A detailed evaluation of ramp metering impacts on driver behaviour

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Abstract

Ramp metering was first installed in Chicago in 1963 and is now widely employed in North America and European countries to alleviate motorway traffic congestion. A detailed investigation was carried out to study the potential impacts of ramp metering on driving behaviour. An instrumented vehicle and 11 video cameras were used to measure detailed driving performance of drivers merging at on ramps and those on motorway carriageways in a ramp metering controlled intersection with and without ramp metering control. The main behavioural parameters used for the study include: speed, headway, acceleration and deceleration, sizes of accepted gap, merge distance, speed at merge, etc. Based on the study, it is believed that ramp metering does result in driving behaviour changes of traffic on the motorway carriageway and on ramp. It improves the merge condition of traffic at the on ramp, but may cause minor reduction of speeds of traffic on motorway carriageway during the metering time.

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1. Introduction

The M3/M27 ramp metering pilot scheme has been operational since August 2000 and has involved the implementation of ramp metering at six on ramps. As a part of the program, the Transportation Research Group (TRG) at the University of Southampton was entrusted to investigate the impacts of the ramp metering program to drivers’ behavior changes, and the impacts to motorway efficiency, journey time of traffic on ramp
metering controlled motorway intersections. The results reported in this paper are a part of the output of the project, the study on potential driving behaviour changes with ramp metering.

There are various ramp metering control strategies (Papageorgiou & Kotsialos, 2002; Sun & Roberto, 2005; Taale & Van Velzen, 1996). However, the principle and objectives are similar to all of them. Ramp metering uses dedicated traffic signals at on ramps to regulate the flow of vehicles entering a busy highway (motorway, freeway or dual carriageway) with the aim to maximise the capacity of the highway and prevent congestion and flow breakdown. Fig. 1 shows the diagram of a typical ramp metering scheme.

The first ramp metering system was installed in Chicago in 1963 (Lomax & Fuhs, 1993). Ramp metering is now widely employed in North America and European countries to alleviate motorway traffic congestion. Descriptions of ramp metering systems are provided in detail by Papageorgiou (1991), Harwood (1993) and Kang and Gillen (1999). Ramp metering control strategies can be classified as local or coordinated. Local ramp metering controls a single on-ramp, while coordinated ramp metering controls a series of on-ramps. Coordinated ramp metering can be achieved by sequential control of on-ramps, where individual ramps are started and stopped according to the spread of congestion in the area, or global control, where traffic measurements for the whole area are used to calculate metering settings.

A ramp metering signal may release a single vehicle or a platoon of vehicles at the on ramp. Platoon release may create merge problems with the motorway carriageway traffic but allows greater merge flows than single vehicle metering. A queue override facility may be installed so that more traffic than normal is allowed to enter the motorway carriageway if the traffic queue at the on ramp extends to the all purpose road network.

1.1. Examples of ramp metering programs

In May 1986, ramp metering was introduced in the morning peak on the southbound on-ramp at junction 10, M6, in the Midlands, England. Owens and Schofield (1988) reported that the downstream throughput capacity of junction 10 increased by an average of 3.2%, and the journey time on the motorway section immediately upstream and downstream of the metered junction decreased by an average of 14–19 s across the peak period. However, the journey time of the merge traffic at the on ramp to downstream of the junction increased by an average of 3–87 s across the peak period. The overall saving in delay was calculated to be 71 vehicle-hours per day without consideration for traffic growth.

McLean, Brader, Diakaki, and Papageorgiou (1998) Diakaki, Papageorgiou, and McLean (1998) reported the evaluation results for an integrated traffic-responsive urban corridor ramp metering control scheme on the M8 motorway in Glasgow, Scotland. Ramp metering using the ALINEA strategy was implemented in the evening peak period at junction 16 of M8 in the eastbound direction. The metering allowed platoons of 1–3 vehicles per signal cycle. The evaluation showed that ramp metering increased motorway throughput by 5%. Traffic flow decreased at the on ramp and increased on urban alternative routes by 13% with associated increases in delay.

