EasyWay Harmonising European ITS Services and Actions

Traffic Management Services

RAMP METERING

Deployment Guideline

TMS-DG03|VERSION 02-00-00 |DECEMEBR 2012

EasyWay is a trans-european project co-financed by the European Commission (DG MOVE)

www.easyway-its.eu

Contact

Coordinator	David Laoide-Kemp, NRA, Ireland, dlkemp@nra.ie
Coordinator support	Jacqueline Barr, IBI Group, UK, jbarr@ibigroup.com

Preamble

EasyWay is a cooperation of road authorities and road operators from 27 European countries that have teamed up to unlock the benefits of cooperation and harmonisation in the deployment of Intelligent Transport Systems (ITS) on Europe's major road network. ITS as a technology is a known contributor to sustainable mobility in terms of improved safety, efficiency and reduced environmental impact. Nevertheless, fragmented deployment on a national level will fail to deliver seamless European services and will not contribute to a coherent European Transport network. The European Member States have consequently launched the EasyWay project together with the European Commission as a platform to harmonise their ITS deployments.

This document has been drafted by EasyWay as part of the set of documents containing the 2012 version of the EasyWay Deployment Guidelines (DG 2012). These guidelines have been developed by EasyWay experts and practitioners. They have undergone a thorough review by international domain experts in an intense peer review exercise and they have been validated by the participating Member State Partners of EasyWay in an extensive formal Member State consultation process, which finally led to their adoption as basis for all deployment activities in future EasyWay phases.

EasyWay as a project is not a standardisation body, nor does it have any power to legally constrain the Member State in their national deployment activities. It is therefore crucial to understand that these documents are neither technical standards, nor are they specifications as they would be required for such cases, e.g. as currently developed by the European Commission as their part of the implementation of the ITS Directive 2010/40/EU. But since a certain level of strictness in compliance is required to achieve the intended goal of the EasyWay Deployment Guidelines – harmonisation and interoperability in Europe – the guideline documents are written in a way that clearly defines criteria that deployments have to fulfil in order to claim overall compliance with the guideline.

Although not legally binding in any sense, compliance may be required for the eligibility of deployments in future ITS road projects co-funded by the European Commission. Deviation from compliance requirements may nevertheless be unavoidable in some cases and well justified. It is therefore expected that compliance statements may contain an explanation that justifies deviation in such cases. This is known as the "comply or explain" principle.

Although not standards themselves, the EasyWay DG2012 Deployment Guidelines in some cases do mention – and sometimes require – the use of such standards. This is the case in particular regarding the use of the CEN/TS 16157 series of technical specifications for data exchange ("DATEX II"). Although standardised data exchange interfaces are a powerful tool towards harmonised services in Europe, it must be understood that real world deployments have to fit into existing – and sometimes extensive – infrastructures and investment in these infrastructures must be protected. It is therefore important to note that the use of DATEX II mentioned below as a MUST is referred to implementation of "new" data exchange systems and not the utilisation of the existing ones, unless these latter affect harmonisation of deployments or interoperability of services.

Service at a glance

SERVICE DEFINITION

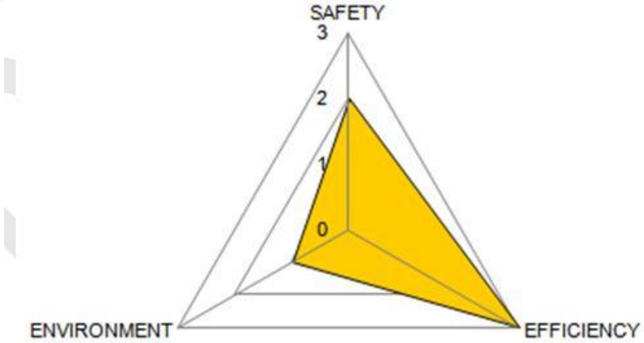
Ramp metering is implemented via the installation of traffic signals on the on-ramps which regulate the flow of traffic joining the motorway during peak or congested periods. It does this by controlling the discharge of vehicles from the on-ramp, holding vehicles back and breaking up platoons of vehicles, thus reducing the interference of merging vehicles and helping maintain the flow of traffic on the main carriageway. The traffic signals are generally operated in dependence of the currently prevailing traffic conditions on both the main carriageway and the on-ramp.

SERVICE OBJECTIVE

The purpose of ramp metering is to prevent or delay the onset of flow breakdown on the motorway, maximising throughput, without disrupting the urban road network. This is achieved by:

- Regulating the flow of additional traffic onto the motorway that, if unregulated would trigger flow breakdown / lead to critical shockwaves;
- Monitoring and managing the traffic flow on the on-ramp, achieving even distribution, to avoid large platoons of vehicles entering the motorway and causing flow breakdown;
- Reduction or avoidance of congestion spillback to the adjacent urban traffic network or to other merging motorways; and
- Ramp metering is not used directly to deter drivers making short trips but can have the added benefit that it will discourage drivers who do make short trips from using the motorway network.

SERVICE BENEFIT RADAR



EUROPEAN DIMENSION

Harmonisation relating to ramp metering are focussed on end-user aspects (drivers and operators), ensuring drivers across Europe encounter similar conditions (including “look and feeling”) when driving in ramp metered areas. This includes:

- Pre-signing on the on-ramp
- Differentiation between ramp metering signal heads and regular road junction signal heads
- Use of GREEN-AMBER-RED signal cycle

Owing to the heterogeneity of existing deployments and traffic management procedures, technical aspects, such as specific algorithms and detecting methods are not required to be harmonised.

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List of abbreviations

ANPR	Automatic Number Plate Recognition
AWV	Administratie Wegen en Verkeer, Flemish Roads and Traffic Administration
DG	Deployment Guideline
DGT	Dirección General de Tráfico, The Directorate of Traffic , Spain
DIRIF	Direction Interdépartementale des Routes d'Ile de France
DoT	Department of Transport
EURAMP	EUropean RAmp Metering Project
EW	EasyWay
EU	European Union
FHWA	Federal Highway Administration
GUI	Graphical User Interface
HA	Highways Agency
HGV	Heavy Goods Vehicle
ICT	Information and Communications Technology
ITS	Intelligent Transport Systems
NRW	Nordrhein-Westfalen
OE	Operating Environment
RFC 2119	Request For Comments 2119
RM	Ramp Metering
RWS	Rijkswaterstaat
TEMPO	Trans-European intelligent transport systems Projects
TERN	Trans European Road Network
TTS	Total Time Spent
UML	Unified Modelling Language
VMS	Variable Message Sign
FR<#>	Functional requirement <number>
OR<#>	Organisational requirement <number>
TR<#>	Technical requirement <number>
CL&FR<#>	Look and feel requirement <number>
LoSR<#>	Level of Service requirement <number>

1 Introduction

1.1 The concept of the EasyWay Deployment Guidelines

1.1.1 Preliminary note

This document is one of a set of documents for the EasyWay project, a project for Europe-wide ITS deployment on main TERN corridors undertaken by national road authorities and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders. It sets clear targets, identifies the set of necessary European ITS services to deploy (Traveller Information, Traffic Management and Freight and Logistic Services) and is an efficient platform that allows the European mobility stakeholders to achieve a coordinated and combined deployment of these pan-European services.

EasyWay started in 2007 and has since established a huge body of knowledge and a consensus for the harmonised deployment of these ITS services. This knowledge has been captured in documents providing guidance on service deployment - the EasyWay Deployment Guidelines.

The first iteration of the Deployment Guidelines mainly captured best practice. This strongly supported service deployment within EasyWay by:

- making EasyWay partners in deployment aware of experiences made in other European deployment programmes.
- helping to avoid making errors others had already made
- reducing risk and facilitating efficient deployment by highlighting important and critical issues to consider

Meanwhile, this best practice has already successfully contributed to ITS deployments across Europe. It is now possible to take the logical next step and actually start recommending those elements of service deployment that have proven their contribution to both the success of the local deployment, as well as the European added value of harmonised deployment for seamless and interoperable services.

1.1.2 Applying Deployment Guidelines – the “comply or explain” principle

The step from descriptive best practice towards clear recommendations is reflected in the document structure used for this generation of the Deployment Guidelines. Apart from introduction and the annexes that cover specific additional material, the Deployment Guidelines consist of two main sections:

Part A – this part covers the recommendations and requirements that are proven to contribute to successful deployment and have been agreed by the EasyWay partners as elements that should be part of all deployments of this particular service within the scope of EasyWay. Thus, the content of this section is prescriptive by nature. EasyWay partners are expected to ensure that their deployments are compliant with the specifications in this section. Wherever concrete circumstances in a project do not allow these recommendations to be followed fully, EasyWay partners are expected to provide a substantial explanation for the need for this deviation. This concept is known as the “comply or explain” principle.

Part B – this part offers an opportunity to provide more valuable but less prescriptive information. Supplementary information may be contained including – but not limited to – regional/national examples of deployment and business model aspects like stakeholder involvement or cost/benefit analysis results.

1.1.3 Use of Language in Part A

It is essential for every prescriptive document to provide specifications in a well-defined and unambiguous language. There are various definitions that clarify the use of particular words (such as those listed below) within their prescriptive texts.

For the purpose of the EasyWay Deployment Guidelines, the well-established provisions of the RFC 2119 (http://www.ietf.org/rfc/rfc2119.txt, see (1)) are used, which is used to specify the basic Internet standards:

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

An overview of the keywords, their meaning and the possible answers in the context of part A provides the following table. In general the keywords in brackets are possible, but their use is not recommended in order to avoid confusion which may arise as a consequence of different common linguistic usage of the terms in the different EU member states.

Requirement wording	Meaning in RFC 2119	Meaning in EasyWay	Possible checklist answers
MUST (REQUIRED, SHALL)	the definition is an absolute requirement	there may exist insurmountable reasons to not fulfill (e.g. legal regulations…)	**fulfilled: yes** **or** **Fulfilled: no - explanation of insurmountable reasons**
MUST NOT (SHALL NOT)	the definition is an absolute prohibition		
SHOULD (RECOMMENDED)	there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.	The Definition is very close to a "MUST", "MUST NOT" Meaning in EasyWay conform to RFC 2119	**fulfilled: yes** **or** **Fulfilled: no - with explanation**
SHOULD NOT (NOT RECOMMENDED)	there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label		
MAY (OPTIONAL)	The item is truly optional. One deployment may choose to include the item because of particular local circumstances or because it is felt to deliver a special added value	Meaning in EasyWay conform to RFC 2119	**fulfilled: yes - with explanation** **or** **Fulfilled: no**

Table 1: Part A - requirement wording

Note: the capitalisation of these keywords that is frequently used in IT standards is not recommended for EasyWay Deployment Guidelines.

The use of this 'requirements language' allows the direct transfer of the requirements stated in part A to a compliance checklist.

The following paragraph gives an example for a functional requirement:

<u>Functional requirement:</u>

- **FR2:** Data and information collected by both automatically and non-technical sources must be based upon both a consistent geographic reference model and a time validity model, which both **must** be part of data description.

Beneath "Requirement" a new semantic element "Advice" is proposed for part A, which has not the character of a hard requirement but of a "recommendation" and hence must not be listed in the compliance checklist. "Advice" is not immediately related to the three pillars of ITS-service harmonization (Interoperability, Common look & feel, Quality criteria) but to "inner features" of an ITS-service. Nevertheless such an element delivers a European added value and hence should be addressed by the deployment guidelines. The notation for using the advice element in the text is as follows:

<u>Organisational advice:</u>

- Clear definitions of organisational aspects are a crucial precondition for the successful implementation of a "Forecast and real-time event information service" and should be documented and accepted of all involved parties/partners in form of a Common partner arrangement/MoU - Memorandum of understanding, which establishes the details of co-operation.

1.2 ITS-Service Profile

1.2.1 ITS-Service Strategy

1.2.1.1 General Service Description

During peak or congested periods on the motorway, the addition of traffic from on-ramps causes vehicles to break or change lanes giving rise to higher occupancy and lower headways. Shorter headways cause drivers to reduce their speeds; resulting in a sustained loss of throughput.

This speed reduction often causes following vehicles to brake, resulting in a propagation wave of slowing vehicles that travels back along the line of traffic on the main carriageway upstream of the on-ramp. This speed adjustment can occur over a distance of up to 2 km prior to the on-ramp. During this time more vehicles will be attempting to join the main carriageway, and if vehicles continue to join, the speed on the main carriageway will fall to a point where flow breakdown occurs. Additionally, during peak periods when congestion is increased there may also be a higher risk of accidents.

Ramp metering (RM) is implemented via the installation of traffic signals on the on-ramps which regulate the flow of traffic joining the motorway during peak or congested periods. It does this by controlling the discharge of vehicles from the on-ramp, holding vehicles back and breaking up on-ramp platoons, thus reducing the interference of merging vehicles and helping maintain the flow of traffic on the main carriageway.

