Interim Advice Note ##/05

Advice regarding the Assessment of

Sites for Ramp Metering

Contents

List of Tables:

List of Figures

1. Introduction

1.1 This Interim Advice Note, provides advice upon the circumstances where ramp metering may be of benefit in improving the flow of traffic on the main line carriageway of a motorway, in the vicinity of an entry merge from a slip road or interchange link at grade separated junctions. It draws on the experience gained to date from ramp metering schemes located on the M3, M6 and M27. The advice is therefore directed primarily at motorways, though it may be equally applicable in many respects to all purpose dual carriageway trunk roads.

1.2 Principles of Ramp Metering:

Section 2 of this Interim Advice Note explains the mechanism by which the speed and flow of main line traffic can be adversely affected by merging traffic from slip roads and interchange links. It describes how ramp metering seeks to minimise these effects by regulating the entry flow at merges in order to provide a degree of co-ordination between the main line and merging traffic streams.

1.3 An Overview of System Operation:

An overview of the operation of a ramp metering system is provided in Section 3. The various components of the system are described and an explanation is provided of the function of each.

1.4 Criteria for the Installation of Ramp Metering:

Criteria based on observed levels of congestion have been developed to assist in identifying merge locations where ramp metering may be of benefit. These criteria are set out in terms of vehicle speeds in the vicinity of the merge and are detailed in Section 4. Based upon operational experience at existing ramp metering sites, it has also been necessary to specify certain criteria in relation the traffic flow and physical layout of a site in order to determine the feasibility of ramp metering. These criteria relate to the volume and composition of traffic flow on the main line and merge, the type of merge arrangement and the length and gradient of the slip road/interchange link.

1.5 Economic Assessment:

In the case of schemes funded by the Highways Agency, it will be necessary to undertake a cost benefit analysis based upon the principles described in Section 5.

2. Principles of Ramp Metering

2.1 The problem ramp metering addresses:

2.1.1 For the purposes of this section the terms concentration and occupancy are used, these terms are similar as they both refer to the relationship between vehicles in terms of headway. They are not however completely interchangeable:

- Concentration refers to the amount of a length of carriageway covered by vehicles and is unrelated to speed, whereas;
- Occupancy is the amount of time a loop is covered by a vehicle expressed as a percentage. Where concentration over an area remains constant, the occupancy at a fixed point can alter as traffic bunches and as speed alters over an area.

2.1.2 When traffic flow on the main carriageway is high this means that the traffic concentration is also high. The concentration is the amount of carriageway covered by a vehicle. A high concentration directly equates to smaller distances between vehicles or a low headway, in such conditions the road's capacity is close to being reached and small changes in the nature of the traffic flow causes it to become volatile and susceptible to flow breakdown.

2.1.3 The introduction of traffic from the on ramp can cause vehicles to change lanes and bunch leading to higher concentration and lower headways. These shorter headways can be unsustainable at the speed of the main carriageway, for comfort and safety drivers will adjust their speed to account for the short stopping distances available. This adjustment of headway occurs over a distance of up to 2km after the on slip.

2.1.4 Often this adjustment of headway will cause following vehicles to brake, propagating a "wave" of braking vehicles in the traffic stream. Traffic concentration in the wave will be even higher. To compound the problem more vehicles will be entering the main carriageway boosting concentration even higher. If vehicles continue to join, ultimately the main carriageway speed will drop to a point where flow breakdown occurs. In this situation vehicles are stopping at the back of a queue and then driving off the front of the queue. This stationary traffic is typically seen between the merge area and approximately 2km downstream.

2.1.5 As a result of standing traffic, sometimes called a "phantom jam", the road effectively has its lowest throughput when the demand is at its highest.

2.1.6 Weather conditions, daylight, vehicle mix and gradients amongst other things can all affect the maximum throughput of any section of motorway.

2.2 How ramp metering addresses this problem:

2.2.1 To address this problem, ramp metering aims to maximise throughput on the main carriageway without disrupting the local road network. It does this by controlling the discharge of traffic from the slip road to reduce the interference of merging traffic on the main line flow thereby maintaining speeds at a higher level. Maintaining higher speeds will

postpone the onset and duration of flow breakdown on the main carriageway. To do this it relies on the measurement of traffic conditions on the main carriageway and attempts to maintain this at a 'target occupancy' by restricting the flow from the on ramp.