Papageorgiou, Hadj-Salem, and Middelham (1997) presented results of ramp metering at three on-ramps along a 6-km section of the southern part of the Boulevard Périphérique, Paris. ALINEA local control

Fig. 1. Diagram of a typical ramp metering scheme (Stewart, 2003).
resulted in a 9.7% decrease in total travel time and a 0.9% decrease in vehicle kilometres. Tarry and Harrison (1997) reported that ramp metering at five on ramps on the M6 in the Midlands, England, resulted in increases in peak period throughput of 3–4%, whilst throughputs remained constant elsewhere on the motorway. Preliminary analysis of accident data indicated a 4% lower accident rate at sections with metering relative to adjacent sections without metering.

1.2. Objectives of the study

Many researchers have reported the success of ramp metering on increase of throughput capacity (e.g. Diakaki et al., 1998; Hadj Salem, Blosseville, & Papageorgiou, 1991; McLean et al., 1998; Owens & Schofield, 1988; Papageorgiou et al., 1997), reduction of journey time (e.g. Owens & Schofield, 1988; Papageorgiou et al., 1997), decrease of accident rates. However, some researches have also reported some negative impacts of ramp metering, for example: increased journey time of the merge traffic at the on ramp (e.g. Owens & Schofield, 1988), increased accident rates and reduced traffic at the on ramp and increased diversion traffic to urban alternative routes (e.g. McLean et al., 1998; Diakaki et al., 1998). Obviously, the effect of ramp metering may be influenced by many unrevealed factors particularly the difference on driving behaviour between the ramp metering on (RM ON) and ramp metering off (RM OFF) conditions. Although there are many researches on ramp metering, most of these researches focused on the general description of flow/throughput changes, travel time changes and accident rates changes as discussed above. Very little has been found on the study of driving behaviour changes with ramp metering.

A better understanding of driving behaviour changes with ramp metering will help traffic engineers and researchers to produce better design of ramp metering schemes, and better achieve the goal of ramp metering program. In addition, it is generally believed that ramp metering system may reduce the stress of merge drivers at the on ramp and smoothes the traffic flow with reduced deceleration rates and increased headways downstream of the metered junction. This paper is, therefore, to study the driving behaviour changes associated with ramp metering, focusing to answer whether a ramp metering system can reduce the stress of merge drivers at the on ramp and smoothes the traffic flow downstream of the metered junction based on the study of the data collected from real system.

The paper has the following structure. Section 1, introduction, presents the background of the study, literature reviews and objectives. Section 2, research method, presents the behavioral parameter identification and experiment/survey design. Section 3, results and analysis, presents the data, analysis results and discussion. The last, Section 4, is the conclusions and discussion.

2. Research methods

2.1. Identification of behavioural parameters

The common behavioural parameters for motorway driving traffic includes

(i) Acceleration/deceleration.
(ii) Speed.
(iii) Headway.
(iv) Lane changing rates.

For traffic to merge at the on ramp, the following further behavioural parameters are used:

(v) Gap acceptance.
(vi) Merge distance (to be defined later, and see Fig. 15).
(vii) Speed at merge.

This study uses the above 7 behavioral parameters for discussion of the differences of driving behavior between with and without ramp metering.
2.2. Experiment tools

It is difficult to measure the driving behaviour parameters such as acceleration/deceleration, speed, headway of all the passing traffic (vehicles passing the junction on the motorway carriageway) and merge traffic (vehicles merging to the motorway carriageway from the on ramp), and the speed at merge of all the merging traffic. Therefore, this study used an instrumented vehicle to measure the above driving behavioural parameters of a group of selected test driving subjects.

An instrumented vehicle is a vehicle specially equipped with various devices to measure the vehicle’s acceleration, speed, headway, time, location (x-, y-coordinates), and driver’s manoeuvre, performance and reactions. The IV used in the study is one of the few fully instrumented units in Europe (McDonald, Brackstone, & Sultan, 1998). The vehicle is equipped with a range of sensors allowing measurement of driver performance and how the motion of the vehicle relates to surrounding vehicles, including:

- Speed, acceleration and distance traveled (see below).
- Distance and relative speed to vehicle ahead, behind, and up to 12 adjacent vehicles.
- Steering wheel movements.
- Indicator use.
- Pedal displacement and pressure.
- Up to 4 quad mixed video inputs from cameras typically viewing the road ahead, behind, and driver’s head and eye movements.
- Vehicle position by GPS.
- GSM data communication links.

