Modeling Factors Influencing the Capacity of Motorway Merge Actions Controlled by Ramp Metering

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Abstract

This paper focuses on studying factors which are likely to affect motorway merge capacity when ramp metering controls are in use. A newly developed traffic micro-simulation model has been used for this purpose and the well known ALINEA and Demand-Capacity local ramp metering algorithms were integrated within it. Several parameters such as critical occupancy to trigger the signals, position of ramp traffic signals, position of loop detectors and length of ramp were considered. The effectiveness of ramp metering for a range of traffic flow conditions has been tested for various scenarios to show the range of values where ramp metering is beneficial.

Keywords: motorway merges capacity; ramp metering; micro-simulation, occupancy

1. Introduction

Recently, ramp metering systems are increasingly being implemented on UK motorways to control the rate of vehicles entering from slip roads. The idea is to avoid congestion by preventing downstream traffic from being higher than the overall capacity of the motorway by storing some merge traffic on the slip road. Theoretically, the amount of traffic to be released from the installed traffic signals should be the difference between the motorway downstream capacity and upstream traffic (Masher et al., 1975).

The success of ramp metering is subject to an appropriate design for related factors such as the ramp length and selection of suitable algorithms to control and update traffic signals timing. For example, previous research suggested that ramp metering could successfully prevent traffic congestion if infinite ramp length (storage) is available (Carlson et al., 2010). Also, simulation studies by for example Smaragdis and Papageorgiou (2003) and Papamichail et al. (2010) explain how ramp metering is useful when the on-ramp queue length is not considered. Empirical study by Wu et al. (2007) on a section of the M27 J11 stated that the merge speed when the ramp metering was in use was lower than that when the signals were off. That was explained by the effect of traffic signal position.

Another important factor that is part of most existing ramp metering algorithms is the critical occupancy. This factor is usually related to the position of a traffic loop detector. Typically, higher values of occupancy are expected within the merge area because drivers in this area accept smaller headways than in normal sections (Laval and Leclercq, 2008).

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This paper investigates, using a newly developed micro-simulation model, the effect of these parameters (i.e. ramp length, position of traffic signal, critical occupancy and position of traffic loop detector) on the performance of ramp metering. The linear feedback control ALINEA algorithm (Asservissement LINéaire d’Entrée Autoroutière) (Papageorgiou et al., 1991) was integrated into the model together with the Demand-Capacity algorithm (Masher et al., 1975). A brief summary on ramp metering algorithms, explanation on the developed simulation model, selected flows for test and the results are presented in the next sections.

2. Background on ramp metering

Ramp metering strategies could be classified into either local or area wide ramp metering (coordinated) (Sarintorn, 2007). Local ramp metering calculates the metering rate for an isolated on-ramp to control the traffic characteristics of the motorway in the vicinity of this ramp while coordinated ramp metering tries to alleviate traffic congestion through controlling merging traffic from a series of slip roads (on-ramps).

2.1 Ramp metering algorithms

Currently, Demand-Capacity (D-C) and the ALINEA local ramp metering algorithms are widely used across many countries. The former (see Equation 1) is derived based on the idea that the metering rate should not exceed the difference between the motorway capacity downstream of the merge and the upstream traffic flow. Congestion is identified when the downstream occupancy exceeds a critical value. In this case, only the minimum metering rate ($r_{min}$) will be allowed at the merge.

\[ r(k) = q_{cap} - q_{in} \quad \text{if} \quad O_{out} < O_{cr} \]
\[ r(k) = r_{min} \quad \text{if} \quad O_{out} \geq O_{cr} \]  

(1)

where

- $r(k)$ is the metering rate during the current time interval (k), (veh/hr),
- $q_{cap}$ is the motorway capacity (veh/hr),
- $q_{in}$ is the upstream flow (veh/hr),
- $O_{out}$ is the measured downstream occupancy, and
- $O_{cr}$ is the critical occupancy.

Applying the D-C algorithm requires knowledge of the motorway capacity from historical data. This capacity is subject to change due to many factors such as environmental conditions (Papamichail and Papageorgiou, 2008) as well as the percentage of heavy goods vehicles within the traffic (Hounsell and McDonald, 1992).

