UK- M6 Motorway Ramp Metering
1986-1997

TEMPO Secretariat

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This evaluation report presents results of the M6 Ramp Metering trials in the UK Midlands.
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KEY EVALUATION RESULTS

The platoon based Ramp Metering system used on the M6 has:

- Increased the throughput of traffic on the motorway; and
- Reduced journey times on the main carriageway; but has also
- Increased delays at on-ramps by up to 1.5 minutes at the busiest times.

Between 1986 and 1988 at M6 J10 (S) there was a net saving of between 71 and 107 hours per day in journey times. This equates to a saving of between £67,000 and £110,000 per year at 1986 prices.

Capacity has been increased on the mainline around the M6 J10 (S) ramp metering site by 3.2 % at peak times.

A preliminary accident analysis based on three years of data (1993-1995) at all six ramp metering sites found a modest reduction in accidents of between 1 and 10 %, although these findings were not assessed for statistical significance.

This report summarises the results from the following documents:


1. DESCRIPTION OF THE PROBLEM

1.1 SITE

In 1986 the first ramp-metering scheme in Britain was installed on the M6 Motorway near Birmingham (UK). The ramp-metering tool was initially implemented at junction 10 south. Soon after, further ramp metering sites were introduced at J7 south; J10 north; J5 south; J9 south; J9 North. This evaluation report considers results from the M6 J10 (S) site for most indicators. The accident analysis was conducted later on all six sites.

The M6 in Birmingham is at the heart of the UK strategic road network. It is a dual three lane plus hard shoulder motorway of which a large proportion is elevated.

The motorway is urban in nature and has gantries with lane control signs at regular intervals. These gantries can display lane availability information and advisory speed limits, but not mandatory speed limits. The national speed limit of 70 miles per hour (c110 km/h) applies on this section.

The busiest section of the M6 between J9 and J10 carries in excess of 150,000 vehicles per day (Annual Average Daily Traffic) in both directions during peak times. In 1998 the maximum hourly reported flow was 174,200

Figure 1: Site locations

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Junction 10 of the M6 is located at the following coordinates:

<table>
<thead>
<tr>
<th>Lat (WGS84)</th>
<th>N52:35:06 (52.585071)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long (WGS84)</td>
<td>W2:00:52 (-2.014568)</td>
</tr>
</tbody>
</table>

Junction 5 of the M6 is located at the following coordinates:

<table>
<thead>
<tr>
<th>Lat (WGS84)</th>
<th>N52:30:34 (52.509503)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long (WGS84)</td>
<td>W1:47:17 (-1.788156)</td>
</tr>
</tbody>
</table>

The whole section is lit.

Queueing occurs regularly along the section, particularly on all approaches to Junction 8, which is an unregulated motorway-to-motorway intersection with the M5. The M5 is also a dual three-lane plus hard shoulder urban motorway at this point, which is lit with gantries. The congestion, which begins in the vicinity of merges and diverges at Junction 8, can stretch upstream on the M6 for more than 10 km at busy times.

The on slip at Junction 10 (S) is on a downward sloping gradient as can be seen in Figure 1.

Figure 2: The M6 looking south at Junction 10. The ramp metering signals can be clearly seen.

1.2 ISSUES ADDRESSED

The ramp metering system was developed to relieve congestion on the main carriageways of the M6 without affecting the local road network with the aim of making journey times faster and more reliable.
2. DESCRIPTION OF THE ITS PROJECT

2.1 OBJECTIVES

The objectives of the ramp-metering project were to determine whether ramp metering could:

- Reduce the incidence and effects of congestions problems;
- Assist with the recovery of the traffic speed through the merge when the speed falls below a defined limit.

2.2 SYSTEMS AND TECHNOLOGIES APPLIED

The project began in 1989 with the installation of a ramp metering system at Junction 10 Southbound on slip on the M6. The UK Government wholly funded the project. The scheme used conventional traffic signals with standard minimum stage lengths and amber periods to control traffic joining the motorway. Control was exercised using a stage selection control algorithm, which responds to speed and flow information obtained from detectors on the carriageway. Downstream flow is monitored continuously so the signals are only changed to red if there is insufficient downstream capacity to absorb both mainline and slip road traffic.