2.2.2 By having stop lines with signal heads on the slip road, merging traffic can be held back as the target occupancy on the main carriageway is approached. The slip road behind the stop line is used as a buffer allowing traffic to be stored temporarily and then 'metered' out onto the main carriageway.

2.2.3 The amount of traffic which can be stored on the on ramp is finite and it is important that queues do not interfere with the local road network. In order to ensure that the best use is made of the available slip road space, a queue management system is included in the ramp metering system. The expected benefits of ramp metering are:

- Shorter journey times for vehicles on the main carriageway;
- Reduced congestion on the main carriageway;
- Improved journey time reliability for vehicles on the main carriageway;
- Improved safety.

2.2.4 The expected dis-benefits of ramp metering are delays to slip road traffic arising from stops at the signals.

3. An Overview of System Operation

3.1 The main control unit for an individual ramp metering site is contained in a cabinet at the junction near the ramp metering signals. The equipment in the cabinet monitors the inputs from the traffic detection loops on the main carriageway and from the queue length detectors on the on-ramp. It uses these inputs to select the most appropriate signal plan to achieve the target occupancy.

3.2 The system works through the use of stop lines in association with standard traffic light signal heads. The ramp metering site can operate in isolation without connection to external communications. However, it is also possible to control the settings and monitor the system from a terminal remote from the site. The information collected from the traffic detection loops includes; flows, speeds, occupancy, headway and four categories of vehicle lengths, for each lane of the main carriageway. The information used to operate the ramp metering system is occupancy, speed and flow. These are used in different ways depending on the configuration of the system. The other information collected is used to assist in configuring the system.

3.3 The important loops needed on the slip road for the ramp metering to work, are part of the queue detection and management system. This involves queue length detectors (loops) at regular intervals along the storage part of the slip road. Based on the information provided by these and the occupancy information supplied by the traffic detection loops on the main carriageway, the correct metering strategy is selected to make the best use of the storage available while trying to keep as close as possible to the target occupancy on the main carriageway.

3.4 Ultimately, if the queue on the on-ramp becomes too long, the final queue detection loops set at the beginning of the slip road at the junction with the local road network will trigger the ramp metering signals to change to green. This is known as a queue override and is designed to protect the stored traffic from interfering with the local road network. To see a typical ramp metering layout see Figure 2

3.5 Inductive loops are used for traffic detection for traffic on the main carriageway. The loops are used for both the operation of the system and for evaluation purposes.

3.6 The loops are in each running lane on the main carriageway and should be able to count traffic, measure speed, vehicle length, occupancy and headway.

3.7 The loops are usually placed both upstream and downstream of the merge area and ideally having one set of loops in the vicinity of the point where flow breaks down.

4. Criteria for the Installation of Ramp Metering

4.1 The criteria for assessing the suitability of a site for ramp metering relates to both the traffic and physical characteristics of the site. These criteria are set out in the following paragraphs and have been derived from experience gained with existing ramp metering schemes on the motorway network. Figure 1 contains a flowchart which illustrates the suggested procedure for evaluating the criteria at individual sites.

4.2 Traffic Characteristics:

4.2.1 Sites that may be suitable for ramp metering should show flow breakdown on the main line carriageway where average speeds drop below the 50kph threshold for at least one hour every workday, Monday to Friday. Moreover, the flow breakdown occurring on the main carriageway should only be attributable to the presence of the merge, ramp metering will not be effective in reducing congestion if the congestion:

- Commences upstream of the merge, (ramp metering can not solve a problem that is not caused by merging traffic.);
- Commences further than 2km downstream of the merge, (the problem is unlikely to be as a result of the merging traffic.);
- Lasts for less than one hour, (the costs of reducing delays to mainline traffic will not be sufficient to justify the costs of installing and operating ramp metering).

4.2.2 Slip road traffic flow should be high enough for it to have an impact on the main carriageway traffic (a minimum slip road flow of 400veh/lane/hr is suggested based on experience to date). If the slip road flow is lower than this, its interaction is unlikely to be enough to be the cause of flow breakdown on the main carriageway.