According to Smaragdis et al. (2004), using a critical occupancy which corresponds to the maximum flow gives more stable results than relying on the capacity value. Based on this approach, the ALINEA algorithm tries to keep occupancy levels downstream of the merging area close to the critical occupancy. This requires only one detector stationed downstream of the merge area to measure occupancy ($O_{out}$). The algorithm uses the system output from the previous cycle $r(k-1)$ (which normally ranges between 10 and 40 seconds) as an input in the calculation of the current metering rate $r(k)$, as in Equation 2.

\[ r(k) = r(k-1) + K_R(O_{cr} - O_{out}(k-1)) \times 100 \]  

(2)

Where $K_R$ is the regulator parameter (veh/hr).

Several extensions to the ALINEA algorithm have been implemented over the past few years based on locations where flow and occupancy were measured (Smaragdis and Papageorgiou, 2003). Examples of these algorithms are FL-ALINEA (based on downstream flow), UP-ALINEA (based on upstream occupancy) and UF-ALINEA (based on upstream flow).

2.2 Queue override algorithms

To deal with ramp queues, different queue override algorithms have been proposed to keep the queue length near the maximum allowable. Gordon (1996) suggested allowing the metering rate range to be 700-900 veh/hr in cases where the calculated occupancy for ramp entrance is in the range of 30-40%. Smaragdis and Papageorgiou (2003) proposed the ALINEA X/Q algorithm to deal with ramp queues when the ALINEA (or any of its derivatives) algorithms were applied. This algorithm tries to make the queue length less than the available storage area (i.e. the ramp length). Two metering rates are calculated, the first one is based on equations 1 or 2 and the second is the minimum rate to keep the ramp queue at or below the maximum allowable queue length (as in Equation 3).

\[ r'(k) = -\frac{1}{T} [\dot{w} - \omega(k)] + \omega(k-1) \]

(3)
The selected metering rate in the current time interval is the maximum of these two metering rates. The number of vehicles in the ramp queue is calculated using Equation 4.

\[ w(k) = w(k-1) + T \left[ d(k-1) - r'(k-1) \right] \tag{4} \]

Where:
- \( d(k-1) \) is the demand flow entering the ramp in the previous time interval,
- \( r'(k) \) is the minimum rate to prevent queue build up,
- \( r'(k-1) \) is the minimum rate to prevent queue build up in the previous time interval,
- \( T \) is time period over which measurements are taken (hr),
- \( \hat{w} \) is the maximum allowable queue length (veh),
- \( w(k) \) is the number of vehicles in ramp queue (veh), and
- \( w(k-1) \) is the number of vehicles in ramp queue in the previous time interval.

Zheng (2003) stated that the procedure adopted for the queue override (mostly used on ramp metering sites in the UK) is by triggering a 20 second green time signal (based on a cycle time of 30 seconds) when the estimated occupancy at the ramp entrance exceeds a specific value. If after 20 seconds of green time, the estimated critical occupancy is lower than the selected value, the calculation of the next metering rate will revert back to the ramp metering logic as in Equations 1 or 2.

In this paper, both ALINEA and D-C algorithms have been integrated in the simulation model used to study the effect of changing their parameters on motorway throughput, speed and delay.

3. Simulation model

A new traffic micro-simulation model has been developed in order to investigate the performance of some ramp metering strategies. It is developed to take into consideration the geometric layout of ramp controls (with various configurations) including the positioning of signals, detectors, length of ramp and length of acceleration (auxiliary) lane, as applied in practice. It deals with general as well as more specific driver’s behavioral tasks such as their cooperative nature when they allow other drivers to merge in front of them either by decelerating or shifting to other lanes. The model is based on car following, lane changing and gap acceptance rules. Each specific part of the model has been tested and the overall model has been calibrated and validated using motorway data from the UK (e.g. the “Motorway Incident Detection and Automatic Signaling - MIDAS” data) as well as other available data sources from video recordings.

Table 1 represents the statistical test results of comparing the simulated and actual data taken from loop detectors at stations downstream of the nose of different motorway sites in the UK. The selected parameters for these statistical tests are speed, flow and occupancy. The adopted tests are the root mean square error percent (RMSEP), the coefficient of correlation (\( r \)), the Theil’s inequality coefficient (\( U \)), the Theil’s mean difference (\( Um \)) and the Theil’s standard deviation difference (\( Us \)). All of these tests are widely used in traffic studies and for further details see Barceló and Casas (2002), Hourdakis et al. (2003) and Brockfeld et al. (2005). The results from the Table show that they are within acceptable levels, indicating that the simulation model can represent real traffic data.