The ramp signals are mounted on a gantry over each lane about 250 metres from the top of the entry slip road. There is then a 450-metre acceleration area (200m of slip road and 250 m of merge area). There are rotating prism variable message signs are located at the top of slip roads to advise motorists that there are part time signals on the ramp.

Introducing a ramp metering system on the M6 improves the operation of the Motorway by limiting, regulating and timing the entry of vehicle from ramps on the main carriageway. The ramp metering system is fully automatic and switches on using an inbuilt timetable.

The control is exercised through a stage selection control algorithm that responds to speed and flow information, from the detectors located on the ramp. Red stages are triggered when either:
- the mainline and slip road demand flows exceed a short term critical flow limit, or
- when traffic speeds through the merge fall below a predetermined threshold.

The flow metering is to prevent or delay the onset of congestion. The speed metering is designed to clear congestion once it has occurred. Any red stages are cancelled either by flows returning above thresholds, a maximum red time being reached or if queue detectors at the top of the slip roads detect excess queue lengths.

The system was subsequently installed at J10(N), J9 (N&S), J7(S), and J5(S).

The DEC PDP 11 based control system was not year 2000 compliant and the remainder of the system was life expired. Thus during 2001/02 the system was decommissioned at all six junctions and replaced with a new ramp metering system. This reuses the same slip road gantries.

Results on the performance of the new ramp metering system are not yet available.

2.3 STATUS OF THE PROJECT

The project has been completed. The original equipment has now been replaced with next generation ramp metering equipment.
3. EVALUATION

3.1 TIMING AND TYPE OF EVALUATION

This evaluation was carried out with pre and post-implementation evaluation. No simulation was carried out as part of the evaluation.

3.2 OBJECTIVES FOR THE EVALUATION

The following assessment objectives for the pilot were determined at the outset of the trial:

- Assessment of Motorway Capacity Improvements;
- Assessment of Motorway Journey Time Reductions;
- Assessment of the Impact of Ramp Metering on the All-Purpose Road Network;
- Economic appraisal of scheme benefits (& cost benefit appraisal);
- Assessment of Driver behaviour and safety.

3.3 RESEARCH QUESTIONS

The four principal stakeholders in the project were the Department of Transport (DoT) as the strategic network manager, the Police, the Local Authority and the ramp metering system manufacturer; they have the following research requirements:

- The DoT, wanted to know if the scheme would improve the efficiency of the M6 motorway, this would be measured in terms of capacity, throughput, journey times and congestion;
- The Police and DoT needed to assess the scheme’s impact on safety;
- The Local Authority needed to know whether the ramp metering scheme would affect the surrounding all-purpose road network;
- The ramp metering system manufacturer wanted to know if the system itself is worthwhile, this more of a qualitative rather than quantitative result and depends on the results of the other research questions.

3.4 STUDY AREA FOR THE EVALUATION

The deployment of the M6 Ramp Metering Scheme was carried out in two phases; initially it was only installed on the M6 J10 south, later the scheme was expanded to include J7 south, J10 north, J5 south, J9 south and J9 north. The two separate phases of the deployment involved two different studies into the effects of Ramp Metering.

The initial deployment was designed to test the economic benefits of installing a ramp metering scheme on a British motorway. The scheme looked at benefits to motorway traffic in terms of increased throughputs and reduced delays; it also looked at potential disbenefits to vehicles on the ramps and on the all-purpose road network. To carry out such an evaluation detailed data were required about traffic flows on the M6 J10 south link, as well as on the ramp itself and the immediate surrounding all-purpose road network. These data were collected from four different sources, firstly a series of detector loops on the motorway provided minute–by-minute data on a daily basis about the traffic on the motorway, further loops on the ramps collected data about queuing on the ramps. A video recording survey was conducted twice on separate mornings of each month between autumn and spring both before and after the scheme was implemented, this survey was taken from various vantage points overlooking the motorway between junctions 11 and 9. The final source of information was a series of surveys undertaken on the road network surrounding junctions 9 and 10. It was felt that junction 10 may be affected by excessive queuing on the ramp, it was also felt that congestion on the ramp may cause people to reroute and join the M6 at junction 9 causing congestion there, and so both sites needed to be assessed. Five surveys were carried out at these sites before ramp metering was installed and seven after, here journey time and flow information were collected manually.