4.2.3 If the slip road demand is too high, ramp metering operation will be impeded because the queue over-ride algorithm will set the signals to green to prevent traffic queues on the slip road interfering with the local road network. A suggested maximum value from the experience to date is 900veh/lane/hr but ramp metering may work with higher slip road flows depending on factors such as the length of the slip road.

4.2.4 For ramp metering to work, the combined value of the upstream flow and the slip road flow should not be too large otherwise flow breakdown will occur at the merge. Hence the experience gained from the M6 and M3/M27 trials suggests that slip road flow should be at least 5% of the upstream flow and should not exceed 900veh/lane/hr.

4.2.5 During the installation of the ramp metering system queue length detectors will be installed on the slip road between its beginning at the local road junction to the ramp metering stop line, the ideal spacing for these loops is at 50m intervals.

4.2.6 See Figure 2 for a diagram of the layout of a typical ramp metering installation.

4.2.7 A high percentage of HGVs, i.e. more than 25%, on the slip road means that vehicles will take longer to reach mainline speeds, particularly if there is an uphill gradient. It is possible therefore that a high percentage of HGVs using the slip road could preclude the use of ramp metering.

4.2.8 Schemes for immediate implementation should be based on current data with no adjustment for traffic growth.

4.3 Data Collection:

4.3.1 A good example of the type of detection required is the MIDAS system which includes the installation of inductive loops at nominal 500m intervals and provides average values of speed, flow and occupancy every minute.

Without this type of data available for a site it is not possible to:

- Identify and assess the traffic problem;
- Control the algorithm and signals for ramp metering;
- Monitor the performance of the ramp metering.

4.3.2 If such a traffic detection system is present, the infrastructure must be deemed to be sufficiently robust with minimum malfunctioning loops, (e.g. it is essential that working loops exist upstream of the back of the queue, upstream of the merge area and downstream of the bottleneck).

4.3.3 If suitable traffic detection does not currently exist at a site, route managers should assess the suitability of their site for its installation prior to any implementation of ramp metering. Provision will add significantly to the cost of installing ramp metering. In this case, to assess the site's suitability for Ramp Metering, alternative traffic detection methods should be applied to get the necessary information.

4.3.4 The traffic problem at the merge location should be assessed over a number of days (excluding school holidays and special events) by collecting and analysing data at the one minute level (if possible) and also by making observations of traffic behaviour on site.

4.4 Physical Characteristics:

4.4.1 This advice is based on current experience of junction layouts that are common on the network, for example using straight, two lane slip roads with tapered merges onto three lane main carriageways. If the site being considered has any of the following characteristics, a special case could be made and further advice sought:

- Lane gain from slip road;
- Single lane slip road;
- Motorway to motorway link; or
- Two or four lane carriageways.

4.4.2 With ramp metering in operation, the slip road should satisfy two requirements:

- It should be able to store a sufficient number of vehicles so that, when vehicles are queuing, vehicles do not back up beyond the start of the slip road (see Figure 2 “storage space”); and
- There should be a sufficient length from the stop line (when ramp metering is implemented) and the main carriageway for vehicles to accelerate. Stop line placement will be part of the design process.

4.4.3 For the purposes of site selection it is sufficient to ensure that the slip road from its junction with the local road to the tip of the nose marking is 300 metres. Then the merge area should be at least 205metres long. There is some flexibility in the 300 metre slip road length as it also depends on the flow of HGVs and the gradient of the slip road. This interaction can be seen in Figure 1.

4.4.4 Platoon size, vehicle acceleration and gradient are all factors which will be considered in the design guidance for the placement of the stop line.

4.5 Summary of Criteria:

4.5.1 Table 1 summarises the criteria set out above.

Table 1 – Criteria for the Installation of Ramp Metering.