The model is designed to overcome one of the serious problems inherent in some existing micro-simulation models when dealing with merging traffic. For example, AIMSUM uses a maximum waiting time for a vehicle before merging after which the vehicle will be deleted from the system (Hidas, 2005). The well known VISSIM model uses a “waiting time before diffusion” parameter to deal with such cases. MERGSIM (Wang, 2006) claimed to be the first in developing a model to represent merging behavior including the cooperative process between drivers. However, the model also has the same problem where the number of diffusion vehicles that disappear before merging reaches about 20% in some cases. Moreover, MERGSIM was designed for a simple geometry which consists of one lane on-ramp with the nearest lane of the motorway (i.e. MERGSIM ignores the effect of lane changing occurring within the motorway section in the vicinity of the merge section on merging traffic). It is likely that such assumptions will affect the capability of the above mentioned models to deal with real traffic behavior and limit their applications. This highlights the need for developing a new model to take into consideration such issues making use of existing rules and algorithms and applying the necessary modifications as required.
Table 1 Statistical comparison between the simulated and actual data from some UK motorway sites

<table>
<thead>
<tr>
<th></th>
<th>M56 - J2</th>
<th>M62 - J11</th>
<th>M6 - J20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lanes</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Flow range (veh/hr)</td>
<td>2950-4440</td>
<td>1900-6750</td>
<td>3900-8250</td>
</tr>
<tr>
<td>Duration</td>
<td>50 min</td>
<td>4 hours</td>
<td>10 hours</td>
</tr>
<tr>
<td>Variable</td>
<td>Flow</td>
<td>Speed</td>
<td>Occupancy</td>
</tr>
<tr>
<td>RMSEP (%)</td>
<td>2.9</td>
<td>3.8</td>
<td>7.0</td>
</tr>
<tr>
<td>R</td>
<td>0.976</td>
<td>0.882</td>
<td>0.88</td>
</tr>
<tr>
<td>U</td>
<td>0.015</td>
<td>0.018</td>
<td>0.038</td>
</tr>
<tr>
<td>Um</td>
<td>0.0046</td>
<td>0.059</td>
<td>0.04</td>
</tr>
<tr>
<td>Us</td>
<td>0.058</td>
<td>0.140</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The newly developed model is capable of eliminating cases of “diffusion vehicles” since this is not a realistic option as observed from real traffic. This means that the model allows stopping vehicles at the end of the acceleration lane to merge due to its capability to minimize such stopping cases. This is supported by the fact that there are minor cases where vehicles do not get enough gaps before reaching the end of acceleration lane as reported by other studies such as Zheng (2003) and Wang (2006).

Specifications for the developed simulation model may be listed as follows:

- Car following rules are based on the safety car following models.
- The lane changing model consists of mandatory and discretionary lane changing.
- Discretionary lane changing is classified into either necessary or unnecessary lane changing.
- Gap acceptance for mandatory lane changing is lower than for discretionary lane changing.
- Drivers on the on-ramp try to match the speed in the nearest lane of the motorway once they approach the merge section (Hounsell and McDonald, 1992 and Zheng, 2003).
- Drivers may accelerate or decelerate in the acceleration lane to fit the available lead and lag gaps (Zheng, 2003 and Wang, 2006).
- Both yielding and cooperative behaviors for nearest lane motorway traffic are integrated within the model.
- The default value for updating the time scan is 0.5 seconds.
- Driver’s reaction time is reduced in alerted situations (Wang, 2006).

4. Methodology

Both ALINEA and demand-capacity local ramp metering algorithms are integrated within the developed simulation model to update the timing of the ramp metering traffic signals. Factors that are considered in studying the capacity of the merging area include critical occupancy to trigger the signals, position of ramp traffic signals, positions of loop detectors on the main motorway lanes and length of ramp before the nose. In testing the effects of individual factors, different values for each were used (i.e. minimum, maximum and incremental values, respectively) and the combinations of changing these differing values for each factor were analyzed. Values of (17, 30, 1%) are used for the critical occupancy, (0, 1000, 50m) for the position of traffic detectors downstream of the nose, (0, 300, 25m) for the position of the ramp traffic signals upstream from the nose and (150, 1000, 50m) for the length of the ramp.