The later deployment looked again at economic factors, but also considered other factors that may arise due the implementation of a ramp metering scheme. The economic factors considered again included the throughputs and delays; furthermore, the scheme also looked at the effects of ramp metering on accident rates. However, this survey did not consider the impact of the ramp metering scheme on the surrounding road network. To analyse
the effects of ramp metering, data was collected from three sources, vehicle detectors on the carriageway around the junctions and on the ramps themselves provided journey time, throughput and queuing data, this enabled the economic factors to be assessed. To analyse the effects of ramp metering on accident rates, a comparison was made between the number of accidents per 100 million vehicle kilometres before and after the scheme was implemented. These data were obtained from the Road Accident Statistics Branch of the Department of Transport.

3.5 IMPACTS

The impacts assessed were:

- Motorway capacity improvements expressed in vehicles per minute and in percentage terms under various meteorological conditions;
- Motorway journey time reductions;
- Impact of ramp metering on the all purpose road network between junctions 9 and 10 of the M6;
- Economic appraisal of scheme benefits excluding traffic growth;
- Effectiveness of the queue back algorithm;
- Accident levels following scheme introduction.

3.6 METHODS

Motorway capacity improvements were assessed by collecting mean capacity values from downstream inductive loop detectors for one year before and after system introduction. The highest continuous hours flow within each peak period per day (the carriageways capacity) was determined and then aggregated to provide the mean capacity values for a range of traffic and driving conditions. Separate mean values were collected for wet and for dry conditions subdivided according to lighting conditions.

Indicator

The performance indicator used was: Average peak 60-minute traffic throughputs with and without ramp metering.

Expected performance

Capacity was expected to increase by a modest amount.

Journey time reductions were assessed using video recordings. A random sample was taken from both light and heavy vehicle classes. Data was aggregated and averaged over successive half hour periods.

Indicator

The performance indicators used were average journey time change in seconds and vehicle hours saved. This was presented on sections both upstream and downstream of the junction, at a control site and on the on slip at J10. Only statistically significant data values were included in the final analysis to determine net vehicle hours saved on the network. This value included both journey time reductions on the mainline and journey time increases on the on slip.

Expected performance

Journey times were expected to remain broadly neutral or improve slightly.

Impacts of ramp metering on the all purpose road network were assessed by surveying the all purpose network between M6 J10 and J9 on 12 separate occasions. Five before ramp metering was installed and on seven occasions after it was installed.
Indicator
A network performance criterion was used created by summing over all the links and for the whole peak period (07:30 to 09:30) flow weighted journey times (vehicle hours per hour) and link lengths (vehicle km / hour). An analysis of covariance was then performed on the data points obtained.

Expected performance
Network performance of the all-purpose road network was expected to remain broadly neutral or deteriorate slightly.

Economic appraisal of scheme benefits were assessed in relation to the reduction in travel delays and increased throughput achieved by the introduction of ramp metering. Benefits were assessed with and without consideration of the traffic growth that occurred between the before and the after situation. The mean journey time savings were used to calculate estimated daily and then annual savings (with appropriate weighting for meteorological conditions over the year). In order to remove the effect of traffic growth on the figures, a method of analysis was used based on the known relationship between duration of saturation and delay with and without ramp metering. By observing both the level of saturation and associated delay before and after introduction of ramp metering a time saving excluding the additional traffic volume could be calculated using an empirically derived relationship.

A cost/benefit analysis was also undertaken.

Indicator
A rate of return on investment was calculated.

Expected Result
A positive rate of return was expected.

Effectiveness of the queue back algorithm was assessed by visual inspection of the junction.

Expected Result
The queue back algorithm was expected to be effective.

Driver behaviour and safety was closely monitored in the early months of the project, but no quantitative data was collected related to driver behaviour. Compliance rates with the signals was not assessed in detail, but were described as “extremely good, with very few observed violations of the red stop signal.”