In the test driving, each selected driver (subject) drove the IV, either merge at the on ramp (merge route survey) or pass the intersection from upstream of motorway carriageway (pass rout survey) according to the experiment plan. The IV speed, acceleration, headway to vehicle ahead, and speed at merge were logged to a CD-ROM in a frequency of 10 readings per second for further analysis. Fig. 2 shows the photo of the IV doing a merge route test driving (on the photo, IV is the first vehicle, in purple colour, at the on ramp).

In this study, roadside video cameras were employed to measure the interaction of the merging traffic at the on ramp and the passing traffic on the motorway carriageway within the merge section (the section road where a merge vehicle may move into the motorway carriageway from the on ramp). The video camera data

Fig. 2. Picture of a merge route test driving of the IV.
combined with the IV data in a synchronised time base formed the database of the behavioural parameters: gap acceptance, speed at merge and merge distance.

Based on the length of the merge section of the selected survey site, 11 video cameras (including one on the bridge) were employed to monitor the dynamics of the merge process over the length of motorway over which it occurs. The camera locations used to monitor the merge and passing traffic were arranged as shown in Fig. 3. The over bridge camera was used to measure the parameter: lane change rates in the pre-merge zone (definition later).

Further, one loop detector on the motorway upstream of the merge section provides detailed information of traffic in the pre-merge zone (definition see Fig. 9) and another loop detector at the on ramp measures the merge traffic.

The combination of the above measurements provided a substantial database to answer questions about changes in driving behaviour. Each measurement system on its own is unlikely to provide robust results for the study.

2.3. Experiment/Survey site selection

As an RM ON and RM OFF survey will last for over two months minimum and involve much equipment, surveyors and test driving subjects, it is too expensive to do multi-site surveys. Therefore, it is necessary to select one of the most suitable sites among the six ramp metering sites to carry out the survey. This selected survey site must be typical, with frequent traffic congestions particularly in the morning and/or afternoon peak hours. It also needs to be convenient to set the video cameras for measurement. After a pre-survey, and consulting project authorities, it was found that junction 11 on the M27 (M27 J11) (see Fig. 4) satisfies the above requirements. First, it has an average traffic flow of 3800-4000 (veh/h) upstream of J11 of the 3 lane motorway carriageway, and 1800–1900 (v/h) from the on ramp; having regular traffic congestion down stream in the morning peak hours. Second, the 10 video cameras can be set on the hill in the nearside of the motorway (refer to Fig. 3), therefore, the M27 J11, and the section of motorway from junction 10 to junction 12 (see Fig. 5) were selected for the survey.

2.4. Experiment subjects

The IV enabled the measurement of driving behaviour of different test driving subjects on motorway driving and merge at the on ramp. To make the research results of representative, 16 drivers of different genders, ages and driving experiences were selected to reflect the differences on driving behaviour. However, the focus
of this study is not on the difference of driving behaviour between different drivers, but the changes of driving behaviour between with and without ramp metering. Therefore, same group of drivers were used for both RM on and RM OFF test-driving.

2.5. Experiment design

The on site investigation included a 4 week RM ON survey and a 4 week RM OFF survey. The ramp metering in M27 J11 uses the ALINEA algorithm with cycle times of 10, 12, 15, 20, 24 and 30 s. Within each cycle, the duration of the green was sufficient to allow three vehicles per lane to pass the stop line. There were no changes to algorithm during the study.
2.5.1. RM OFF survey

For the RM OFF survey, the ramp metering system was switched off on Monday 21 May 2001 for five weeks. The week starting Monday 28 May was a half-term school holiday and was therefore excluded from consideration. The 4 weeks considered were those starting 21 May and 4, 11 and 18 June.