The traffic signals are generally operated in dependence of the currently prevailing traffic conditions on both the main carriageway and the on-ramps.

1.2.1.2 What is the Vision?

From the operational perspective the vision for ramp metering is effective control of on-ramp vehicles during congested periods, resulting in fewer in accidents and maximised mainline output. This on-ramp control has minimal (and controlled) impact on the adjacent road network.

For drivers, encountering ramp metering in an unfamiliar area (i.e. another country) would not be cause for anxiety as it has a similar look and feel; the driver knows what to expect and how to proceed. Drivers would accept that the small delay experienced on the on-ramp will mean safer, less congested conditions on the motorway.

1.2.1.3 What is the Mission?

The purpose of ramp metering is to prevent or delay the onset of flow breakdown on the main carriageway, maximising throughput, without disrupting the urban road network. This is achieved by:

- Regulating the flow of additional traffic onto the motorway that, if unregulated would trigger flow breakdown / lead to critical bottlenecks;
- Monitoring and managing the traffic flow on the on-ramp, achieving even distribution, to avoid large platoons of vehicles entering the main carriageway and causing flow breakdown;
- Reduction or avoidance of congestion spillback to the adjacent urban traffic network or to other merging motorways.
- Ramp metering can also be used to deter drivers making short trips on the motorway, and use the urban roads instead. Ramp metering is not used directly to deter drivers making short trips but can have the added benefit that it will discourage drivers who do make short trips from using the motorway network. Coordination with other road operators, urban authorities etc, is required.

Pre-signs and distinct signal heads are used to indicate to drivers there is ramp metering in operation.

1.2.1.4 EasyWay harmonisation focus

Harmonisation relating to ramp metering are focussed on end-user aspects (drivers and operators), ensuring drivers across Europe encounter similar conditions (including "look and feeling") when driving in ramp metered areas. This includes:

- Pre-signing on the on-ramp
- Differentiation in appearance between ramp metering signals and regular road junction signal heads
- Use of GREEN-AMBER-RED signal cycle

Due to heterogeneity of existing deployments and traffic management procedures, technical aspects, such as specific algorithms and detecting methods are not required to be harmonised.

1.2.1.5 Distinctiveness from other ITS-services

Ramp metering is a traffic management measure designed to reduce the disruption from platoons of vehicles entering the main carriageway at on-ramps. The measure is characterised by:

- mainline and ramp traffic monitoring
- regulation of the flow of traffic entering the main carriageway via traffic signals positioned on the on ramp
- the use of algorithms to determine the required flow and thus the signal timings

Relevant complementary information, not included within this Deployment Guidelines and covered by other DGs, is:

- *TIS Pre-trip and On-trip Traveller Information* – Information dissemination techniques employed by other motorway management functions may be used to inform to motorists en-route or pre-trip about the current operational status of ramp meters.
- *TMS-DG05_08 Incident Warning and Management* – Surveillance and incident warning systems can be used to determine and adjust ramp operational conditions. Data from detectors on the ramp or main carriageway can be used to adjust ramp metering parameters. CCTV can be used to verify that ramp meters are functioning optimally or to observe the effects of ramp metering on traffic flow.
- Incident management procedures and plans may be integrated with ramp metering to improve safety and restore operations on ramps and the main carriageway in a more timely fashion. Through active management of ramp meters, and other devices, operators may monitor motorway conditions during emergencies and clear on-ramp queues to allow a faster response to emergencies.
- *TMS-DG04 Hard Shoulder Running and TMS-DG01 Dynamic Lane Management* - Hard shoulder running and dynamic lane management may be used to direct motorists to use certain lanes and to merge out of other lanes. Ramp management strategies can be used in conjunction with lane use controls to manage the demand, leading to motorway sections where lane use controls are active.

1.2.2 Contribution to EasyWay Objectives

1.2.2.1 Service radar

Ramp metering evaluation objectives, methodologies and methods of data collection differ from country to country. The figure below, Figure 1, shows a basic graphical relationship between ramp metering and the EasyWay objectives. Network efficiency and safety are the main benefits of the service; this achieved by:

- Improved merging behaviour and less lane changing leads to a reduction in accidents
- Increasing mainline traffic speed, reducing congestion and making travel times more reliable
- Smoother traffic flows can lead to a reduction in emissions

The graph below provides a quantification of the added value of "Ramp Metering" services regarding the three main objectives of EasyWay which are: safety, efficiency and environment. This is based on an expert view and not on specific scientific analysis.

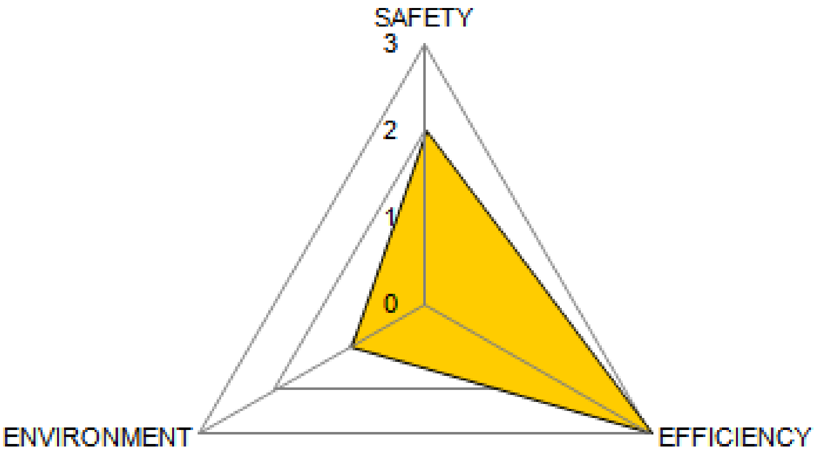


Figure 1: Service radar "Ramp Metering"

1.2.2.2 Safety

Improvement in the merging behaviour of traffic has a positive impact on traffic safety due to less lane changing. The breakup of merging slip road vehicle platoons reduces the incident and congestion potential on the main carriageway as well as the frequency of accidents. The long-term impact analysis of existing and comparable ramp metering systems confirms the positive effect on road safety due to the confirmed drop in the number of recorded accidents. In Germany, evaluation has shown that ramp metering can lead to reductions in accidents of up to 40%[1].

1.2.2.3 Environmental impact

Mixed results have been obtained relating to the environmental impacts of ramp metering. Currently there is little conclusive evidence of the environmental benefits or dis-benefits of ramp metering. It is believed that smoother traffic flow resulting in less speed variation on a metered motorway can lead to reduction in emissions and fuel savings; although some studies have found fuel consumption and emissions have risen following ramp metering implementation. The results available relating to environmental impact are as follows:

- Twin Cities, Minnesota – emissions reduced by 1,160 tons (1,052 tonnes) / year
- Twin Cities, Minnesota – fuel use rose by 5.5 million US gallons (20.8 million litres) / year
- Long Island – 6.7% increase in nitrogen oxide emissions
- Long Island – 17.4% reduction in carbon monoxide
- Long Island – 13.1% reduction in hydrocarbons[2]
- Denver Colorado – emissions reduced by 24%
- Portland Oregon – fuel use fell by 540 US gallons (2,040 litres) per weekday[3]
- Delft, The Netherlands – emissions reduced by 2%

[1] EURAMP Deliverable 6.3 (http://www.euramp.org/) Project Number 507645

[2] Twin Cities Ramp Metering Evaluation – Minnesota Department of Transportation, February 2001(this report was the source for Long Island and Minnesota results)

[3] Assessing the Benefits and Costs of Intelligent Transportation Systems: Ramp Meters UCB-ITS-11-19 California PATH Research Report Seungmin King, David Gillen 1999 (Denver and Oregon results)

1.2.2.4 Network efficiency

Network efficiency impacts include the reduction of network travel time variability and increased throughput by eliminating the stop-go behaviour associated with congestion. Ramp metering significantly improves the traffic flow on the main carriageway therefore reducing travel times/costs and operating costs. There are several studies related to the impact of ramp metering on traffic flows:

- In Germany, traffic speed increases of up to 35% and up to 50% less congestion[4] were experienced.
- The Highways Agency (HA) found that the overall increase in peak period traffic flows observed on the mainline after the installation of ramp metering varies by site with individual increases in traffic flow ranging from 1 – 8%. Despite the increases in traffic flow the implementation of ramp metering has resulted in downstream traffic speed increasing by between 3.5% and 35%[5].
- The HA found an average journey time saving for mainline traffic of 13% across all sites evaluated. The average on-ramp delay per vehicle with ramp metering operational ranged from 15s to 78s, however the sites with the highest delay on the on-ramp in general also delivered the highest benefit on the main carriageway.
- In the Netherlands an increase of capacity of 0-5% has been measured; speed on the main carriageway showed increases in the range of +4 km/hr to +30 km/hr.
- The EURAMP Project impact analysis found ramp metering could improve Total Time Spent (TTS) in the system; this includes time on motorway, on ramps, travelling and waiting time.

Detailed evaluation results from several sites and testing various algorithms can be found in the European Ramp Metering Project EURAMP Deliverable 6.3.

1.2.3 Current Status of Deployment

Ramp metering has been installed in several countries in Europe, including the United Kingdom, Germany and the Netherlands. Several evaluations have been conducted for deployments and test sites, some of the main results from ramp metering evaluations are noted above.

These deployments allow the main advantages/disadvantages of this traffic management service to be determined from both the users and road traffic manager perspectives. Further details relating to national ramp metering deployments are included in the Section 3.3.

1.2.4 European Dimension

There are numerous aspects of ramp metering that differ from one installation to another across EasyWay regions. These include the type and number of detectors, control strategies, signing etc.

Harmonisation relating to ramp metering should be focused on end-user aspects ensuring drivers across Europe encounter similar conditions when driving in ramp metered areas. This topic was initialised in the CENTRICO Ramp Metering Synthesis Project[6]. This includes:

- Pre-signing on the on-ramp – see Section 2.5 Common Look & Feel
- Ramp metering signal heads - see Section 2.5 Common Look & Feel
- Signal Cycle - see Section 2.5 Common Look & Feel
- Layout of the system – installation of low level (1000mm - 2500mm) and in some cases high traffic signals (around 5500mm or overhead). These are usually either gantry mounted, or mounted on passive poles at either side of the slip road with high and low signal heads on each.

[4] German North Rhine Westphalia Ramp Metering, 2006 (Rene.Usath@mbv.nrw.de)

[5] HA Ramp Metering Summary Report, 2007; evaluation of the first 30 ramp metering sites

[6] CENTRICO Ramp Metering Synthesis, 2001 (www.centrico.org/documents/RAMP%20METERING%20SYNTHESIS.pdf)

The exact positioning of detectors, road markings, traffic signals and signs is generally undertaken following the individual road organisations and national regulations, using their specific rationale / guidance.

- User information – aimed at increasing end-user acceptance. When first deploying a ramp metering installation a formal public information campaign should be in place, clearly explaining the benefits of ramp metering, including examples and quantified benefits. This would aid gaining higher acceptance and compliance of ramp metering schemes, see Section 2.3 Organisational Requirements.

Surveys among road users show that the majority of drivers feel safer when accessing a motorway in the area of a ramp metering system, as they are no longer forced by following drivers to merge without adequate safe distance or without sufficient time to find a suitable gap in the traffic.

Technical aspects, such as specific algorithms and detecting methods do not require harmonisation; and it should be noted that harmonisation of existing installations could be possible but would have significant time, cost and effort implications.

2 Part A: Harmonisation Requirements

2.1 Service Definition

Ramp metering is implemented via the installation of traffic signals on the on-ramps which regulate the flow of traffic joining the motorway during peak or congested periods. It does this by controlling the discharge of vehicles from the on-ramp, holding vehicles back and breaking up on-ramp platoons, thus reducing the interference of merging vehicles and helping maintain the flow of traffic on the main carriageway. The traffic signals are generally operated in dependence of the currently prevailing traffic conditions on both the main carriageway and the on-ramps.

