excessively long. This could happen if the pedestrian phase ran, but this wasn’t the case on most observed incidences. Perhaps the all-red extension loops were intermittently faulty.

General efficiency
Operational efficiency was slightly hampered by the fact that the westbound exit traffic was running over the X detector. This frequently meant the calculated minimum unnecessarily ran to its maximum, wasting green. Unidirectional detectors would avoid this; setting the max-min to a lower value during off-peak.

One cycle was observed to be marked as oversaturated when it very clearly wasn’t.

Bonuses
A small bonus due to a short bay is present on the West arm but has not been included in the data. It is thought that including a reduced STLOST would help keep the calculated minimum green more efficient.

Link structure
Correct.

Lost time
Lost time values will be a compromise due to the presence of all-red extension detectors. They may well benefit from being set using intergreen values typically experienced during peak periods.

Phasing complexity
Not an issue.

Other
None.

Geometry
See notes above in Accident records

Phase lags
There were no phase delays.

Speed limits and speeds in general
Speeds were not high and reflected the speed limits. The Southbound was visibly faster than the other with some vehicles exceeding 30mph. Speeds in quiet conditions could well be notably higher.

B.4 Expert site visit to site T012
Site visit
5th March 2004.

Conditions
Weather was fine and dry, mainly dry roads, about 8°C.

MOVA version
M2.9b. Microsense.

Changes since last accident data used
The site has had red light cameras installed on the main road. The side roads used to run together with an early cut off in favour of one of them, but now run separately. A pedestrian phase has been introduced across station road which delays the start of the other side road for approximately 10s.

Accident record under VA and MOVA
No details. 18.0/yr under VA, 13.0/yr under MOVA (ratio 0.72).

Safety issues
Comments about the accident types were not available prior to the site visit.

Amount of delay optimisation
MOVA messages could not be observed. Delay optimisation was probably minimal due to the high traffic flows and the fact that there were four stages. It cannot be said whether this was the case before the changes, but it is likely that same applied then as now. It is likely that high main road flows made the marking of end-sat less likely simply because of the rate of arrivals even after the queue had finished discharging. Having said that, there were some cycles where delay optimisation appeared to be in action.

Fault record
It was not possible to obtain a fault record.

General efficiency
Bonuses
Bonus data seemed acceptable with boncuts in use.

Link structure
Correct.

Lost time
Lost time values will be a compromise due to the presence of all-red extension detectors. They may well benefit from being set using intergreen values typically experienced during peak periods.

Phasing complexity
Not an issue.

Other
None.
Geometry
See notes above in Accident records.

Phase lags
There were no phase delays.

Speed limits and speeds in general
Speeds were not high and reflected the speed limits. The Southbound was visibly faster than the other with some vehicles exceeding 30mph. Speeds in quiet conditions could well be notably higher.

B.5 Expert site visit to site T007

Site visit
5th March 2004.

Conditions
Weather was fine and dry, mainly dry roads, about 8°C.

MOVA version
Probably M2.9b. Microsense. (Could not open the controller).

Changes since last accident data used
Nothing obvious.

Accident record under VA and MOVA
No plain language descriptions up to 1999. A lot of shunts under MOVA, apparently when the pedestrian phase was showing, plus a few shunts / lane changes and U-turns.

Safety issues
It is not clear which direction the shunt accidents would have been from or why they might have been worse under MOVA. The pedestrian phases ran every cycle, which would explain the observation and that there might not necessarily be any association.

It was observed that the eastbound traffic arrived as large platoons about every two minutes. When comparing MOVA and VA in this situation, there is nothing in general that is thought to change the safety in reaction to this platooning, although the specifics of the VA arrangement were not known or observed in this case.

Amount of delay optimisation
MOVA messages could not be observed. Delay optimisation may have been substantial in some stages with a modest amount of side-road traffic compared with the main road.

Fault record
It was not possible to obtain a fault record.

At least three of the signal heads were incorrectly aligned, with the secondary for the left-turn from the side road (and the only one that could be seen from the stopline) pointing such that drivers waiting to make that manoeuvre were unable to see it.
Appendix C: Questionnaire to local highway authorities involve in this study

We are in the final stages of completing a project to look at the safety of MOVA signal controlled junctions. Your area contained sites included in this study.

One of the important conclusions that we have come to is that the quality and accuracy of the MOVA configuration data plays a part in the level of safety. We are interested in knowing what could be done to make the setting up of sites easier and, therefore, better.

Could you, therefore, spend a few minutes answering the questions below please? Whatever information you supply us will be treated in complete confidence and we would be grateful for a return even if you cannot answer all the questions:

1 In the past, who have you used to configured MOVA sites (no names please)? Who do you use now?

<table>
<thead>
<tr>
<th>In the past</th>
<th>Now</th>
</tr>
</thead>
<tbody>
<tr>
<td>a External consultant?</td>
<td></td>
</tr>
<tr>
<td>b Term consultant?</td>
<td></td>
</tr>
<tr>
<td>c Low ranking internal staff?</td>
<td></td>
</tr>
<tr>
<td>d More senior internal staff?</td>
<td></td>
</tr>
</tbody>
</table>

2 Have the persons involved in setting up MOVA sites had any training?

3 How have cruise speeds and saturation flows been measured? (tick one or more)

<table>
<thead>
<tr>
<th>(tick one or more)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Using TRL software MOVA Speed and Satflow?</td>
</tr>
<tr>
<td>b Estimated from RR67 (Saturation flows only)?</td>
</tr>
<tr>
<td>c Speed gun?</td>
</tr>
<tr>
<td>d Upstream from junction?</td>
</tr>
<tr>
<td>e Educated guesswork?</td>
</tr>
</tbody>
</table>

4 What proportion (if any) of your sites were installed with MOVA for safety reasons?

5 Have you any comments on the ease of setting up MOVA data?

Thank you for taking the time to answer the questions.
Abstract

MOVA is a traffic signal control system, originally designed for junctions that are not part of a linked UTC system. It has proven to be significantly better than standard Vehicle Actuated (VA) system in terms of capacity and delays. Currently there are estimated to be about 1,000 MOVA sites in the UK with installation rates of at least 100 per year.

During the development of MOVA, there were no specific requirements to improve safety compared with existing control strategies. However, early studies at high speed sites proved that MOVA can reduce red-running substantially and accident data from the early high speed sites suggested they could well be safer. In the study reported here, 25 high speed sites currently equipped with MOVA and previously equipped with VA and Speed Assessment/discrimination equipment were studied. The accident period was 15 years, with at least three years prior and three years post MOVA implementation at each site. The result was that, overall, MOVA was no safer than the previous control strategy. After considering the quality of MOVA data, it was shown that the better configured sites had a lower accident frequency under MOVA than under VA and the reverse was true for the poorly configured sites.

Related publications

RR279  MOVA: The 20 site trial by J R Peirce and P J Webb. 1990 (price £20, code B)
RR170  MOVA: traffic responsive, self-optimising signal control for isolated intersections by R A Vincent and J R Peirce. 1988 (price £20, code B)
RR67   The prediction of saturation flows for road junctions controlled by traffic signals by R M Kimber, M McDonald and N B Hounsell. 1986 (price £20, code B)
AG42   Traffic Engineering Software ‘BUNDLE’ 3.0 USER GUIDE by J C Binning. 2002 (available only as part of software package)

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