2.5.2. RM ON survey

Ramp metering was switched on on Monday 25 June 2001 after 5 weeks off for RM OFF survey. The 4 weeks for RM ON survey were those starting 25 June and 2, 9 and 16 July.

Either RM OFF survey or RM ON survey includes pass route surveys and merge route surveys.

Pass route survey: In a pass route survey, the test driving route for IV is: From Junction 10 to Junction 12 and return.

Merge route survey: In a merge route survey, the test driving route for IV is: From Junction 10 to Junction 11, off Junction 11 and then merge from Junction 11 via the on ramp, down to Junction 12 and return.

In a pass route survey, the IV driver was requested to drive the vehicle on motorway lane 1 (nearside lane) as long as possible. This enabled detailed information, e.g. speed, headway, etc., of motorway lane 1 to be collected by the IV as a passing vehicle from upstream to downstream of the surveyed junction (J11).

A merge route survey was designed to collect the merge behaviour data of traffic along the on ramp and the interaction with passing traffic on the motorway merge section.

2.6. Data management

When the IV driver either passed or merged at J11, time-series data traces and footage from in vehicle video cameras were recorded. These databases enabled the manoeuvres of the IV and interactions between the IV and the adjacent vehicles to be analysed in a coordinated way.

As in Monday morning traffic flow may be significantly different from that of other working days, to ensure traffic flow data comparable, surveys were only made on the mornings of Tuesday to Friday. Therefore, there were only 16 days (4 days per week) in total for ramp metering on (RM ON) surveys, and the same for ramp metering off (RM OFF) surveys. Excluding one unsuccessful surveying day in the RM OFF survey period and one in the RM ON survey period (faults in the IV data recording system), there were 15 days valid data for

Table 1
Summary of the behavioural and traffic parameters collected

<table>
<thead>
<tr>
<th>Behaviour parameter</th>
<th>Data resource</th>
<th>Experiment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration/deceleration</td>
<td>IV test driving</td>
<td>Pass route and merge route</td>
<td>To test driving behaviour changes of passing traffic and merge traffic with and without a ramp metering</td>
</tr>
<tr>
<td>Speed</td>
<td>IV test driving</td>
<td>Pass route and merge route</td>
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</tr>
<tr>
<td>Headways</td>
<td>IV test driving</td>
<td>Pass route and merge route</td>
<td>To test driving behaviour changes of passing traffic and merge traffic with and without a ramp metering</td>
</tr>
<tr>
<td>Lane change rates</td>
<td>Over bridge video camera</td>
<td>All time during survey</td>
<td>To test the lane change behaviour change of traffic in upstream (pre-merge zone) of the junction</td>
</tr>
<tr>
<td>Gap acceptance</td>
<td>IV test driving and over bank video camera</td>
<td>Merge route test driving</td>
<td>To test the behaviour changes of merge traffic</td>
</tr>
<tr>
<td>Speed at merge</td>
<td>IV test driving and over bank video camera</td>
<td>Merge route test driving</td>
<td>To test the behaviour changes of merge traffic</td>
</tr>
<tr>
<td>Merge distance</td>
<td>IV test driving and over bank video camera</td>
<td>Merge route test driving</td>
<td>To test the behaviour changes of merge traffic</td>
</tr>
<tr>
<td>Flow from motorway</td>
<td>Loop detectors upstream of Junction 11</td>
<td>All time during survey</td>
<td>Provided by ramp metering operator’s authority</td>
</tr>
<tr>
<td>Flow from on ramp</td>
<td>Loop detectors at on ramp</td>
<td>All time during survey</td>
<td>Provided by ramp metering operator’s authority</td>
</tr>
</tbody>
</table>
each of the RM ON and RM OFF conditions. In either RM ON survey or RM OFF survey, there were
approximately 150 IV test driving runs, with about 70–80 runs for merge and a similar number for passing
manoeuvres. All the test driving data was collected on weekdays (except Monday) from 07:00 to 09:00. Fur-
ther, to remove potential impacts of motorway incidents on the results, the data measured in the following two
days have also been excluded.