2.2 Functional Requirements

2.2.1 Functional Architecture

The following figure shows the typical functional architecture:

<u>Functional Architecture</u>

Monitoring of traffic situation on main carriageway (upstream and downstream of access point) and on-ramp; algorithms to monitor and control the release rate; and traffic signals to release the on-ramp traffic; Figure 2 below shows a simple situation:

Analysis of traffic situation → Algorithms → Signals and release of traffic

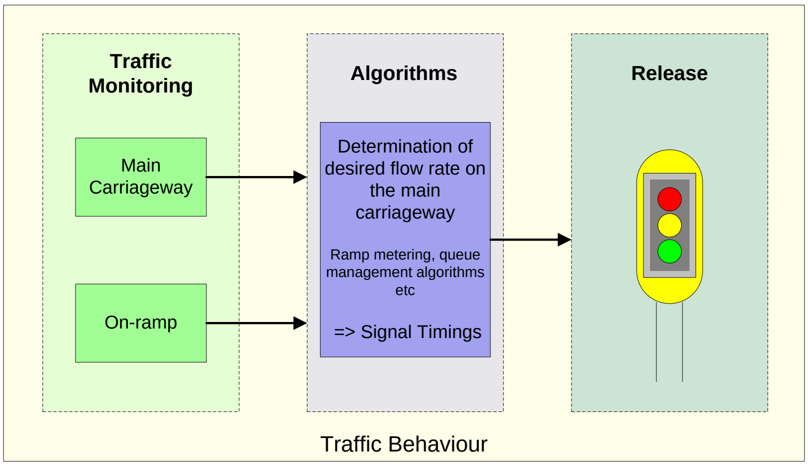


Figure 2: Typical Functional Architecture

Cooperation with the adjacent network operators and their traffic control systems also need to be considered where appropriate.

2.3 Organisational Requirements

Organisational requirements:

- **OR1:** Inter- and Intra-Agency Coordination - agreements and cooperation **should** be established between all authorities / operators when implementing ramp metering from one network to another (e.g. city authority urban roads to motorways or from one regional operator to another).
- **OR2:** Public Information Campaign – a formal public information campaign **should** be undertaken in areas where ramp metering is new.

2.4 Technical Requirements

2.4.1 ICT Infrastructure Requirements

Technical advice:

- System Architecture

It is advised that a 3 level system architecture is considered for ramp metering. The architecture can consist of the following elements, Figure 3:

- External facilities: can consist of detectors, video cameras, VMS and information panels, permanent illuminated signs, barriers, traffic signals

- Local control: local control station with data input/ output devices, connection to power supply and data communication

- Area control: control (sub) centre is hierarchically structured and consists of optional control centre, control sub-centre and local control station.

Further information on this can be found in 3.1.4.

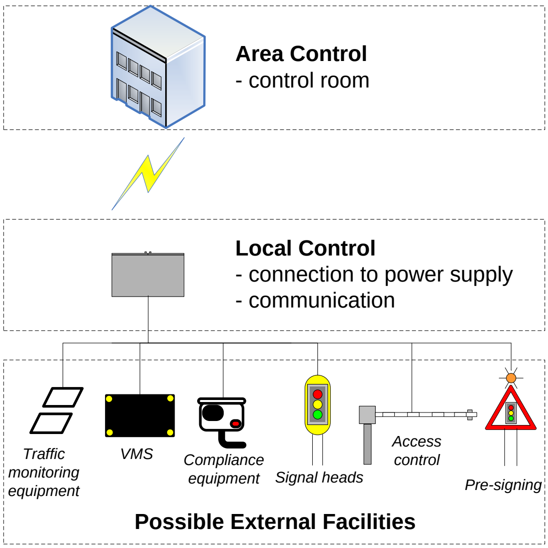


Figure 3: System Architecture

- Traffic Monitoring

The devices and methodologies for traffic data collection are not covered by this Deployment Guideline. They depend amongst others on the particular used data collection system and are left to the operator to select; provided a reasonable level of accuracy and reliability is guaranteed.

Usually there are vehicle detectors on the on-ramp and main carriageway to measures traffic conditions:

- Main carriageway detectors: the location of upstream and downstream detectors depends on the ramp metering algorithm requirements. In some cases motorways are already equipped with a high density of traffic detectors (i.e. every 500m) or another real-time estimation system providing information on the current main carriageway traffic conditions. If this is the case no additional detectors are needed.

- On-ramp detectors: these detectors are needed for queue management and traffic light operation. For queue management purposes the number and location depends again on the chosen ramp queue management strategy.

- Local Controller / Outstation

The outstation provides control functionality and calculates release rates and the resulting signal timings based on traffic flow. The outstation can be equipped with a remote communications so that administrative functions can be carried out remotely.

Ramp metering controllers typically operate in the following states:

- Standby mode – ramp metering lights are switched off
- Switching on – turns the system on
- Steady state – state of "normal operation"
- Queue override – prevents congestion on the local network; higher release rate
- Switching off – turns the system off
- Fail-safe mode - prevents or mitigates unsafe consequences of the system's failure; depending on the situation this could be switching off or fixed-time control.

The above states are described in many documents, EURAMP Deliverable 7.5 for example. The controller activates the ramp metering lights in accordance with the algorithms and contains an interface to traffic detectors (on the main carriageway and on-ramps).

The specific combination of switching criteria and threshold values depends on the traffic conditions and control installation; i.e. the system may only be active as long as it is required by the traffic situation; when the traffic situation eases, the system goes into standby mode.

- Ramp Metering Algorithms

Appropriate RM algorithms are used to monitor the traffic conditions and regulate traffic flow on the on-ramp onto the main carriageway. It is recommended that all algorithms are configurable.

- Fallback / Failsafe

If lights or local controller fails, it is recommended that the central coordinated strategy be able to continue its operation and coordination of available ramps taking to account of the missing ramp. If there are communication failures to the local controller the local controller should automatically switch to fail-safe mode.

- Communications

Ramp metering systems require power supplies and telecommunication systems such as fibre optic cable or telephone to provide links to the traffic operations centres and the signal controllers; remote communications are becoming more commonly used (sufficient bandwidth is required).

- Central Control System
  - Operational Graphical User Interface (GUI): this is recommended to allow easy inspection, maintenance and repair of local signal controllers. A traffic operations centre GUI should allow for easy access to parameters, variables and display during operation. At times, analysis of historic variables may be required (i.e. in cases of errors or reconstruction of previous scenarios) and so archiving facilities are advantageous.
  - Computing Devices: the necessary computing devices may be centralised or decentralised depending on the adopted architecture. It can be of benefit if devices selected are easily scalable and have sufficient computing power to allow for future additions, updates and future strategy changes.

2.4.2 Standards and Agreements: Existing and Required

One of the major deliverables of the DATEX II specifications is to offer a toolbox for applying one of the most common IT technologies for data definition, the Unified Modelling Language (UML, ISO/IEC 19501:2005).

The use of DATEX II is required for the service implementation. What makes this so important is that providing one such formal data definition for each service supported by all implementations in EasyWay ensures technical interoperability (“Plug & Play”) because interfaces generated from the same data definition are sure to be able to process the exchanged data.

This integration of the DATEX II profile in the Deployment Guideline provides a solid dimension in terms of service standardisation and harmonisation; this also guarantees the information exchange among traffic managers and the wide dissemination of traffic information and traffic management services thanks to the facilities for providing standardised DATEX II publications to service providers.

Technical requirement:

- **TR1:** Whenever road operators have to exchange data requiring interoperability between two or more different organisations, they **must** enable their system to use DATEX II.

The relevant DATEXII-Profiles[7] are shown below. A "push"-type exchange for safety relevant data would avoid delays in data transmission.

The Ramp Metering service is characterised by the following elements:

- The location of the ramp metering
- The length affected by the measure (in case of the measure is applied on several successive ramp access)

These elements and the ramp metering measure itself must be described in the DATEX II Model as follows:

Location information

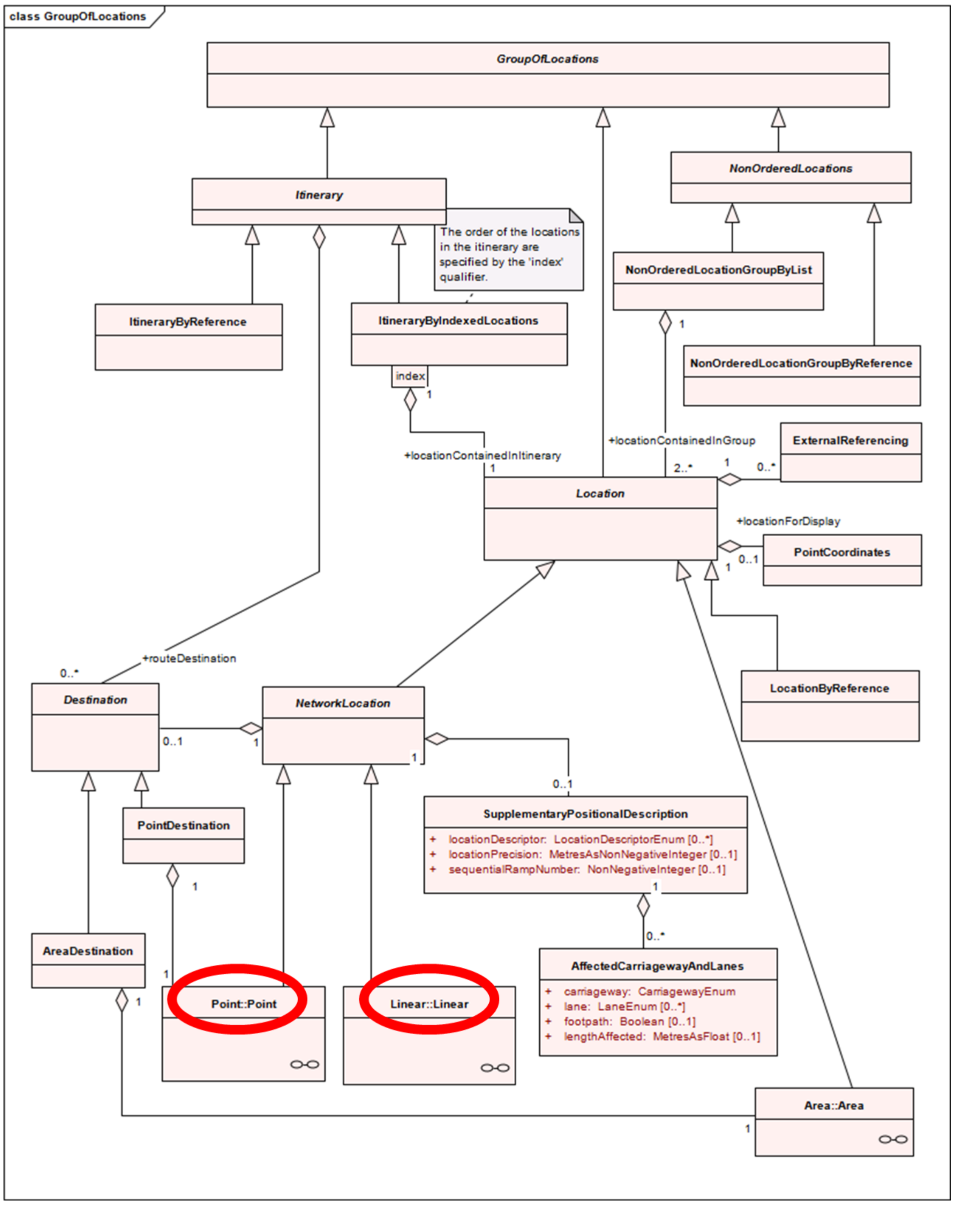


Figure 4: DATEX II Ramp Metering Location Information

[7] DATEX II profiles consist of a set of data elements taken from the overall DATEX model and can include a subset (Schema) of relationships between those elements

The DATEX II model offers various possibilities for describing location. Depending on the ramp metering coordination, the location reference can be considered as a specific point or linearly:

- When the measure is applied on an isolated ramp access, the location referencing is restricted to the Point class.
- When the measure is applied on several successive ramp access (in case of an integrated ramp metering service along a motorway section) the location referencing can be described either by Point class (one point description for each location, or can be described by Linear class (this means the ramp metering measure is operated on a linear section).

Note that for the linear description the **SupplementaryPositionalDescription** feature is needed to define the length of the measure.