The estimation of the optimum critical (target) occupancy and position of downstream detector is obtained by running the simulation model for the whole combinations of the selected ranges mentioned above for these two parameters using three different random seed numbers. This process required about 1100 simulation runs to cover the necessary testing process for all the factors studied in this paper. For each detector position, a target occupancy is selected based on what value gives the maximum upstream flow “throughput” with relatively lower delays for the motorway section. From these selected critical occupancies, the same procedure is replicated to estimate the optimum position of downstream detectors. A two lane on-ramp section with a length of 300m is used as a base default value to estimate these parameters. A 300m ramp has been selected because most existing on ramp lengths are either lower or within the range of this value (Highways Agency, 2008). The values obtained for critical occupancy and position of loop detectors are then used to examine the effect of ramp storage area (i.e. ramp length) and the position of traffic signals.
For queue override control, two techniques, as described by Gordon (1996) and Zheng (2003), were used in the simulation model. The position of the loop detector downstream of the ramp entrance is taken as recommended by the Highways Agency (2008) at 39 m. The model calculates the average occupancy at this location for each 15 seconds interval. When the estimated occupancy at the ramp entrance exceeds a value of 30%, the metering rate is increased to be the maximum of either 900 veh/hr or a value obtained from the ramp metering logic (i.e. from Equations 1 or 2). Once the calculated occupancy at the ramp entrance reaches a value of 50% or more, the override signal of 20 seconds green time (as described by Zheng, 2003) is applied until the calculated occupancy reduces to below 50%.

Although the ALINEA X/Q override algorithm is extensively used in previous research for simulation of ramp metering to manage ramp queues (see for example, Papamichail and Papageorgiou (2008), Bai et al. (2009) and Papamichail et al. (2010)), this algorithm has not been used in this study. This is because further investigation regarding the use of such algorithm in the developed simulation model revealed some limitations. One of these limitations is that in some cases when the queue reaches the ramp entrance (i.e. exceeding the position of the detector used to calculate the entering ramp flow) the flow registered by this detector will be sharply reduced due to the presence of queues. As a result, the queue length calculated from Equation 4 will be highly inaccurate.

The geometry used in testing the different scenarios consists of a 3 lane motorway with a two lane on-ramp. The length of the acceleration lane is 200m. Warm-up and cool-off sections were selected as 500m and 1000m, respectively. The default value for the position of the main motorway upstream detector is selected at 100m upstream of the nose. Figure 1 shows the main flow inputs used both for the motorway and the ramp. A standard composition of heavy goods vehicles (HGVs percent) of 15% is assumed (as suggested by Hounsell and McDonald, 1992). The effectiveness of the selected ramp metering algorithms has been tested by using the optimum parameters for the critical occupancy and position of loop detector with different flows.

![Figure 1: Selected input flows for simulation](image)

5. Results and discussion

5.1 Calibration of ALINEA algorithm

This section describes the results obtained from the sensitivity analysis to estimate the optimum parameters for the ALINEA algorithm. Figure 2 provides a three dimensional surface representing the results obtained for the various sets of input variables to show the relationship between upstream capacity, critical occupancy and position of downstream loop detector. It indicates that the maximum throughput was obtained within the range of 200 to 300m for the position of loop detector and with occupancy values ranging between 21 and 25%. This is better explained in Table 2 which provides a summary for the optimum critical occupancy for each selected position of the downstream loop detector. Also, the Table shows the case for the “without ramp metering” scenario. In the Table, delay is considered as the difference between the actual travel time and the travel time based on the desired speed of vehicles. Here ramp delay is measured from a ramp vehicle enters the system until it merges with other motorway...
traffic. The overall delay saving represents the average weighted delay values for both motorway and merge traffic compared with the case of “without ramp metering”.