(1) 11th June 2001, Horses at Junction 9 eastbound caused reduced traffic from upstream, (during RM OFF
survey), and
(2) 9th July 2001, an accident happened between J11 and J12, which caused a large tail back, (during RM
ON survey).

After excluding the above two day’s data, there are a total of 14 days valid data for each of RM ON and
RM OFF survey.

The following Table 1 summarised the behaviour and traffic parameters collected by the above surveys. All
the parameters were collected in RM ON and RM OFF surveys using the same group of test driving subjects.
All the following analysis will be based on the above data.

3. Results and analysis

In this section, results are discussed in the following three subtitles: (i) behaviour of passing traffic, which
discusses the driving behaviour of traffic passing the junction on motorway carriageway; (ii) behaviour of traf-
ffic in pre-merge zone, which discusses the behaviour of traffic in the pre-merge zone immediately upstream of
the merge section of motorway carriageway; and (iii) behaviour of merge traffic, which discusses the behaviour
of traffic merging from the on ramp to the motorway carriageway.

3.1. Behaviour of passing traffic

Passing traffic behaviour was measured using the IV in the “Pass route survey”. There were 44 sets of valid
test driving data for RM OFF and 69 for RM ON conditions recorded by the IV. Behavior parameters such as
speeds, headways, and accelerations and decelerations were recorded by the in vehicle data logger system at a
rate of 10 readings per second during the journey from junction 10 to junction 12 M27. Each journey took
about 4 to 6 min in average, which means each journey of test driving can collect 2400–3600 sets of data.

3.1.1. Speeds

The speed distributions of test driving between RM ON and RM OFF are shown in Fig. 6 in percentile. It
shows in the Figure that the mean speeds of the journey are slightly higher (about 3.5% or 3.8 km/h in aver-

Fig. 6. Comparison of speed distribution with RM ON and RM OFF.
age) in the case of RM OFF than that in RM ON. However, the difference on average speed of test driving between RM ON and RM OFF were insignificant (Mean(RM ON) = 22.35 m/s; Mean(RM OFF) = 22.97; \( t(111) = .2725; \rho = .05 \)).

3.1.2. Time headway

The headway data were collected by the IV test driving. In the study, the time headway is defined as

\[
\text{Time headway} = \frac{\text{head to head distance}}{\text{(following vehicle speed)}}
\]

The time headway distributions in RM ON and RM OFF are shown in Fig. 7 in percentile. The Figure shows that the mean time headways in RM ON are marginally greater than that in RM OFF. But this difference is insignificant (m(RM OFF) = 1.40; m(RM ON) = 1.55; \( t(111) = .065; \rho = .05 \)).

3.1.3. Acceleration and deceleration

Acceleration rate is of significant importance on flow stability, safety, environment impacts, and energy consumption. There are 69 valid average acceleration deceleration rate data for RM ON and 44 for RM OFF. The difference is insignificant on the average acceleration and deceleration rates between RM ON and RM OFF (m(RM ON) = -.0042; m(RM OFF) = -.0045; \( t(111) = .9256; \rho = .05 \)).

3.1.4. Summary to “Behaviour of Passing Traffic”

To summarise this section, the differences were found to be insignificant on mean speeds, headways and acceleration/deceleration rates of passing traffic between RM ON and RM OFF conditions. In other words, the employment of ramp metering has insignificant impacts on driving behaviour of passing traffic up and down stream of the motorway intersection based on the surveyed data in the study.

3.2. Behaviour of traffic in pre-merge zone

3.2.1. Number of lane changes from lane 1 to 2

The pre-merge zone defined in this study is shown in Fig. 8. The results of the number of lane changes from lane 1 to lane 2 in the pre-merge section were based on the analysis of the footage from the over bridge video camera recording from 7:00 am to 9:00 am on each survey day. Lane changes were counted in 5-min time slots for both RM ON and RM OFF conditions. During analysis, it was noted that, sometimes, the first and the last 5 min had incomplete measurements (i.e. not full five minutes measured). Therefore, data used for the analysis were taken from 7:05 to 8:55 am for all the surveys.