Parameter	Minimum Value	Maximum value
Congestion (hours below 50kph per year)	250	No maximum value
Upstream mainline flows (vph across 3 lanes)	4000	5000
Slip road flows (vph per lane)	400	900
Slip road flow as percentage of upstream flow (%)	5	30
Average mainline speeds in congestion	No minimum value	70kph
Slip road length (local road to start of merge)	300metres	No maximum
Merge length	205metres	No maximum

Figure 1 - Flow chart process FC1 to assess whether ramp metering is likely to give benefits at a site

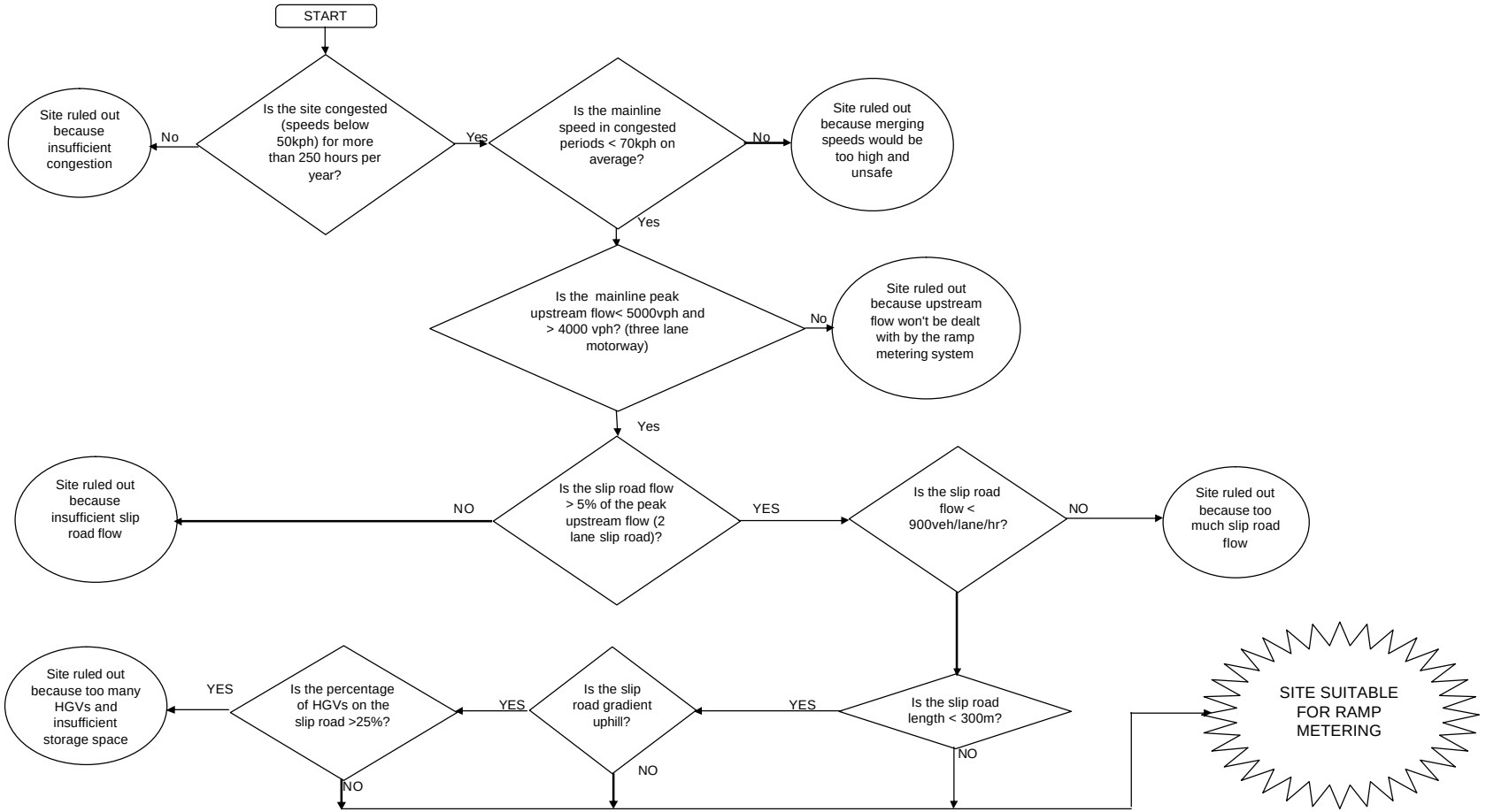
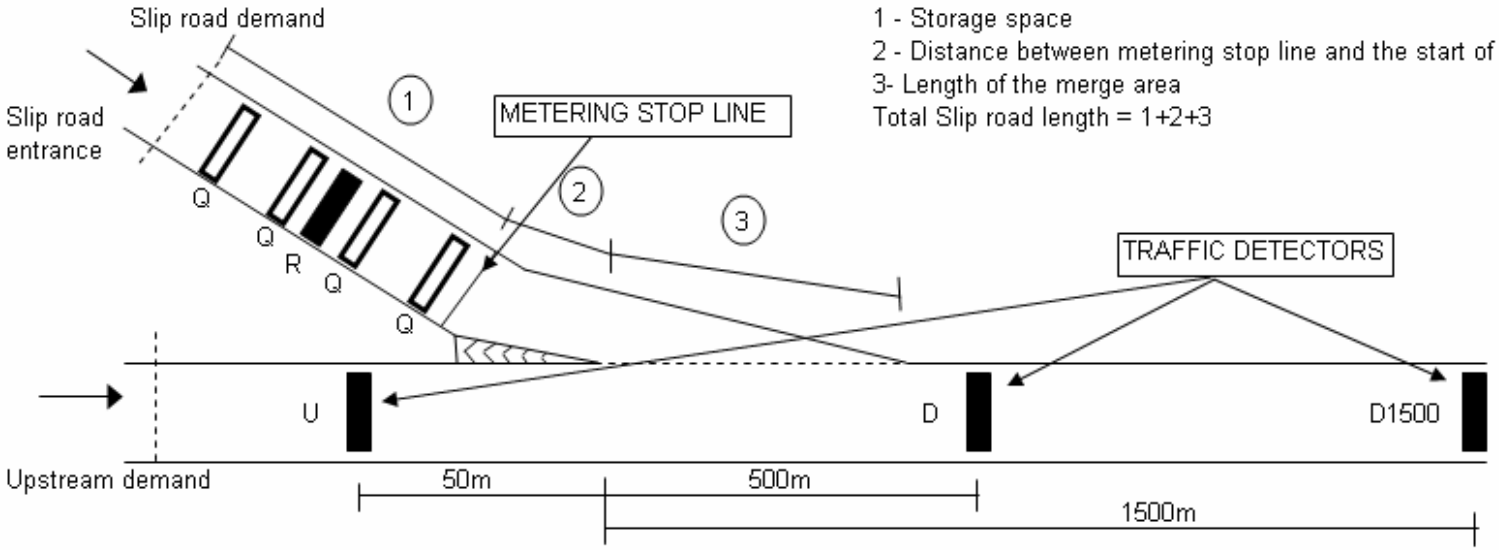