**Table 2 optimum critical occupancy at each selected loop detector position**

<table>
<thead>
<tr>
<th>Detector position (m)</th>
<th>Optimum occupancy (%)</th>
<th>Motorway delay (sec/veh.km)</th>
<th>Ramp delay (sec/veh)</th>
<th>Overall delay saving (%)</th>
<th>Motorway upstream speed (km/hr)</th>
<th>Upstream capacity (veh/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30</td>
<td>19.8</td>
<td>115.8</td>
<td>17.25</td>
<td>49.1</td>
<td>5084</td>
</tr>
<tr>
<td>50</td>
<td>29</td>
<td>29.05</td>
<td>136.8</td>
<td>-8.33</td>
<td>45.3</td>
<td>4982</td>
</tr>
<tr>
<td>100</td>
<td>29</td>
<td>16.6</td>
<td>126.4</td>
<td>25.22</td>
<td>53.3</td>
<td>5126</td>
</tr>
<tr>
<td>150</td>
<td>27</td>
<td>16.9</td>
<td>120.0</td>
<td>24.14</td>
<td>53.5</td>
<td>5110</td>
</tr>
<tr>
<td>200</td>
<td>27</td>
<td>21.2</td>
<td>137.0</td>
<td>10.45</td>
<td>47.4</td>
<td>5027</td>
</tr>
<tr>
<td>250</td>
<td>25</td>
<td>19.73</td>
<td>116.3</td>
<td>17.43</td>
<td>50.0</td>
<td>5054</td>
</tr>
<tr>
<td>300</td>
<td>23</td>
<td>15.7</td>
<td>127.7</td>
<td>32.11</td>
<td>57.3</td>
<td>5148</td>
</tr>
<tr>
<td>350</td>
<td>22</td>
<td>23.9</td>
<td>130.2</td>
<td>4.96</td>
<td>48.0</td>
<td>5060</td>
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<tr>
<td>400</td>
<td>20</td>
<td>22.8</td>
<td>160.3</td>
<td>9.41</td>
<td>50.4</td>
<td>5074</td>
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<td>500</td>
<td>19</td>
<td>34.8</td>
<td>144.5</td>
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<td>42.7</td>
<td>4889</td>
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<tr>
<td>600</td>
<td>19</td>
<td>39.0</td>
<td>104.5</td>
<td>-13.77</td>
<td>41.3</td>
<td>5000</td>
</tr>
<tr>
<td>700</td>
<td>19</td>
<td>37.9</td>
<td>45.4</td>
<td>4.63</td>
<td>43.5</td>
<td>4941</td>
</tr>
<tr>
<td>Without ramp metering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 Capacity of upstream section with respect to the critical occupancy and the position of loop detector.
In general, the Table suggests that the critical occupancy is decreasing with increasing location of the loop detector downstream of the nose. This could be interpreted as drivers in the vicinity of this area usually maintain close following behavior for a relatively short period of time and this results in higher occupancy. The detail of this behavior is well explained by Laval and Leclercq (2008) and also mentioned by Papageorgiou et al. (2008). Also, triggering ramp metering with low values of critical occupancies within the merge section will cause unnecessary long queues for ramp traffic which will lead to limited efficiency of ramp metering.

The negative values in the table represent cases where ramp metering causes increasing overall delay for both motorway and ramp traffic. In estimating the optimum critical occupancy at the optimum position for the traffic detector location, the Table suggests a value of 23% at a location 300m downstream of the nose. The location of 100-150m also seems reasonable as it offers an increase in throughput (similar to that of the 300m). The results are consistent with other studies (see for example Hasan et al. (2002) and Papageorgiou, et al. (2008)) regarding the position of bottleneck in merge sections. Since the position of loop detectors in the real situation is close to 300m downstream of the nose, a decision has been made to consider this location for any further analysis in this paper.

For the selected optimum location of downstream detector (i.e. 300m), Figures 3 to 5 show the effect of the target occupancy (i.e. critical occupancy) on the upstream speed, upstream capacity and motorway delay, respectively. In these figures and also for following figures, the straight dashed line represents the case of no ramp metering.

Figures 3 to 5 show that the optimum (critical) occupancy value is 23%. If a lower critical occupancy value is used to trigger the ramp metering signals (i.e. less than 23%), this could result in having longer queues on the ramp as a result of stopping ramp vehicles sooner. When queues reach the end of the ramp, this will trigger the queue override algorithm and will limit the efficiency of the ramp metering control. This critical occupancy value (i.e. 23%) is consistent with the findings of Zhang and Levinson (2010).

Figure 3  Effect of selected critical occupancy on upstream motorway speed

Figure 4  Effect of selected critical occupancy on upstream maximum throughput
5.2 Calibration of the D-C algorithm