The 14 day average lane change numbers against the time for the cases of RM ON and RM OFF are shown in Fig. 9. In RM ON, lane change rates were more consistent through the two hours than those in RM OFF.
For example, there is only 1 time slot (7:50–7:55), which has an average lane change number lower than 8 when RM is on. However, there are 4 time slots (7:45–7:50, 7:50–7:55, 7:55–8:00 and 8:15–8:20), which have an average lane change number lower than 8 when RM is off. The statistical results shown significant differences on lane change rates between RM ON and OM OFF (m(RM ON) = 10.3; m(RM OFF) = 9.2; t(21) = 3.52; p = .05).

3.2.2. Headway and speeds

Data of vehicle headway and speeds in pre-merge zone were measured by the detector, No: 9394A2, which is located 300 m upstream of the merge start point (see Fig. 13) of J11 on the M27 (eastbound), within the pre-merge zone (see Fig. 8).

*Headway:* The difference on average time headway of traffic on motorway carriageway lane 1 is shown in Fig. 10. The x-axis represents time in 5-minute steps and the y-axis shows the 14 day average time headways for both RM ON and RM OFF conditions. The difference on the average of time headways is significant between RM ON than RM OFF conditions (m(RM ON) = 5.08; m(RM OFF) = 4.95; t(23) = 2.8; p = .05).

*Speeds:* The average speeds in lane 1 of motorway carriageway in pre-merge zone are marginally higher with RM ON than that with RM OFF as shown in Fig. 11. But, the difference is insignificant (m(RM ON) = 85.25 km/h; m(RM OFF) = 85.51 km/h; t(23) = .43; p = .05).
3.2.3. Speeds and headways on lane 2 and 3 in pre-merge zone

Although there are significant differences on headways on lane 1 in pre-merge zone, the differences of the headways and speeds on lane 2 and 3 are insignificant (see Table 2).

3.2.4. Summary to “Behaviour of Traffic in Pre-merge Zone” of motorway carriageway

Traffic in lane 1: Ramp metering resulted in significantly higher lane change rates from lane 1 to lane 2. This is further shown as significantly higher headways of traffic with RM ON than that with RM OFF. However, the average speeds are not significantly different. Therefore, ramp metering may cause reduced flow in the pre-merge zone in lane 1 because of the increased headways.

Traffic in lane 2 and 3: Survey results do not show significant differences on speeds and headways of traffic on lane 2 and 3 between RM ON and RM OFF.

3.3. Behaviour of merge traffic

This section discusses the impacts of ramp metering on merge traffic at the on ramp.

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**Table 2**

<table>
<thead>
<tr>
<th>Behavioural parameter</th>
<th>Headways (meters) Mean(RM ON)</th>
<th>Mean(RM OFF)</th>
<th>t(23)</th>
<th>Speeds (km/h) Mean(RM ON)</th>
<th>Mean(RM OFF)</th>
<th>t(23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 2</td>
<td>23.19</td>
<td>23.02</td>
<td>0.14</td>
<td>94.47</td>
<td>94.17</td>
<td>0.72</td>
</tr>
<tr>
<td>Lane 3</td>
<td>22.3</td>
<td>22.12</td>
<td>0.46</td>
<td>100.03</td>
<td>99.71</td>
<td>0.75</td>
</tr>
</tbody>
</table>
3.3.1. Merge distance

The merge distance (point of merge) was measured from the lane separation markings, which delineate the offside of the on ramp and the motorway (see Fig. 12), to the point where the offside front wheel of the IV touched the marked line.

Fig. 13 compares the data of merge distances collected in RM ON and RM OFF periods. The figure shows a reduction of merge distance with RM ON, with the peak of the histogram shifted to the left side of that of RM OFF (see Fig. 13). However, statistically, the differences were found insignificant (m(RM ON) = 32.8; m(RM OFF) = 33.6; t(161) = .75; \( p = .05 \)).