Preliminary accident analysis was undertaken in 1997 for accidents recorded from 1993 to 1995 at all six ramp metering sites. Comparison of accident rates were made between sections affected by ramp metering and those unaffected by ramp metering. The sections affected by ramp metering stretched from halfway from the preceding junction to halfway to the subsequent junction. 15 unidirectional route sections were defined.

Indicator
Accident rates per million vehicle kilometres.

Expected Result
The accident rate was expected to remain broadly neutral or show slight improvement.

Reference case
The reference case for accident stats was the national average accident for motorways for the period 1993/1995. The reference case for other statistics was the observed data for one year before scheme implementation at J10 South.
Data collection

Data was collected through:

- Inductive loops providing minute by minute data;
- Video traffic surveys (for journey time monitoring); and
- Stats 19 Accident records produced by the Police.
4. THE IMPACT OF THE PROJECT

4.1 TECHNICAL PERFORMANCE

Technical evaluation of the system was carried out during the course of its lifetime. In the beginning, the scheme performed relatively well, but towards the end of its design life (from 1995 onwards) the system became increasingly unreliable. Reasons for unreliability included failures of the upstream, downstream and ramp detectors, (occasionally resulting in a need for new loops to be cut), intermittent data transmission faults with upstream and downstream detectors, occasionally no output at all from detectors, message sign faults, isolation of controllers and traffic signal lamp failures.

The reliability of the system varied greatly between the six junctions on which it operated. The table below states the reliability of the ramp metering system on each of the six junctions, during two evaluation periods late in its design life.

<table>
<thead>
<tr>
<th>Junction Number (Direction)</th>
<th>% of time ramp metering system in operation at junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction 10 (Southbound)</td>
<td>0</td>
</tr>
<tr>
<td>Junction 10 (Southbound)</td>
<td>79</td>
</tr>
<tr>
<td>Junction 10 (Southbound)</td>
<td>0</td>
</tr>
<tr>
<td>Junction 10 (Southbound)</td>
<td>55</td>
</tr>
<tr>
<td>Junction 10 (Southbound)</td>
<td>74</td>
</tr>
<tr>
<td>Junction 10 (Southbound)</td>
<td>62</td>
</tr>
</tbody>
</table>

Table 1: Reliability of ramp metering system on each junction

The safeguard built into the signal control algorithm to prevent queuing back to the A454 roundabout has been very effective. At no point have queues seriously interfered with the operation of the operation of the roundabout, although there has been occasionally very brief periods of queuing onto the roundabout. In these periods, the queues formed did not extend beyond the A454 entry from Walsall. As experience was gained of the system’s performance, adjustments were made to parameters within the algorithm to improve the operation of this aspect of the system. The adjustments affected the queue prediction and dissipation detection procedures, allowing more flexibility in the choice of red and green times.

4.2 RESULTS

Motorway capacity

Motorway capacity increased during the periods when ramp metering is in operation both with and without ramp metering.

The table below indicates the levels of throughput as average peak 60-minute traffic throughput with and without ramp metering under different traffic and weather conditions.

<table>
<thead>
<tr>
<th>Status</th>
<th>Weather Condition</th>
<th>No flow breakdown</th>
<th>Breakdown clearing within the peak</th>
<th>Breakdown not clearing within the peak</th>
<th>Average (unweighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Ramp metering</td>
<td>Dry, Light</td>
<td>5377</td>
<td>5610</td>
<td>5443</td>
<td>5477</td>
</tr>
<tr>
<td>With Ramp Metering</td>
<td>Dry Light</td>
<td>5600</td>
<td>5783</td>
<td>5602</td>
<td>5662</td>
</tr>
<tr>
<td>% change</td>
<td>+ 4.1%</td>
<td>+3.1%</td>
<td>+2.9%</td>
<td>+3.3%</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>Statistically significant increase</td>
<td>At 95% confidence level</td>
<td>At 95% confidence level</td>
<td>No</td>
<td>At 95% confidence level</td>
<td></td>
</tr>
</tbody>
</table>