The D-C algorithm has been used to find the optimum critical occupancy for the same location as was selected for that in the ALINEA algorithm (i.e. 300m downstream from the nose). Values of critical occupancy of (21%-27%) have been tested with an increment of 1%. The results of this process suggest that the same value of 23% (as obtained from the calibration process of the ALINEA algorithm) was obtained. The application of the D-C algorithm resulted in a 1.6% increase in motorway throughput compared with the case of “without control”. However, this throughput is lower than that obtained using the ALINEA algorithm (i.e. 4.34% compared with the case of “without control”). The time series comparisons for flow and speed for the cases of no control, ALINEA and D-C algorithms is presented in Figure 6. Figure 6b clearly illustrates that while the D-C algorithm can delay the occurrence of congestion for a considerable time, ALINEA was found to be able to prevent congestion for a longer period. This is represented by the upstream speed values for these three scenarios. The figure also shows that recovering from congestion and retuning back to normal conditions has started earlier (by about 5 minutes) in the case of ALINEA. The following analysis is therefore based on using the ALINEA algorithm.
5.3 Testing the effectiveness of ALINEA using different flow rates

Different flows for ramp and motorway traffic have been used for further testing of the ALINEA algorithm. This required at least 280 simulation runs. A 300 m is used as the position of the traffic detector as obtained from the calibration process. Values of 21, 22 and 23% have been used to test the validity of selecting 23% as the critical occupancy using different flow rates. The results confirmed that even if the flow rates are changed, the critical occupancy of 23% gave better throughput results. Figure 7 shows the results for the 23% occupancy value. In general, the figure illustrates that ramp metering controls could be useful at flows close to those of the motorway capacity. For flow rates lower than motorway capacity, ramp metering control is not required. Also, for total upstream flows (i.e. main motorway and ramp) much higher than the capacity, ramp metering effectiveness will be reduced because of the limitation of the storage length (as shown in section 5.4). The results also indicate that ramp metering could not significantly improve downstream capacity.

5.4 Effect of ramp length

The effect of ramp length on the upstream throughput, speed and delays are shown in Figure 8. The Figure indicates that as the ramp length increases, speed and throughput for the main motorway increase, as well as ramp delay. As a result, delays on the main motorway will decrease. For the selected flow inputs shown in Figure 1 and for the selected optimum position of detector (i.e. 300m downstream of the nose) and for a critical occupancy of 23%, Figure 8 shows that the ramp length has a limited effect on the above parameters when it exceeds 500m. This could be explained by the fact that the whole storage length is not used because the critical occupancy is
selected to optimize speed, throughput and delays for the motorway based on a ramp length of up to 300m. However, if there is a relatively higher ramp length, the selected critical occupancy could theoretically be reduced to less than 23% and this will produce further delay for ramp traffic.

Figure 7  Upstream capacity benefit of ALINEA

Figure 8  Effect of ramp length on (a) motorway throughput, (b) motorway upstream speed, (c) motorway delay and (d) ramp delay.
Figure 9 compares the queue length obtained from simulation for two occupancy values, 21% and 23%. The Figure reveals that for the lower occupancy value (i.e. 21%), longer ramp queue lengths will be obtained. In practice, lower critical occupancy rates could be applied when there is no limit to the storage ramp area (e.g. motorway to motorway merge sections).

![Figure 9: Effect of selected occupancy values on queue length based on simulation](image)

5.5 Effect of traffic signals position

Figure 10 shows that motorway throughput increases as the position of signals increases up to 100m followed by a general decrease as the position of signals increase. This is mainly due to a decrease in the storage length as the length of ramp has been fixed to 300m for this analysis.

![Figure 10: Effect of position of traffic signal on motorway throughput](image)

6. Conclusion

Sensitivity analyses have been presented in this paper for some related parameters with ramp metering controls. Two algorithms which are widely used have been tested, namely ALINEA and D-C algorithms, taking the effect of the on-ramp queue length into consideration. A new traffic micro-simulation model has been developed and used in this study. The optimum position of the traffic detector and optimum critical occupancy for the ALINEA algorithm has been estimated by running the simulation model using different possible values for these parameters. Such optimum parameters have been used to investigate the effect of ramp storage length (i.e. ramp length) and position of traffic signals on motorway capacity, speed and delay. The calibration process for the ALINEA algorithm shows that there is room for improvement if appropriate values for its parameters are selected such as using a critical occupancy of 23% with a downstream detector position of 300m from the nose. The effect of ramp length was significant on the motorway throughput, speed and delay, as well as ramp delay. The results were not sensitive to the effect of position of traffic signal because the increase in the distance of traffic signals and the merge section
affects the storage length. Different motorway and ramp flows were also used to test the effectiveness of the ALINEA algorithm. The results show that ramp metering controls could be useful at flows close to the motorway capacity.

References


Highways Agency (2008). Ramp metering technical design guidelines. MCH 2470/B.