<u>Length</u>

Description about the length of the ramp metering service has to be defined with the attribute **lengthAffected**:

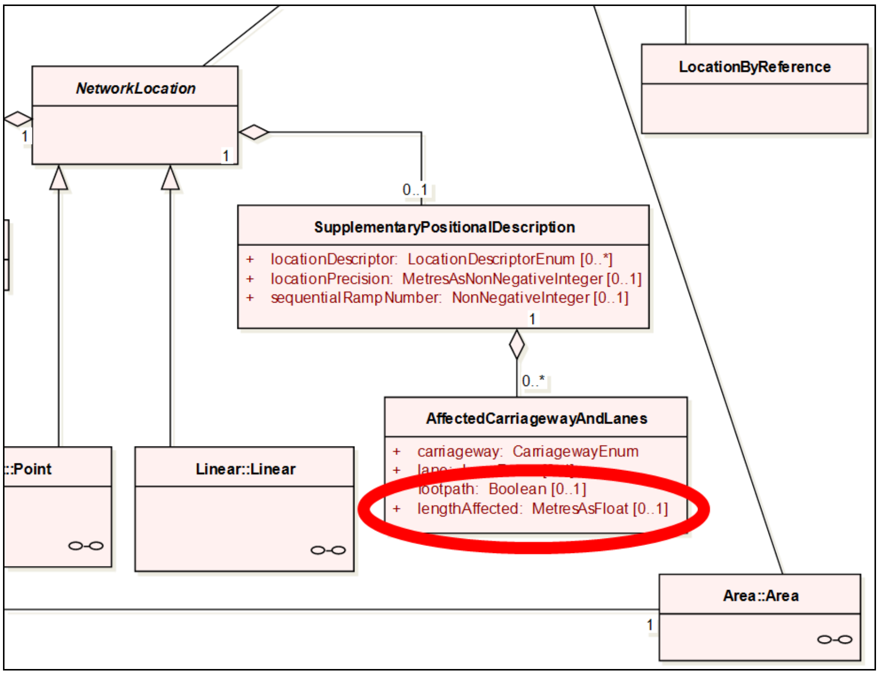


Figure 5: DATEX II Ramp Metering Length of Service

The mapping of information related to Ramp metering service into the DATEX II level A is easy. DATEX II has a dedicated class for this type of information called **GeneralNetworkManagement**. In this class, select the attribute **rampMeteringInOperation** in the **GeneralNetworkManagementTypeEnum**.

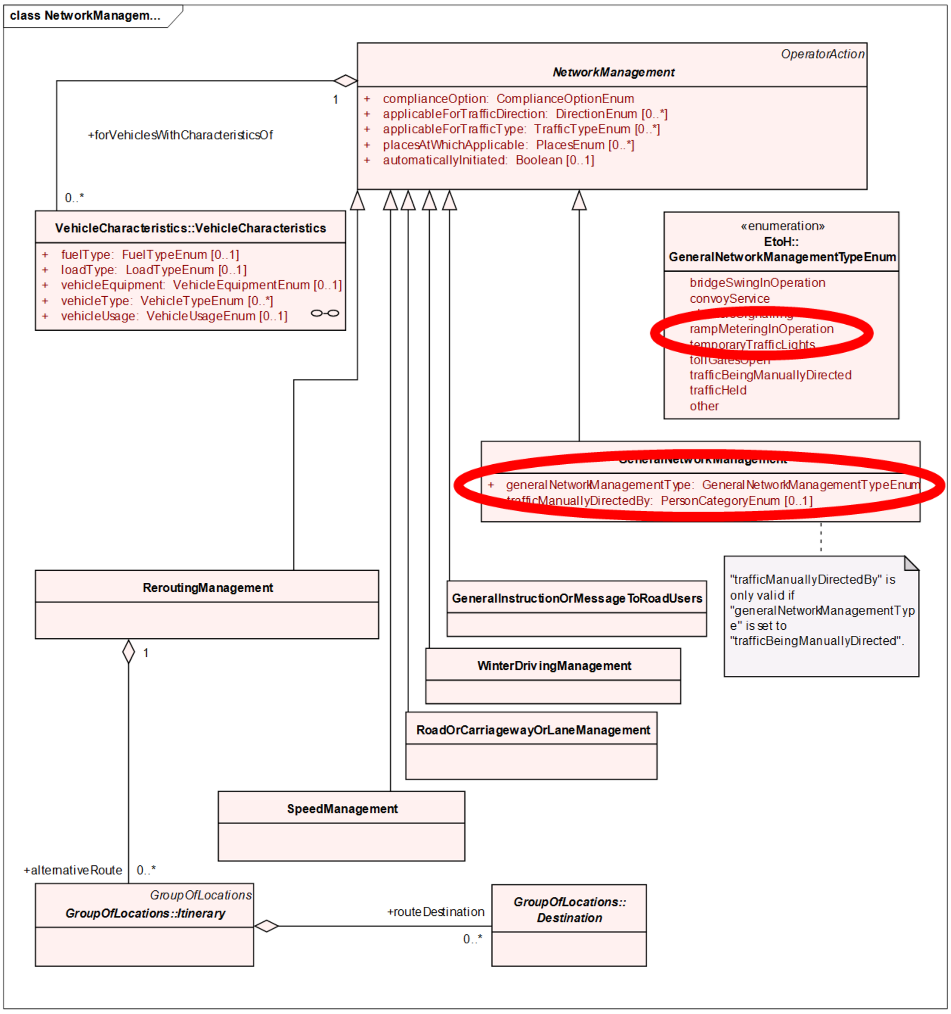
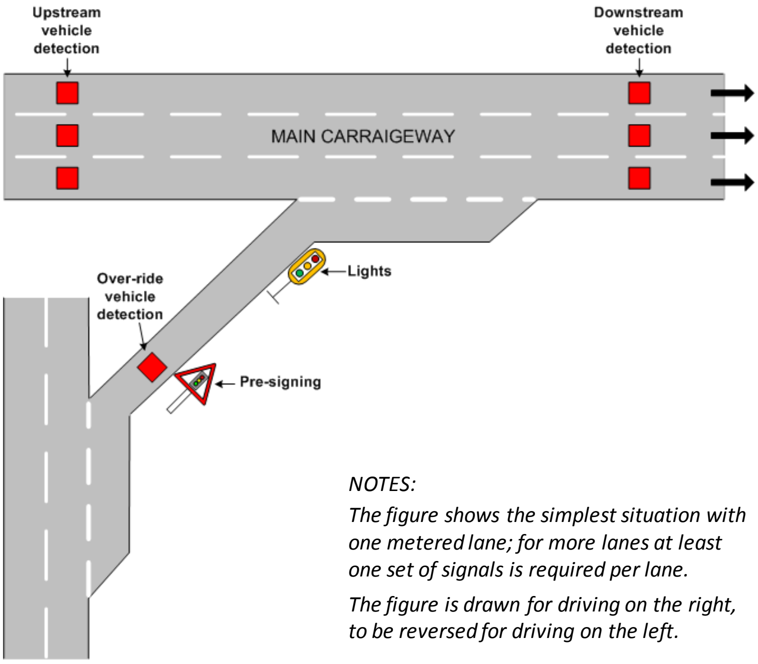


Figure 6: DATEX II Ramp Metering Mapping of Related Information

2.5 Common Look & Feel

Common Look & Feel requirements:

- **CL&FR1:** Ramp metering traffic signals **should** be positioned sufficiently far from the merging point to ensure drivers can accelerate enough to reach the speed of the main carriageway and to maximise the storage space on the on ramp
- **CL&FR2:** Ramp metering traffic signals **should** be installed at the metered on-ramps at a low level to face drivers at the beginning of the queue
- **CL&FR3:** Traffic signals **may** additionally be installed at a high level
- **CL&FR4:** At least one set of traffic signals **should** be installed per lane
- **CL&FR5:** Fixed or variable warning pre-signs **should** be installed on the on-ramp sufficiently upstream of the traffic lights or the on-ramp entrance



NOTES:
The figure shows the simplest situation with one metered lane; for more lanes at least one set of signals is required per lane.
The figure is drawn for driving on the right, to be reversed for driving on the left.

Figure 7: Example Infrastructure

- **CL&FR6:** The display of signs/pictograms on VMS or other end-user devices **should** be in accordance with prevailing national road codes and where applicable be in line with the requirements of the EW-DG for Variable Message Signs Harmonization VMS-DG01:
  - o MS which ratified the 1968 Convention MUST respect the 1968 Convention and SHOULD consider the Consolidated Resolution on Road Signs and Signals (R.E.2);
  - o MS which did sign but not ratify the 1968 Convention SHOULD follow the 1968 Convention and also consider the R.E.2

  It is up to the deploying road operator to ensure that real signs are well and widely understood by the road users

The 1968 Convention states that:

- Warning Signs – equilateral triangle (A^a) / diamond (A^b), as shown in Figure 8.
  Normal sized sign A^a shall measure approximately 0.90m; the small sized sign shall measure not less than 0.60m. Normal sized sign A^b shall measure approximately 0.60m; small sign A^b shall measure not less than 0.40m.

- An example ramp metering warning sign using A^a is shown in Figure 9. Additionally, the words "Ramp Metering" or equivalent in native language are added beneath the warning sign.

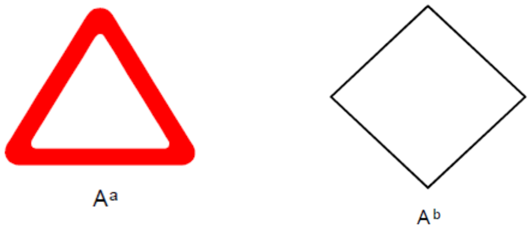


Figure 8: 1968 Convention Warning Signs

Figure 9: Example Ramp Metering Warning

- **CL&FR7:** Ramp metering signals **should** be distinguishable from regular junction signals.

<u>Common Look & Feel advice</u>**:**

- It is advised to install a contrasting yellow shield behind the traffic signals (Figure 10), as used in many European countries.

Figure 10: Yellow backing shield

<u>Common Look & Feel requirements:</u>

- **CL&FR8:** The traffic signals **should** operate a "Green – Amber – Red" cycle
- **CL&FR9:** At locations where ramp metering has a fixed release time to allow a fixed number of vehicles to pass during each release phase; the number of vehicles released **should** be communicated to the driver using a sign; i.e. "X car(s) per green" / "(x) Fahrzeug(e) bei Grün".

2.6 Level of Service Definition

2.6.1 Preliminary remark

The scope of EasyWay is to provide Core European Services to the European road users. These services are harmonized in content and functionality, but also in their availability: The road users shall be able to expect a certain services offer in a specific road environment. In order to provide a basis for the harmonisation process EasyWay needs a tool to define such environments in an agreed manner. This tool is the Operating Environments – a set of pre-defined road environments combining physical layout of the road and network typology with traffic characteristics.

In essence, EasyWay has agreed on a set of 18 pre-defined Operating Environments (OE) where each OE is a combination of three criteria:

- Physical characteristics – Motorways, other 3/4 lane roads or 2-lane roads
- Network typology – Corridor, Network, Link or Critical spot
- Traffic characteristics – Traffic flow and road safety situations (with optional additions)

For more information and details, visit http://www.easyway-its.eu/document-center/document/open/490/ and download the Guidance for Classifying the EasyWay Network into OE ver 1.0.

2.6.2 Level of Service Criteria

Different elements of ramp metering can have different levels of service, Table 2:

Levels of Service Table: Ramp Metering			
Core Criteria	**A**	**B**	**C**
Coverage	Spot coverage	Section coverage	Total route coverage on critical links on the network
Pre-signing	Fixed	Rotating Prism VMS	VMS
Metering Strategies	Fixed-Time	Local Response	Centralised System-Wide

Table 2: Level of Service

The levels show technological advancement in the ITS solutions that can be implemented where appropriate; and can be cross referenced to the EasyWay Operating Environments (see Table 3).

The Levels of Service described here are not intended to indicate that by deploying Level C at all sites there will be improved results over Level B deployments, i.e. Level B is not “better” that Level A. The Levels only indicate advanced ITS technologies or techniques.

The Level of Service selected is closely related to the operating environment (traffic characteristics, level of incidents, road use etc). As stated earlier, ramp metering is highly site specific in nature; i.e. Level A deployments may achieve the desire results in certain circumstances; but in other more complex situations another Level of Service may be more appropriate; see Section 3.1.5.

Using the table above, implementers can select the level of service of each element that is most appropriate; i.e. Level A Pre-signing with a Level 3 Metering Strategy. Greater detail on each element and definition of each level of service is given in Section 3.1.5 and 3.1.6.

Coverage

1: Point coverage – RM is deployed at on-ramps with a specific problem junction

2: Section coverage – RM is deployed at several junction on-ramps on a section

3: Wider route coverage – RM is deployed at on-ramps over longer routes where there are several bottlenecks / critical sections where congestion occurs

Pre-signing

1: Fixed signs - set number of vehicles per green / fixed operation time

2: Rotating prism VMS – allows changes in the number of vehicles per cycle based on current traffic conditions

3: VMS - provides maximum flexibility and can also be used to provide additional information to road users

Metering Strategies

The sophistication and size of a ramp metering system should reflect the amount of desired improvement and existing conditions. Ramp metering strategies can be based on fixed metering rates (historical), real-time data, or predicted traffic demand. Strategies can be implemented to optimise conditions locally or system-wide. Each control mode has an associated hardware configuration. If ramp control is linked at several junctions there is greater overall equity. Distinguished by their responsiveness to prevailing traffic conditions, metering systems fall into three categories:

1: Fixed Time Operation

2: Local Traffic Responsive Operation

3: Centralised System-Wide Traffic Responsive Operation

More detailed information is provided in Section 3.1.5.