Figure 2 - General layout of a ramp metering site



U = Traffic detection loops upstream of merge location
D = Traffic detection loop downstream of merge location
D1500 = traffic detection loop 1500m downstream of merge location
R = Trafic detection loop on slip road
Q = Queue detection loop on slip road number dependant on slip road length, ideal spacing 50m

5. Next steps

5.1 Once the process outlined in these guidance notes has been completed, it should be known whether a site is suitable.

5.2 If the site is a Highways Agency road a cost benefit analysis should take place based on the supporting data available from Nanu Rayman at the Highways Agency. Once this analysis has been completed estimates of costs and benefits of implementing ramp metering at that site should be known.

When a site has been identified as suitable, a check should be made as to whether it lies within an Air Quality Management Area (AQMA) and if there is a property within 200 metres of the site. If this is the case air quality modelling will be required. Either Simon Price or Michele Hackman of the Highways Agency's Environmental Policy (EP) team can give guidance on how this should be carried out.

For more assistance regarding ramp metering, business case development and implementation, please contact:

Mr Nanu Rayman,

Highways Agency

Temple Quay House

Temple Quay

Bristol BS1 6HA

5.3 These notes may be revised as more information becomes available following implementation of ramp metering at further sites. It is hoped that more information on site characteristics and their interaction, as well as benefits can be obtained from this.