Without Ramp metering

<table>
<thead>
<tr>
<th>Status</th>
<th>Weather Condition</th>
<th>Without Ramp metering</th>
<th>With Ramp Metering</th>
<th>% change</th>
<th>Statistically significant increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Dark</td>
<td>Wet, Light</td>
<td>5427</td>
<td>5475</td>
<td>+0.9%</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5269</td>
<td>5463</td>
<td>+3.7%</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5153</td>
<td>5343</td>
<td>+3.7%</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5283</td>
<td>5427</td>
<td>+2.7%</td>
<td>No</td>
</tr>
</tbody>
</table>

With Ramp Metering

<table>
<thead>
<tr>
<th>Status</th>
<th>Weather Condition</th>
<th>Without Ramp Metering</th>
<th>With Ramp Metering</th>
<th>% change</th>
<th>Statistically significant increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Dark</td>
<td>Wet, Light</td>
<td>5475</td>
<td>5500</td>
<td>+3.0%</td>
<td>At 95% confidence level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5463</td>
<td>5672</td>
<td>+4.0%</td>
<td>At 95% confidence level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5343</td>
<td>5447</td>
<td>+2.6%</td>
<td>At 95% confidence level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5427</td>
<td>5541</td>
<td>+3.2%</td>
<td>At 95% confidence level</td>
</tr>
</tbody>
</table>

Table 2: Summary of traffic flows during different weather conditions with and without ramp metering
Motorway journey time reductions

Motorway journey times were reduced on the main line even with flow increases. The following table presents the results for both the mainline and the on slip with and without ramp metering. There was some increase in journey times for a limited number of drivers on the entry slip but the overall result was very positive. Benefits were felt upstream of the junction on the section between junction 10 and 10A. There was no significant change in journey time between Junction 11 and Junction 10A the control section.

<table>
<thead>
<tr>
<th>Motorway Section</th>
<th>Time Period</th>
<th>Without Metering</th>
<th>With Metering</th>
<th>Change Flow %</th>
<th>Change Journey Time (secs)</th>
<th>Statistically significant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean Flow (veh)</td>
<td>Mean Journey Time (sec)</td>
<td>Mean Flow (veh)</td>
<td>Mean Journey Time (sec)</td>
<td></td>
</tr>
<tr>
<td>J10 (s) entry slip</td>
<td>0730-0800</td>
<td>605</td>
<td>150</td>
<td>630</td>
<td>186</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>0800-0830</td>
<td>595</td>
<td>193</td>
<td>575</td>
<td>280</td>
<td>-4</td>
</tr>
<tr>
<td></td>
<td>0830-0900</td>
<td>455</td>
<td>179</td>
<td>455</td>
<td>228</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0900-0930</td>
<td>380</td>
<td>164</td>
<td>385</td>
<td>167</td>
<td>+1</td>
</tr>
<tr>
<td></td>
<td>0930-0945</td>
<td>180</td>
<td>133</td>
<td>190</td>
<td>125</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>0730-0945</td>
<td>2215</td>
<td>2235</td>
<td>&lt;0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J10- 9 Main carriageway</td>
<td>0730-0800</td>
<td>1970</td>
<td>159</td>
<td>2225</td>
<td>145</td>
<td>+13</td>
</tr>
<tr>
<td></td>
<td>0800-0830</td>
<td>2010</td>
<td>198</td>
<td>2205</td>
<td>183</td>
<td>+10</td>
</tr>
<tr>
<td></td>
<td>0830-0900</td>
<td>2025</td>
<td>182</td>
<td>2245</td>
<td>163</td>
<td>+11</td>
</tr>
<tr>
<td></td>
<td>0900-0930</td>
<td>1935</td>
<td>147</td>
<td>1900</td>
<td>132</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>0930-0945</td>
<td>800</td>
<td>110</td>
<td>835</td>
<td>103</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>0730-0945</td>
<td>8740</td>
<td>9410</td>
<td></td>
<td></td>
<td>+7.5</td>
</tr>
<tr>
<td>J 10A – J10 main</td>
<td>0730-0800</td>
<td>2415</td>
<td>269</td>
<td>2670</td>
<td>286</td>
<td>+10</td>
</tr>
<tr>
<td>carriageway (5.31km)</td>
<td>0800-0830</td>
<td>2385</td>
<td>385</td>
<td>2510</td>
<td>380</td>
<td>+5</td>
</tr>
</tbody>
</table>
Table 3: Motorway flows and journey times with and without ramp metering

Impact of ramp metering on the all purpose road network between junctions 9 and 10 of the M6

There was no significant change in performance of the all-purpose road network during periods when ramp metering was in use.