2.6.3 Level of Service Criteria related to Operating Environment

As noted earlier, EasyWay has agreed on a set of 18 pre-defined OEs, Table 4, where each OE is a combination of three criteria as described in 2.6.1.

The Level of Service to Operating Environment mapping table does not imply any obligation to deploy ITS services. However if services are deployed they should comply with the table.

These requirements apply only to deployments to be carried out by EW or its successor process in 2013 or later on the OE in question.

Level of Service requirement:

- **LoSR1:** Given that pre-deployment surveys / evaluations provide the necessary evidence to proceed with the deployment of the ITS-service "Ramp metering", the minimum and optimum LoS **should** respect the Level of Service to Operating Environment mapping table.

TMS -DG03 **RAMP METERING** Criteria for the Levels of Service			**EasyWay OPERATING ENVIRONMENT**																	
			C1	T1	T2	T3	T4	R1	R2	R3	R4	R5	R6	R7	R8	S1	S2	N1	N2	P1
Coverage	C	Route																	O	O
	B	Section	O			O	O							O	O		O			
	A	Spot	M			M	M							M	M		M		M	M
Pre-signing	C	VMS	O																	O
	B	Rotating Prism VMS				O	O							O	O		O		O	
	A	Fixed	M			M	M							M	M		M		M	M
Metering Strategies	C	Centralised System-Wide	O																	O
	B	Local Response				O	O							O	O		O		O	
	A	Fixed-Time	M			M	M							M	M		M		M	M

Recommendations for LoS per OE: M Minimum LoS recommended O Optimum LoS recommended

Table 3: Level of Service to Operating Environment mapping table

OE	Explanation
C1	critical spots, local flow-related traffic impact and/or potential safety concerns
T1	motorway (link), no flow-related traffic impact and no major safety concerns
T2	motorway (link), no flow-related traffic impact, potential safety concerns
T3	motorway (link), seasonal or daily flow-related traffic impact, no major safety concerns
T4	motorway (link), seasonal or daily flow-related traffic impact, potential safety concerns
R1	two-lane road (link), no flow-related traffic impact, no major safety concerns
R2	two-lane road (link), no flow-related traffic impact, potential safety concerns
R3	two-lane road (link), seasonal or daily flow-related traffic impact, no major safety concerns
R4	two-lane road (link), seasonal or daily flow-related traffic impact, potential safety concerns
R5	three-/four-lane road (link), no flow related traffic impact, no major safety concerns
R6	three-/four-lane road (link), no flow related traffic impact, potential safety concerns
R7	three-/four-lane road (link), seasonal or daily flow related traffic impact, no major safety concerns
R8	three-/four-lane road (link), seasonal or daily flow related traffic impact, potential safety concerns
S1	motorway corridor or network, at most seasonal flow-related impact, possibly safety concerns
S2	motorway corridor or network, daily flow-related traffic impact, possibly safety concerns
N1	road corridor or network, at most seasonal flow-related traffic impact, possibly safety concerns
N2	road corridor or network, daily flow-related traffic impact, possibly safety concerns
P1	peri-urban motorway or road interfacing urban environment, possibly safety concerns

OE type	Number	Flow-related traffic impact				Potential safety concerns	
		NO	SEASONAL	DAILY		NO	YES
Critical spots							
C	1		X	X	and/or		X
Motorway links							
T	1	X			and	X	
	2	X			and		X
	3		X	X	and	X	
	4		X	X	and		X
Road links							
R	1	X			and	X	
	2	X			and		X
2	3		X	X	and	X	
lanes	4		X	X	and		X
R	5	X			and	X	
	6	X			and		X
3 or 4	7		X	X	and	X	
lanes	8		X	X	and		X
Motorway corridor or network							
S	1		X		and		(X)
	2			X	and		(X)
Road corridor or network							
N	1		X		and		(X)
	2			X	and		(X)
Peri-urban motorway or road							
P	1				and		(X)

Table 4: Legend - EasyWay Operating Environments for Core European ITS Services

3 Part B: Supplementary Information

EasyWay Deployment Guidelines are twofold:

- *Part A elaborates on the content of the ITS service addressed, including the entire deployment framework including Requirements and Levels of Services.*
- *Part B is an appendix of educational content. Its objective is to illustrate part A with examples and feedback from deployments in the field.*

This lively chapter is subject to continuous development and update. It consists in a database of national practices and experiences which, as cross-fertilisation material, can benefit any road operator in Europe.

Bearing in mind the cyclic nature of the elaboration of EasyWay Deployment Guidelines, one can assume that the first edition of the 2012 Guidelines will not yet include users' experience on its content. Forthcoming ITS deployments based on part A of this Deployment Guideline will generate feedback which will in-turn be integrated into the next revised version of part B.

3.1 Ramp Metering - Additional Information

Part B offers an opportunity to provide valuable but less prescriptive information, through an educational approach. Such supplementary information may contained – but is not limited to – regional/national examples of deployment and business model aspects like stakeholder involvement or cost/benefit analysis results

3.1.1 Conditions for the Deployment

Deployment can be initiated by a road operator looking for a solution to a particular congestion problem or a major ramp metering implementation scheme, Table 5 provides guidance on relevant characteristics:

Characteristics	Considerations
Physical Layout	• Sufficient storage space on the on-ramp is required (storage space = length of feeder road to the start of the merge) • Adequate acceleration distance to the mainline merge point – if this is limited it may not allow all types of vehicles to reach the mainline speed and enter safely. This is especially important for HGVs or if the on-ramp has significant slope • Limited sight distance caused by road curvature and vegetation may require additional advanced warning of ramp metering operation
Safety	• High frequency of accidents within the merging area of an access point • Safety should always be given the highest priority. Safe speeds for ramp metering operation should always be implemented; with designers considering any speed characteristics of the road (e.g. any mandatory speed limits).

Appropriate Network Conditions	• Section related congestion and/or accident development on the upstream segment of the access point is considerably higher than comparable mean values • High on-ramp traffic flow with associated high mainline flow, to ensure it has an impact on the main carriageway; but if demand is too high ramp metering queue protection will have to prevent tailbacks interfering with traffic on neighbouring / feeder roads by: • apply a short cycle; or • setting the signals to green[8]; or • switch off smoothly • Merging /weaving traffic around junctions • The conditions on the adjacent network need to be examined if ramp metering will impact upon it; cooperation with the adjacent network operators and their traffic control systems where appropriate
Truck / HGV	• Acceleration distance and on-ramp ascents (as described above) are considerations • HGVs can be given priority using dedicated lanes – this can provide safety benefits and improve freight mobility
Environment	• Local environmental conditions should be considered: • Trade off between possible increased queuing at on-ramps and increased free-flow
Weather	• Motorway capacity differences become more pronounced in adverse weather conditions: • Traffic responsive control strategies will adapt better to changing conditions (such as weather related congestion) than fixed time strategies

Table 5: Ramp metering conditions for deployment

3.1.2 Limitations of Ramp Metering

There are some congestion problems where ramp metering systems may not provide effective benefits. These situations typically occur when:

- Flow from the on-ramp is low compared to main carriageway flow (there may still be benefits of implementing in this instance but results may not be as positive compared to high on-ramp flow situations)
- Flows are too high on slip road; this will be detrimental for both motorway and local roads
- Where there is limited on-ramp storage space and
- The bottleneck problem causes a large congestion problem, where the capacity of the road is greatly exceeded. Large bottleneck problems would typically include a large change in capacity on a road, for example:
    - o Capacity of road reduction due to lane loss
    - o Traffic backing up from an off-ramp and blocking a lane of the main carriageway
    - o Diverging tailbacks at motorway intersections and

[8] It should be noted this is not possible in a 2-lane system

  - Roadwork traffic management / accident causing lane loss.

It should be noted that sufficient storage space on the on-ramp is required to optimise ramp metering. If storage space is limited the following possibilities can be examined:

- Redesign of the on-ramp (e.g. widening) to increase storage
- Motorway–to-motorway ramp metering (as these are usually longer and wider) if urban ramps are relatively short
- Extend ramp queue within adjacent urban streets (may require redesign of urban intersections and associated signal control adjustments)
- Coordination between the ramp metering system and the signal control system upstream to prevent that too much traffic enters the on-ramp
- If coordinated ramp metering is deployed mainstream flow can be reduced by actions at adjacent ramps to avoid ramp overflow where storage space is limited.

3.1.3 Adverse effects of the service

- Local delays to the on-ramp traffic arising from stops in the signals, which may lead to ramp metering being perceived as ineffective.
- On-ramp queues extending onto the intersection with urban roads, impacting on local traffic, if integrated management is not adopted.
- The disadvantages can be avoided or considerably reduced by careful planning and adjustment of the control algorithms. The time losses on the ramp are frequently compensated by savings in time on the main carriageway.

3.1.4 Functional and Information Architecture

System Elements on the Main Carriageway

The necessary system elements on the main carriageway consist of the traffic detector installations required for data collection. In dependence on the control method one or several measuring sites have to be installed for the detection of the traffic flow on the main carriageway, upstream and/or downstream of the access point. The most common form of detector used is the inductive loop, but other detectors can be used provided the data quality is adequate and required parameters are collected accurately and reliably. For example wireless magnetic sensors have been installed by Utah Department of Transport (DoT) at ramp metering sites.

The type of data to be collected is wholly dependent on the chosen control method. Typically traffic volume or lane occupancy, and in some cases mainline average speed, are taken into account for the control method. A distinction into two vehicle classes (passenger car and lorry) is sufficient for almost all known control methods. Any existing traffic data collection equipment that is located in the area of the mainline access point should be used as far as possible for the ramp metering control.

For current control methods all techniques of traffic data collection can be applied which allow determination of traffic data according to lanes and in intervals of one minute or smaller for:

- Traffic volume,
- Traffic speed and
- Occupancy

In some counties traffic volume and traffic speed is collected separately for passenger cars and HGVs.

The following text and figures use the situation in Germany as an example. It should be appreciated that different situations occur in different countries; some different techniques and approaches are also highlighted below.

Detection on the Main Carriageway

Detection on the main carriageway is required to gather mainstream traffic data. Some motorways may have a high density of existing detectors which can be harnessed for the provision of prevailing traffic condition traffic information. If not, the location of detectors is dependent on the requirements of the ramp metering algorithm.

The installation of inductive loops can be expensive and require lane closures; alternatives such as radar could be considered.

System Elements on the On-ramp

The different components that may be located on and around the on-ramp are presented below, Figure 11, with explanations given with regards to their function. In German installations the One-Per-Green strategy is commonly used and is signed for appropriately.

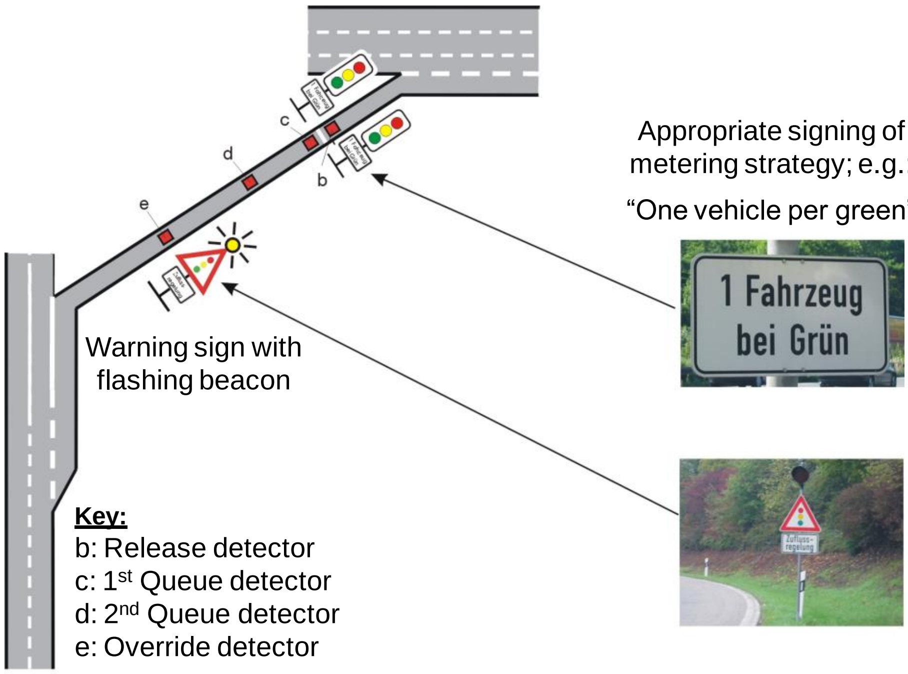


Figure 11: German On-Ramp System Elements

Traffic Detector/Measuring Sites

The exact location and number of detectors varies across Europe and depends on the system configuration and ramp metering algorithm requirements.