3.3.2. Size of accepted gaps

Size of accepted gaps (Gap Size) is the time headway between two successive vehicles where the merge vehicle moved in on motorway lane 1 (see Fig. 14). The Gap Size is measured by the roadside video camera at the time when the front offside wheel of test driving IV touched the lane marking line.

The data of Gap Size in RM OFF and RM ON conditions is shown in Fig. 15. It is clear, the average Gap Size with RM ON is significantly larger than that with RM OFF (m(RM ON) = 11.3 s; m(RM OFF) = 8.1 s; t(161) = 3.43; \( p = .05 \)).

3.3.3. Speeds at merge

Speeds at merge (Merge Speed) were measured when the offside front wheel of the IV touched the lane delineation lines during a merge process. The analysis used data from the roadside video cameras and the IV.

![Fig. 12. Draw of J11 on the M27 (Eastbound).](image)

![Fig. 13. Comparison of merge distance between RM ON and RM OFF.](image)
There are 78 valid merge records in RM OFF conditions and 88 in RM ON conditions. Fig. 16 presents the comparison results of merge speeds data collected in RM ON and RM OFF conditions. The histogram and the “t” test results show that the merge speeds in RM ON are significantly lower than that in RM OFF ($m_{RM~ON} = 68.8$ km/h; $m_{RM~OFF} = 74.5$ km/h; $t(162) = 2.70; \rho = .05$).

3.3.4. Summary to behaviour of merge traffic

Ramp metering resulted in significant increase of accepted gap sizes and reduced merge speeds. The increase of accepted gap sizes (in time headway) means a reduction of workload of merge performance for merge traffic.
4. Conclusions and discussion

Measurements carried out using the roadside cameras, instrumented vehicle and loop detector have enabled the study and resulted in the following conclusions of the impacts on driving behaviour of ramp metering. Ramp metering has resulted in a certain changes on driving behaviour in a certain areas. These are summarised below.

4.1. Impacts of ramp metering

4.1.1. Passing traffic

Ramp metering does not have significant impacts on passing traffic on speeds, headways and acceleration/deceleration rates. In another words, there is no significant evidence to prove that ramp metering system may smooth the traffic flow downstream of the metered junction by increased headway and reduced deceleration rates.

4.1.2. Traffic in pre-merge zone

There is a significant increase of the number of lane changes from lane 1 to lane 2 in pre merge zone with RM ON. This resulted in significant increases of headways of lane 1 traffic in the pre-merge and the merge sections. However, such change only happened in very limited area (e.g. only in pre-merge and merge sections), as there is no significant difference on the average headways of passing traffic in whole journey from upstream junction (J10) to downstream junction (J12) between RM ON and RM OFF.

Ramp metering only has insignificant impacts on speeds and headways of traffic on lane 2 and 3.

There is no clear evidence that the increase in lane change in the pre-merge zone has any adverse effects on motorway safety. The increased lane change in pre-merge zone only has insignificant impacts on speeds and headways of passing traffic.

4.1.3. Traffic merge from the on ramp

Ramp metering resulted in easier merge conditions for merge traffic from the on ramp, presenting with increased gap acceptance and lower merge speeds.

4.1.4. The reasoning of the mechanism of ramp metering impacts

With RM ON, because the distance of the stop line of ramp metering to the merge start point (see Fig. 13) is not long enough for merge vehicles to accelerate to the same level of speeds of that in RM OFF, merge vehicles arrived at the merge section with significantly lower speeds. Meanwhile, when entering the pre-merge zone and seeing the slow moving vehicles coming at the on ramp, more vehicles on lane 1 of motorway carriageway choose to move to lane 2 to avoid potential deceleration and delay. Therefore, gap sizes of the traffic on motorway lane 1 in the merge section significantly increased. This resulted in an easier merging condition for the merge traffic from the on ramp, presenting with larger accepted gaps and shorter merge distances.

The above conclusions are based the study in one ramp metering controlled junction in South England. More such studies in different areas with different traffic conditions and ramp metering control strategies will be useful for further comparison.

References