Economic appraisal of scheme benefits without considering the effect of traffic growth

The amount of time saved every day through the operation of ramp metering at Junction 10 (S) was 71 vehicle hours. This daily saving was converted into an annual figure by multiplying it by the number of days when this saving could be expected (excl weekends, bank holidays, peak summer holidays, likely serious incident days). The annual saving was estimated at: 14200 vehicle hours saved during the year. At 1986 prices this equated to £67,000.

Economic appraisal of scheme benefits independent of traffic growth

When applying the methodology determined in section 3.3 to determine the impact of ramp metering independent of traffic growth an average reduction in delay of 107 vehicle hours per day was derived. This equated to an potential annual saving of 23500 vehicle hours or £110,000 at 1986 prices.

Cost/benefit analysis

Capital outlay for the metering installation at J10 (S) was £255,000 at 1986 prices. Thus the journey time savings equate to a first year rate of return of between 20 and 40 percent dependant on whether traffic growth is
considered in the evaluation. This rate of return assumes an annual running cost of £10,000 at 1986 prices. These benefits are at no additional cost to users of the all-purpose road network.

**Effectiveness of the queue back algorithm**

During the first year of operation there was no queuing which significantly interfered with the circulation of traffic on the roundabout above J10, although there was some queuing back on to the roundabout observed for short time periods. Some refinements to the queue back algorithm were made during the early weeks of implementation.

**Accident levels following scheme introduction**

In 1997 after ramp metering had been in operation for 10 years at J10 (S) and at the other 5 sites for more than 5 years an accident analysis was undertaken.

The reference case for accidents was taken as the national average accident rate for Motorways from 1993 to 1995 this figure compares closely with results for the M6 external to the ramp metered sections.

The results indicated that accident rates in the vicinity of ramp metering sites were at least 1 % and up to 10% lower than surrounding sites unaffected by ramp metering. The results presented were only interim results to determine whether further research was required in this field, but were based on three years of accident data.

No assessment of statistical significance of the results was made.

**4.3 STATISTICAL ANALYSIS**

When values are statistically significant this is stated in the above results. The assessment of performance of the all-purpose road network was undertaken using an analysis of covariance.

**4.4 RESEARCH QUESTIONS ANSWERED**

The four principal stakeholders each had requirements that needed to be researched before the success of the scheme could be judged. The following conclusions have been drawn;

- The Department of Transport wanted to know about the impacts the scheme would have on the efficiency of the M6 motorway, as discussed below in section 4.5.2 below, there were positive impacts in terms of throughput and journey times. As a result, a net saving of between 71 and 107 vehicle hours per day has been gained.
- The Police wanted to know how the system affected the safety of drivers using the M6, as discussed in section 4.5.1 below there was no evidence to suggest additional accidents were caused by ramp metering, and there was some data to suggest that ramp metering actually reduces accident frequency, although this is not statistically significant.
- The Local Authority needed to know whether the ramp metering scheme would effect the surrounding all-purpose road network, the study has shown that there have been no measurable change in journey times or overall flow levels in the surrounding network. It has been concluded that the system has not had any significant impact on the all-purpose road network.
- The ramp metering system manufacturer wanted to know if the system itself was worthwhile. The results of the above research questions have all been positive, further financial analysis was carried out as discussed in section 4.5.4. This indicated that the scheme has a positive rate of return.