Traffic detectors on the on-ramp can be installed for the following purposes:

- Release detector located directly after the stop line to identify when a vehicle has left the stop line and allows dynamic dimensioning of the green phase period. This detector can also be used to identify red light violation and traffic queues that have formed back from the main carriageway;
- Presence detector located directly before the stop line to identify when a vehicle is waiting at the stop line;
- Queue detectors located upstream from the stop line to identify the approximate length of the queue; and
- Override detectors located shortly after the slip road entry to identify on-ramp queuing before it spills back onto the urban road network. When these detectors are triggered the ramp metering control system can ‘flush’ the queue by forcing a high release rate.

The location of these detectors can be seen below in this German example, Figure 12:

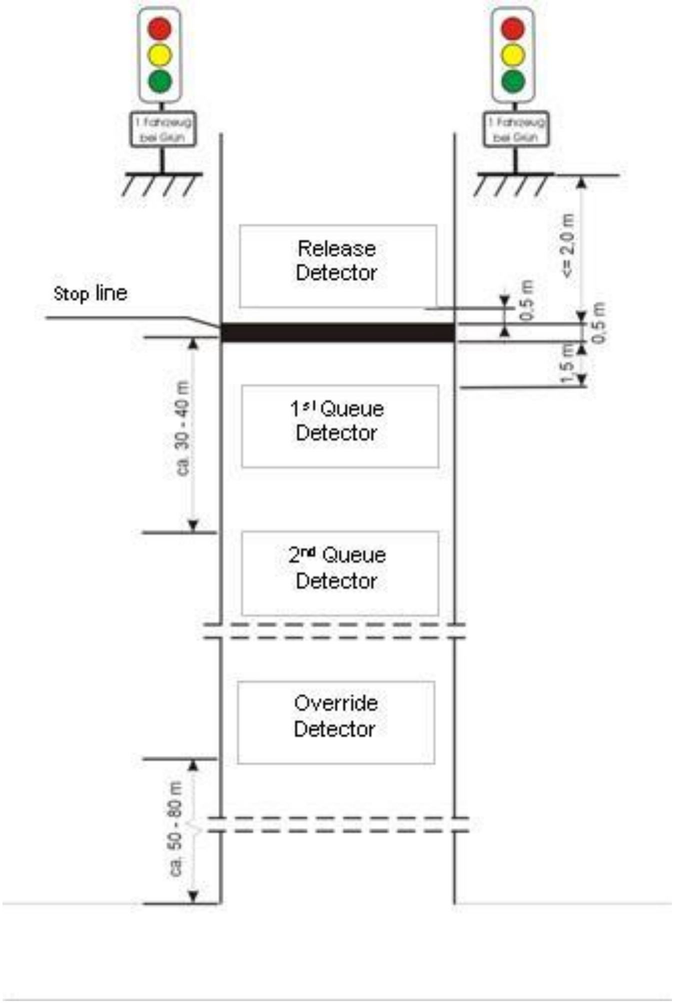


Figure 12: Typical German Signal Head and Detector Plan

As stated above site layouts vary; for example In the Netherlands two detectors are located after the stop line; one to start the amber phase and one to start the red phase; and at la Direction Interdepartementale des Routes d'Ile de France, "la DIRIF", in France only one detector is used to prevent spillback to the adjacent road network.

3.1.5 Metering Strategies

The sophistication and size of a ramp metering system should reflect the amount of desired improvement and existing conditions. Ramp metering strategies can be based on fixed metering rates (historical), real-time data, or predicted traffic demand. Strategies can be implemented to optimise conditions locally or system-wide. Each control mode has an associated hardware configuration. Distinguished by their responsiveness to prevailing traffic conditions, metering systems fall into three categories:

A: Fixed Time Operation - Fixed time or preset operation is the simplest form of metering which breaks up platoons of entering vehicles into single-vehicle entries with a very short period of green time per cycle. This strategy is typically used where traffic conditions are predictable. Although detectors are installed on the on-ramp to actuate and terminate the metering cycle, the metering rate is fixed, based on historically averaged traffic conditions. Fixed time metering can provide benefits associated with accident reductions from merging conflicts, but is less effective in regulating the main carriageway conditions. The hardware configuration for fixed timed ramp metering is the simplest of the three. If a 'one per green' strategy is deployed this should be signed to inform drivers who may be unfamiliar with this.

B: Local Traffic Responsive Operation - For local traffic responsive operation, the metering rate is based on prevailing traffic conditions in the vicinity of the on-ramp. Controller electronics and software algorithms select an appropriate metering rate by analysing occupancy or flow data from on-ramp and carriageway detectors. Traffic responsive systems are more expensive to install and maintain; but, with the ability to deal with unusual and unanticipated traffic changes, they can deliver better results. The hardware requirements for local traffic responsive operation are similar to the pre-timed operation, with the addition of required carriageway detectors upstream of the on-ramp. The main criticism of traffic responsive algorithms is that they are reactive, and adjust metering rates after main carriageway congestion has already occurred. Traffic predictive algorithms such as ALINEA have been developed to anticipate operational problems before they occur.

C: Centralised System-Wide Traffic Responsive Operation - System wide traffic responsive ramp metering operation seeks to optimise a multiple-ramp section of motorway, often with the control of a bottleneck as the ultimate goal. Typically a centralised computer supervises numerous on-ramps and implements control features which override local metering instructions. This centralised configuration allows the metering rate at any ramp to be influenced by conditions at other locations within the network. In addition to recurring congestion, system wide ramp metering can also manage motorway incidents, with more restrictive metering upstream and less restrictive metering downstream of the incident. Road organisations can monitor and control the entire system from a traffic operations centre, and can remotely override or reprogram controllers. The hardware requirements for this mode of operation are the most complex of the three, requiring detectors upstream and downstream of the ramp, as well as a communication medium and central computer linked to the ramps. Traffic signals on the arterial network can also be connected to monitor demand on the wider network and adapt depending on demand.

Table 6 below provides an overview of ramp metering approaches:

Summary of Approaches	
Local Fixed Time	Appropriate for localised problems Not effective for non-static conditions Higher operations costs compared to traffic responsive systems
Local Traffic Responsive	Appropriate for localised problems Detection in the field is needed Higher capital and maintenance costs compared to fixed time systems Produces greater benefits because it responds to conditions in the field
Coordinated Traffic Responsive	Appropriate for widespread problems. Detection in the field is needed Most useful for corridor, system-wide applications Greatest capital and maintenance costs, but produces most benefits where widespread problems occur

Table 6: Summary of Ramp Metering Approach

An important part of all ramp metering strategies is the algorithm to switch the system on and off. This can be done based on time, but preferably based on local or network conditions. Switching on too late would lead to unnecessary congestion and switching on too soon leads to unnecessary queues on the on-ramp. The algorithm should be tuned carefully.

3.1.6 Control Strategies

The one vehicle per green strategy has been adopted on many countries across Europe, providing a maximum capacity of 800 veh/lane/hr, but strategies vary according specific site/network conditions.

Ramp metering algorithms typically deliver the ramp flow value, in vehicles per hour, to be applied during the next period. There are a number of alternative possibilities of implementing the ramp flow value based on the traffic cycle phasing (i.e. green, amber, red and red-amber phases). In some cases non-green phases are skipped to reduce unnecessary metering delays.

The following metering policies can be deployed with different methods of calculating the green phase and traffic cycle time to implement the specific ramp metering flow rate delivered by the ramp metering algorithm:

- **One-Car-Per-Green** – the green phase is fixed to two seconds for example, (the duration of the red phase can be fixed or dynamic) The main advantage of this policy is only one car is released rather than platoon which may disturb the mainstream traffic when merging, but the metered ramp capacity is reduced.
- **N-Cars-Per-Green** – partial relaxation of the first strategy allowing a pre-specified number of cars to exit per green phase.
- **Full Traffic Cycle** – in this case the traffic cycle is always equal to the metering period, allowing a higher ramp metering capacity, but can lead to platoons of vehicles being released which can disturb the flow of mainline traffic.
- **Discrete Release Rates** – compromise between one-car-per-green and full cycle policies in an attempt to reduce the disadvantages of both.

An important part of all ramp metering strategies is the algorithm to switch the system on and off. This can be done based on time, but preferably based on local or network conditions. Switching on too late would lead to unnecessary congestion and switching on too soon would lead to unnecessary queues on the on-ramp. The algorithm needs to be tuned carefully.

3.1.6.1 Ramp Metering Design

It is advised to recognise three phases of design of ramp metering when several systems are influencing each other:

1. First stage - stand alone system, this should first be tuned as a stand-alone system and should work as expected.

2. Second stage - two or more ramp metering systems, develop a good coordination between the ramp metering systems to maintain an optimal flow on the main carriageway.

3. Third stage - consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc.

3.1.6.2 Multi-Lane Design

Multi-lane ramp designs can be used to increase the overall vehicle storage within the available ramp length or to accommodate demands that exceed the capacity of a single metered lane. This design requires not only adequate acceleration distance from the stop line to the carriageway entrance, but also adequate distance for the multiple lanes to merge prior to the carriageway entrance.

Multi-lane metered designs can release vehicles simultaneously (alternating between the lanes), or they can operate independently of one another. With multiple lanes, it is possible for each lane to operate with a different metering rate.

3.1.6.3 Calibration and Optimisation

Ramp metering calibration and optimisation are site specific processes; the following steps should be undertaken:

1. Initial Calibration – this is based on traffic data and site geometry; allowing a safe switch-on

2. Main Calibration – this is conducted during site operation and can be carried out remotely or on site

3. Optimisation – small changes are made after a sustained period of operation to optimise performance

4. Performance Review – this needs to be carried out periodically

3.2 Evaluation

Within EW a wide range of measures are used in ramp metering evaluation, these are dependent on the original objectives of the implementation. Within EW, System Impact Studies, (analysis performed to identify the impact of existing ramp metering strategies) have most benefit and transferability. These typically involve comparison of the conditions “before” deployment and “after”, providing system operators with direct feedback on ramp metering effectiveness.

System impact objectives generally fall into four categories:

1. Safety impact
2. Efficiency: traffic flow and travel time
3. Energy / environmental impact
4. Impact on urban road network

The traffic conditions used for comparison in these impact studies are typically based on observed data collected in the field using manual or automatic data collection methods. Where this is not feasible various models and/or traffic analysis tools can be used to simulate conditions.

Table 7 **Fehler! Verweisquelle konnte nicht gefunden werden.**below provides simple possible measures for these objectives and methods for collecting the required data that could be applied across all regions to collect and compare ramp metering evaluation data:

Evaluation Objective	Measure of Effectiveness	Method
Safety impact	• Change in the number of accidents occurring	• Before and after accident data from police or accident logs
	• Change in the severity / type of accidents occurring	• Before and after accident severity / type data from police or accident logs
	• Change in the number of traffic incidents (rear-end and merging collisions) occurring after the ramp merge	• Examination of data for ramp segments before and after site (rear-end and merging collisions)
Efficiency Traffic flow and travel time	• Change in traffic volume and speed for main carriageway traffic	• Before and after traffic volumes, speeds, occupancy from traffic detector stations
	• Change in travel time for main carriageway traffic	• Before and after floating vehicle studies, ANPR data for vehicles travelling upstream and downstream of site (over a defined distance / corridor at set times)
	• Change in travel time reliability	• Before and after floating car studies, ANPR data
	• Change in traffic volume, travel time, travel speed, and travel time reliability for on-ramps	• Before and after traffic volumes, speeds, occupancy from loop detector stations; travel time data
Energy consumption & environmental impact	• Estimated change in emissions by pollutant	• Can be calculated using a model / formula
	• Estimated change in fuel consumption	• Can be calculated using a model / formula
Impact on urban road network	• Change in traffic volumes on urban streets	• Before and after traffic volumes, speeds, occupancy from loop detector stations
	• Change in the length and severity of ramp queue spill back onto adjacent junctions	• Before and after observations, queue data collected from ramp metering system

Table 7: Possible Ramp Metering Evaluation Measures

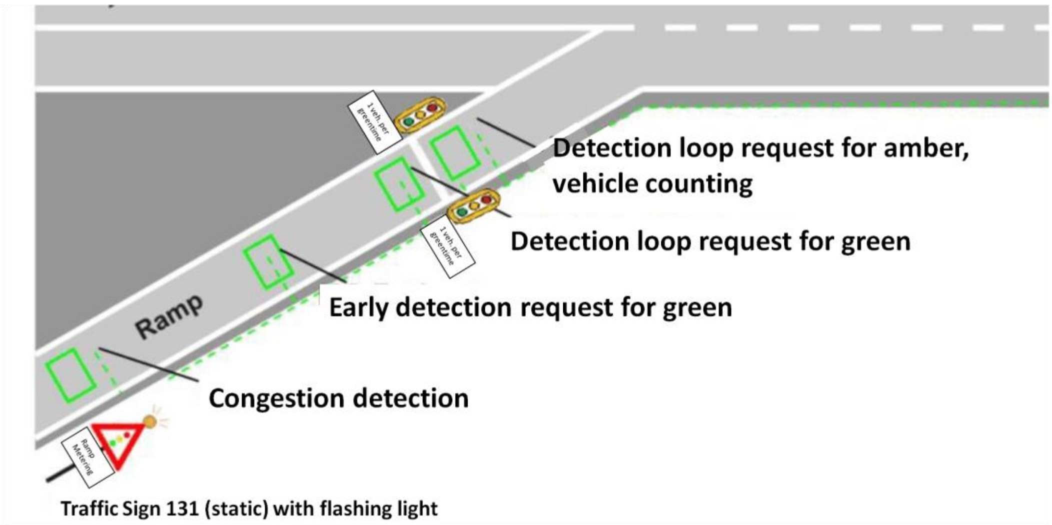
Estimation of the traffic flow is carried out on the basis of current as well as existing traffic data, which can be further supported by on-site traffic surveillance. In the case of complex measures traffic flow estimation can be carried out by means of a simulation of the efficiency of the ramp metering system on the traffic flow.

For indicators such as environmental impacts there needs to be a considerable amount of data collected over a long period of time before changes are noted. For the evaluation of safety benefits at least a year of 'before' data is generally required. As with all evaluation data quality is of great importance. Evaluation should also be carried out in line with the relevant TEMPO[9] criteria and should follow the EasyWay Guidelines for Evaluation.

[9] The TEMPO Programme – 2001-2006: Prior to 2001 individual projects addressed various ITS implementation issues with limited coordination. Aim of the TEMPO programme (2001-2006) was to reach a higher level of coordination and to stimulate a harmonised deployment. http://ec.europa.eu/transport/its/road/deployment_en.htm

3.3 Examples of deployment

3.3.1 Strassen NRW – Germany

LANDESBETRIEB STRASSENBAU NORDRHEIN-WESTFALEN (SHORT: STRASSEN NRW)	
Status	Please **X** to show status: [**x**] Deploy ramp metering widely for TM purposes [ ] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering *If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment* [ ] Not considering deploying ramp metering [ ] Other – please state ....
Main RM objectives	Please indicate with **X** or show priority **1**, **2**, **3** (i.e. 1 highest priority) [**x**] Smoothing of traffic flow on mainline [**x**] Accident prevention [**x**] Improve mainline travel times [ ] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Please provide images to illustrate **Usually they are fixed**  Figure 13 - NRW Ramp Metering Layout
Appearance of signals (signal heads)	Description and image of signals Are these the same as regular road traffic lights? If you do not use a yellow backing shield, why not?

	In NRW the yellow background for signals is installed completely  Figure 14 - NRW Ramp Metering Signal
Layout of signals	Are signal installed on both sides of the road? **Yes, in the most cases!** Are high / low / above lane signals installed? **To increase recognizability in special situations we use high above lane signals installed.**
Signal cycle	For example, is this GREEN-AMBER-RED? **Yes**
Flashing Lights	Are flashing lights used? **Flashing lights are installed for pre-signing and running during operation of ramp metering systems.** If so, what do they mean for road users? **The flash lights should increase attention of drivers.**
Roles and Responsibilities *Agency / actors responsible for the various stages?*	Planning – **Strassen NRW** Project Development - **Strassen NRW** Operation **– Traffic Operating centre (not Part of Strassen NRW)** Maintenance **- Strassen NRW** Data Collection **- Strassen NRW** Enforcement **– Police** Marketing / Communications **- Strassen NRW**
Ramp Metering Design	Do you implement phased design? I.e.: • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc. **In NRW stage two and three have not been realized by now**
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? **No** If so, please describe the reasons for implementing and the positives and negatives of this solution. If not, do you have any views of the implications of this? **No**
National RM Guidelines	Name of relevant national documentation (web link if available online) **Allgemeine Hinweise zum Betrieb von Zuflussregelungsanlagen**
Standards	
Evaluation	Any results or reports available?
Unanticipated problems?	
General comments / Additional images	

3.3.2 Flanders

BELGIUM (FLANDERS)	
Status	Please X to show status: [ ] Deploy ramp metering widely for TM purposes [**X**] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment [**X**] Not considering deploying ramp metering [ ] Other – please state ....
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [**X**] Smoothing of traffic flow on mainline [ ] Accident prevention [ ] Improve mainline travel times [ ] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Please provide images to illustrate
Appearance of signals (signal heads)	Description and image of signals Are these the same as regular road traffic lights? **YES** If you do not use a yellow backing shield, why not?
Layout of signals	Are signal installed on both sides of the road? YES Are low installed?
Signal cycle	For example, is this GREEN-AMBER-RED? **YES**
Flashing Lights	Are flashing lights used? **NO** If so, what do they mean for road users?
Roles and Responsibilities	Planning - Project Development - Operation - Maintenance - Data Collection - Enforcement – Marketing / Communications – **All: Flemish Road Administration AWV**
Ramp Metering Design	Do you implement phased design? I.e.: **N.A.** • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc.
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? **No** If so, please describe the reasons for implementing and the positives and negatives of this solution. If not, do you have any views of the implications of this?
National RM Guidelines	Name of relevant national documentation (web link if available online) **N.A.**
Standards	**N.A.**
Evaluation	Any results or reports available?

3.3.3 The Netherlands

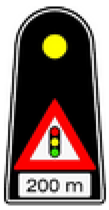
THE NETHERLANDS - RIJKSWATERSTAAT	
Status	Please X to show status: [**X**] Deploy ramp metering widely for TM purposes [ ] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment [ ] Not considering deploying ramp metering [ ] Other – please state ....
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [**2**] Smoothing of traffic flow on mainline [ ] Accident prevention [**1**] Improve mainline travel times [ ] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Please provide images to illustrate **Pre-signing is used, just like normal traffic lights. Most of the time the sign as shown below is used. The picture shows the situation on the Delft-South on-ramp**  Figure 15: RWS Pre-signing (1)  Figure 16: RWS Pre-signing (2)
Appearance of signals (signal heads)	Description and image of signals Are these the same as regular road traffic lights? If you do not use a yellow backing shield, why not? **The signals are normal traffic signals, but with a yellow backing shield. The pictures shows the signals**

	 Figure 17: RWS High and Low Signals
Layout of signals	Are signal installed on both sides of the road? Are high / low / above lane signals installed? **That depends on the situation. For a 2-lane on-ramp the situation is shown in the picture above. For one lane the situation could be different, as is shown below.**  Figure 18: RWS Low Signals **But also other configurations are possible as is shown in the next figure.**

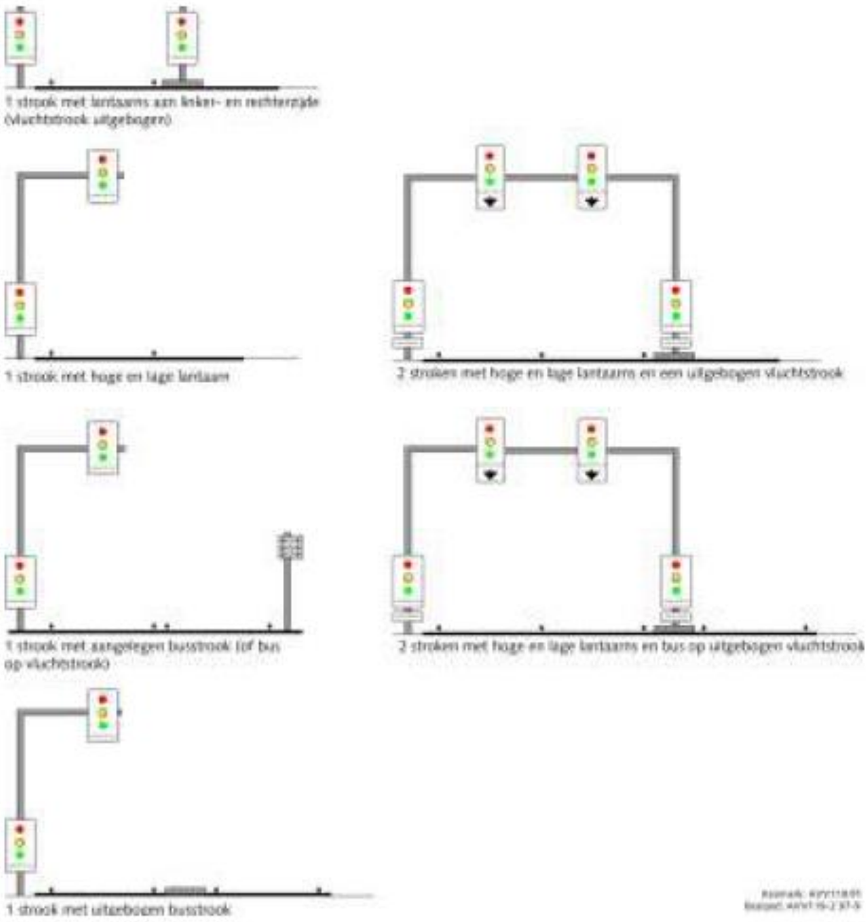
	 Figure 19: RWS Signal Configurations
Signal cycle	For example, is this GREEN-AMBER-RED? **Yes, the normal cycle is green-amber-red. Amber starts when the vehicles**
Flashing Lights	Are flashing lights used? If so, what do they mean for road users? **Flashing lights are only used when the metering system switches on and off.**
Roles and Responsibilities Agency / actors responsible for the various stages?	Planning - **Road Authority, most of the time Rijkswaterstaat, but sometimes in cooperation with other road operators.** Project Development - **Rijkswaterstaat, sometimes in cooperation.** Operation **- Rijkswaterstaat** Maintenance - **Rijkswaterstaat** Data Collection - **Rijkswaterstaat or consultant for evaluation** Enforcement - **Police** Marketing / Communications - **Rijkswaterstaat (see picture)**

	 Figure 20: RWS Road User Information Sign
Ramp Metering Design	Do you implement phased design? I.e.: • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc. **Until now all ramp metering systems (about 100) in The Netherlands are local. Some have coordination with the traffic signal systems of nearby intersections. There are plans for coordination, but this has not been done so far.**
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? **Yes** If so, please describe the reasons for implementing and the positives and negatives of this solution. **If the extra lane adds capacity, ramp metering is no longer needed. Another point is the algorithm. The algorithm takes into account the number of lanes as a static parameter. If the hard shoulder is used dynamically, this causes problems. So, hard shoulder use and ramp metering should be coordinated.** If not, do you have any views of the implications of this?
National RM Guidelines	Name of relevant national documentation (web link if available online) **All relevant documents are on our intranet.**
Standards	• Guideline for the preparation and implementation of a ramp metering system; • Guideline for the tuning of ramp metering systems; • Guideline for maintaining a ramp metering system; • Guideline for evaluation.
Evaluation	Any results or reports available? **H. Taale and F. Middelham, Ten Years of Ramp-Metering in The Netherlands, Proceedings of the 10th International Conference on Road Transport Information and Control, IEE, London, April 2000, ISBN 0-85296-725-X, pp. 106-110.** **Some 17 evaluation studies, but only in Dutch.**
Unanticipated problems?	**Problem with hard shoulder running**