**4.5 OVERALL ASSESSMENT**

**4.5.1 Safety**

There is no evidence to suggest that the implementation of ramp metering has resulted in additional accidents. There is limited evidence to suggest that ramp metering may reduce accident frequency, but there is no statistically significant data to support this.
4.5.2 Efficiency

There is statistically significant evidence to suggest that implementation of ramp metering at J10(S) increased throughput on the M6 mainline by 3.2% with no detrimental effect on the surrounding all purpose road network. Capacity increases appeared greatest during the hours of daylight.

Statistically significant journey time improvements were reported on the M6 mainline. These occurred on sections immediately downstream and immediately upstream of the junction. There was a statistically significant increase in journey times for motorists using the J10(S) on slip.

Taken together the statistically significant increases and decreases in journey times equated to a net saving of between 71 and 107 vehicle hours per day.

4.5.3 Environment

No assessment was undertaken of the environmental impact of ramp metering.

4.5.4 Financial

The financial benefit of introducing ramp metering at J10(S) was estimated to be between £67,000 and £110,000 per year at 1986 prices. This indicates a first year rate of return of between 20 and 40%.

4.5.5 User acceptance

No assessment was made of user acceptance of the system.

4.5.6 Integration

The system has no impact on integration.

4.5.7 Accessibility

The system has no impact on accessibility.
5. **EUROPEAN DIMENSION: TRANSFERABILITY OF THE RESULTS**

There are an increasing number of ramp metering installations across Europe. This early research is useful in quantifying the benefits of one, stand-alone ramp metering site on a UK urban motorway. The evaluation provides a sound analysis of:

- Impacts on traffic flow;
- Impacts on traffic speeds and journey times; and
- A preliminary assessment of accidents.

It should be noted that the M6 Ramp Metering system has the following features, which may limit the transferability of results.

The signal heads are gantry mounted in an urban motorway environment.

The signal sequence includes a red and amber stage between the red and green stages and an amber stage between green and red stages.
## ANNEX 1: TECHNICAL ANNEX

### Selected Indicators

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>SUB-OBJECTIVE</th>
<th>INDICATORS</th>
<th>Expected Result Pre-implementation Qualitative</th>
<th>Expected Result Pre-implementation Quantitative</th>
<th>Actual Results Post-Implementation Qualitative</th>
<th>Actual Results Post-Implementation Quantitative</th>
<th>Statistical Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Accidents</td>
<td>Number of accidents</td>
<td>Stable or reducing accident rate on section with access control</td>
<td>No change</td>
<td>Some positive benefit</td>
<td>Reduction of between 1 and 10 % in accident rate.</td>
<td>3 years of data 1993-1995 (No assessment of statistical significance). At all 6 sites.</td>
</tr>
<tr>
<td>Economy</td>
<td>Efficiency</td>
<td>Journey Time</td>
<td>Reduction in journey time</td>
<td>N/A</td>
<td>Reduced Journey Times</td>
<td>71 vehicle hours saved (net) per day.</td>
<td>Saving per annum 14200 vehicle hours. May rise to 107 hours per day if removing the effect of traffic growth (equates to 23500 vehicle hours per annum).</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Vehicle throughput</td>
<td>Increase number of veh/hour</td>
<td>N/A</td>
<td>3.2 % increase in throughput. 172 additional veh/hour downstream J10</td>
<td>1998 survey from J10 downstream vehicle detectors. Result statistically significant at the 90% level.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Integration</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Financial</td>
<td>Economic assessment not considering traffic growth</td>
<td>Cost Benefit First Year Rate of Return</td>
<td>Positive benefit</td>
<td>N/A</td>
<td>Positive benefit £255,000 £67,000 20 %</td>
<td>At 1986 prices. Results based on statistically significant data. Value of Time / hr £4.70.</td>
<td></td>
</tr>
<tr>
<td>Economic assessment considering traffic growth</td>
<td>Cost Benefit First Year Rate of Return</td>
<td>Positive benefit</td>
<td>N/A</td>
<td>Positive benefit £255,000 110,000 40%</td>
<td>At 1986 prices. Value of Time / hr £4.70.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Acceptance</td>
<td>Behaviour – speed and lane limit</td>
<td>Drivers Behaviour</td>
<td>High level of driver compliance with signals.</td>
<td>N/A</td>
<td>High level of driver compliance with signals.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>