3.3.4 Scotland

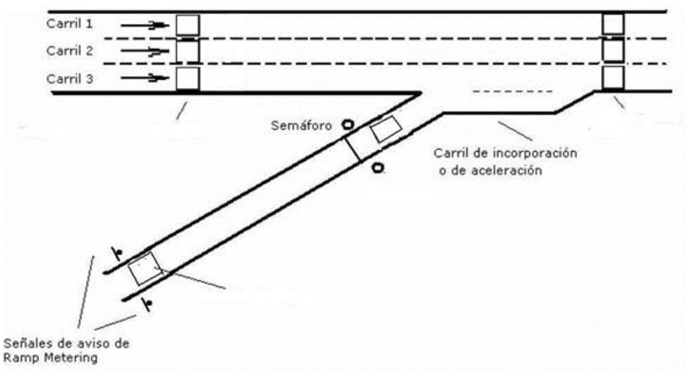
Transport Scotland	
Status	Please X to show status: [**X**] Deploy ramp metering widely for TM purposes In 1997 one site was installed on the M8 J16 (this was a demonstration site of the TABASCO Project) this site is still in operational use today. At the time it was envisaged there would be wider deployment as part of a coordinated RM system on the M8 but it was not progressed. [ ] Deployed trial / test sites [**X**] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment The Forth Replacement Crossing, in design phase currently, will include 2 RM sites from day one. Two further RM implementations will be activated after scheme opening. [ ] Not considering deploying ramp metering [ ] Other – please state
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [**=1**] Smoothing of traffic flow on mainline [**2**] Accident prevention [**=1**] Improve mainline travel times [**3**] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Please provide images to illustrate **At the M8 site a VMS rotating prism sign is installed before the slip road to inform road users on the status of ramp metering; and a fixed warning sign on the slip road to inform drivers traffic lights are sited ahead.** **The VMS flips to display the alternative route avoiding the junction and encourages drivers to divert to this alternative route when appropriate.**  Figure 21: Transport Scotland M8 Pre-signing
Appearance of signals (signal heads)	Description and image of signals Are these the same as regular road traffic lights? If you do not use a yellow backing shield, why not? **3 aspect signal head - the signals are the same as regular urban traffic signals. At the time of implementation the yellow backing shield was not common place. It is expected new deployments will take practices from elsewhere into account to form a harmonised appearance.**  Figure 22: Transport Scotland Signals

Layout of signals	Are signal installed on both sides of the road? - **Yes, 3 sets; 1 on the right and 2 on the left.** Are high / low / above lane signals installed? **Low signals are installed**
Signal cycle	For example, is this GREEN-AMBER-RED? **GREEN-AMBER-RED**
Flashing Lights	Are flashing lights used? **Yes - used on the VMS pre-sign** If so, what do they mean for road users? **Warn road users that ramp metering is in operation**
Roles and Responsibilities Agency / actors responsible for the various stages?	Planning – **Transport Scotland / Forth Replacement Crossing Joint Venture** Project Development - **Transport Scotland / Forth Replacement Crossing Joint Venture** Operation – **Traffic Scotland Operator TSOp (currently Atkins) on behalf of Transport Scotland** Maintenance - **Traffic Scotland Maintenance Contractor (currently Amey) on behalf of Transport Scotland** Data Collection – **not collected currently** Enforcement – **no enforcement at the M8 site but any enforcement activity would be carried out by the Police** Marketing / Communications – **nothing currently, most likely to be Transport Scotland**
Ramp Metering Design	Do you implement phased design? I.e.: • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc. **This was the original plan for the M8 site but additional sites were not implemented.**
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? If so, please describe the reasons for implementing and the positives and negatives of this solution. If not, do you have any views of the implications of this? **No, there will be a hard-shoulder bus lane starting at the ramp metered sites which is intended to be controlled as part of the RM scheme, however any hard-shoulder bus lane running on the main line will be terminated prior to reaching a ramp metered merge slip.**
National RM Guidelines	Name of relevant national documentation (web link if available online) **None at the time of the M8 implementation.** **The FRC Contract calls upon HA IAN 103, MCH2470 and MCH1965 C5**
Standards	**None at the time of the M8 implementation.** **FRC - HA IAN 103, MCH2470 and MCH1965 C5**
Evaluation	Any results or reports available? **TABASCO - Urban Integrated Traffic Control Evaluation Results: Deliverable No. 8.3** **ftp://ftp.cordis.europa.eu/pub/telematics/docs/tap_transport/tabasco_d8.3.pdf**
Unanticipated problems?	
General comments / Additional images	**All possible interactions and impacts on the adjacent urban network need to be taken into account.**

3.3.5 Hungary

State Motorway Management Co. Ltd. (Hungary)	
Status	Please X to show status: [ ] Deploy ramp metering widely for TM purposes [ ] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment [ ] Not considering deploying ramp metering [**x**] Other – The use of RM was come up as an option in the past, but after further analysis, no suitable junction was found as a pilot location.
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [ ] Smoothing of traffic flow on mainline [ ] Accident prevention [ ] Improve mainline travel times [ ] Environmental benefits [**x**] Other – Location related priorities
Pre-signing ramp metering	**Not defined yet, legal basis is missing.**
Appearance of signals (signal heads)	**Not defined yet, legal basis is missing.**
Layout of signals	**Not defined yet, legal basis is missing.**
Signal cycle	**Not defined yet, legal basis is missing.**
Flashing Lights	**Not defined yet, legal basis is missing.**
Roles and Responsibilities	**Not defined yet, legal basis is missing.**
Ramp Metering Design	Do you implement phased design? **n.a.**
RM and Hard Shoulder Running	**The use of RM and Hard Shoulder Running might work together properly, when the hard shoulder is open from the RM controlled junction.**
National RM Guidelines	**n.a.**
Standards	**n.a.**
Evaluation	**n.a.**
Unanticipated problems?	**n.a.**
General comments / Additional images	**Legal basis and exact design parameters for implementation are needed.**

3.3.6 Spain

DGT SPAIN	
Status	Please X to show status: [**X**] Deploy ramp metering widely for TM purposes [ ] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment [ ] Not considering deploying ramp metering [ ] Other – please state
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [**X**] Smoothing of traffic flow on mainline [**X**] Accident prevention [ ] Improve mainline travel times [ ] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Dynamic warning signals Please provide images to illustrate
Appearance of signals (signal heads)	Description and image of signals Are these the same as regular road traffic lights? If you do not use a yellow backing shield, why not?
Layout of signals	Are signal installed on both sides of the road? **Yes** Are high / low / above lane signals installed?  Figure 23: Map with the equipment location in A-1 and on ramp.
Signal cycle	For example, is this GREEN-AMBER-RED?
Flashing Lights	Are flashing lights used? If so, what do they mean for road users?
Roles and Responsibilities Agency / actors responsible for the various stages?	Planning – Project Development - Operation – Maintenance - Data Collection - Enforcement – Marketing / Communications – **In locations where two or more organizations are involved (for example, peri-urban areas) coordination is fundamental.** **Information to end users is recommended.**
Ramp Metering Design	Do you implement phased design? I.e.: • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination

	between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc. The system could be activated in two ways: a) pre-established timetable and b) automated, based on A-1 traffic flow.
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? If so, please describe the reasons for implementing and the positives and negatives of this solution. If not, do you have any views of the implications of this?
National RM Guidelines	Name of relevant national documentation (web link if available online)
Standards	
Evaluation	Any results or reports available? **No results are obtained yet, however first impression are no positive as planned. During on-ramp peak hours traffic management problems occurs in the on ramp and the congestions affects segments upstream**
Unanticipated problems?	
General comments/ Additional images	**Traffic flow increases or variance have a big impact in this type of ITS services. System response time has to be as low as possible, if not when traffic flow increase suddenly in on-ramps, congestion is produced upstream**

3.3.7 England

Highways Agency, England	
Status	Please X to show status: [**X**] Deploy ramp metering widely for TM purposes [ ] Deployed trial / test sites [ ] Considering / planning to deploy ramp metering If you have not yet deployed ramp metering, but are planning to, please provide responses to the questions based on your plans for future deployment [ ] Not considering deploying ramp metering [ ] Other – please state
Main RM objectives	Please indicate with X or show priority 1, 2, 3 (i.e. 1 highest priority) [**X**] Smoothing of traffic flow on mainline [**X**] Accident prevention [ ] Improve mainline travel times [**X**] Environmental benefits [ ] Other – please state ....
Pre-signing ramp metering	What signs are installed prior to the ramp metering? Are these fixed or VMS? Fixed Warning signs Please provide images to illustrate
Appearance of signals (signal heads)	Description and image of signals. **Three aspect GREEN AMBER RED, yellow shield behind** Are these the same as regular road traffic lights? If you do not use a yellow backing shield, why not? **Not the same**
Layout of signals	Are signal installed on both sides of the road? **Yes** Are high / low / above lane signals installed? **Where required**  Figure 24: Highways Agency Signals
Signal cycle	For example, is this GREEN-AMBER-RED? **yes**
Flashing Lights	Are flashing lights used? **No**. If so, what do they mean for road users?
Roles and Responsibilities Agency / actors responsible for the various stages?	Planning – Project Development - Operation – **The Regional Traffic Control Centre monitors performance and adjusts accordingly.** Maintenance - Data Collection - Enforcement – Marketing / Communications –
Ramp Metering Design	Do you implement phased design? I.e.: • First stage: standalone system, first be tuned as a standalone system and should work as expected. • Second stage: two or more ramp metering systems; develop coordination between the ramp metering systems to maintain an optimal flow on the main carriageway. • Third stage: consider the complete network part and try to integrate the ramp metering systems with existing traffic lights etc.
RM and Hard Shoulder Running	Is ramp metering deployed where there is hard shoulder running on the main carriageway? If so, please describe the reasons for implementing and the positives and negatives of this solution. If not, do you have any views of the implications of this?

National RM Guidelines	Name of relevant national documentation (web link if available online)
Standards	
Evaluation	Any results or reports available? Ramp metering systems have proven successful in certain locations where unregulated entry would trigger flow breakdown. Travel efficiency has improved (travel times have decreased and speeds increased). Further research is being undertaken. Operational Assessment Document: http://www.highways.gov.uk/knowledge_compendium/publications/592BF80EE9FF47D9B11A8CCA64A3D4C1.aspx
Unanticipated problems?	
General comments/ Additional images	The functional and technical requirements were developed following a research project, pilot deployments and evaluation of results. The specifications were developed from existing technical specifications and best practice. Stakeholder sessions involving police and local authorities were key to successful implementation. Developing the control algorithm that successfully implements and controls ramp metering requires considerable development, testing and commissioning before the systems are competent.

3.4 Business Model

Resources

Material means:

- Physical Components
- Traffic signals on the on-ramps
- Fixed or variable pre-signs upstream of the traffic signals
- Detectors at the on-ramps and main carriageway for traffic data collection
- Local controllers at the on-ramps for traffic signal operation
- Computing devices for control strategy implementation
- Operational GUI
- Communication links
- Operational Materials
- Detailed description of the final system is essential for future extensions, alterations and repairs
- Operation manual covering basis elements of the ramp metering strategy, queue management, physical architecture and components diagrams, lists and explanations of configurable parameters; and detailed presentation of GUI operations
- Guideline and procedures regarding specific operational events

Human resources:

The planning and operation of ramp metering systems is usually carried out by staff already familiar with traffic-related tasks. The systems are usually integrated into the existing centres and operated and monitored together with the other traffic-related installations of the operator.

- Contracting and Implementation
- Typically undertaken by an experienced system integrator
- Calibration procedure involving engineers familiar with specific algorithms employed for best possible control results
- Operation
- Ramp metering is a standalone system and should not require any operator intervention during normal operation, but it is essential that staff involved in ramp metering operation should have sufficient training on the content of documentation, understanding of the applied strategies, algorithms and procedures
- Public information and user campaigns

3.4.1 Costs and Benefits Analysis

3.4.1.1 Conditions for service provision – Business model

The most important stakeholders are:

Road Organisation / Road Operator – costs and benefits need to be clearly outlined, if ramp metering is to be deployed road organisations need to be convinced of its benefits and that it provides value for money.

Arterial Road Operators – may fear that the traffic queues at the on-ramps and route diversion would reduce the performance of their arterial network, they can be shown that by adopting the correct strategies and integrated management this is not the case

Ramp metering is one of a number of strategies employed to increase the overall efficiency of the road network, reduce point-to-point travel times and increase road safety. It is an important tool in the reduction of congestion with impressive results. For congested corridors without any ramp metering, successful implementation provides a high return on investment.

3.4.1.2 Stakeholders in Service Provision

Road organisations - introduction of ramp metering is the decision of the organisation responsible for the motorway infrastructure. The road organisations are responsible for the planning, implementation and operation of the ramp metering systems, and therefore corresponding guidelines and recommendations have to be taken into account. With regards to implementation and operation of the system the optimisation of traffic safety and traffic flow must be the primary target.

Local Authorities / Municipalities - as ramp metering is situated at the entrances to the motorway system it has interfaces with other traffic networks (mainly urban). There may be concerns over the impact ramp metering may have on the arterial network.

Forces of law and order - important the agency deploying ramp metering work with law enforcement personnel early in the planning process to gain their support for ramp management strategies. Ramp management strategies should comply with existing laws and regulations. Voluntary driver compliance should be promoted; it is unlikely all drivers will comply so law enforcement would be required to physically enforce ramp metering strategies on a periodic basis. Only sufficient acceptance and compliance of the system will promote the full potential of the ramp metering system in view of traffic safety and traffic flow.

Public transport agencies - if ramp metering is on regular public transport routes or priority lanes are to be implemented.

Media - The media can provide a means to gain positive support for ramp metering from motorists and local leaders. Media releases, in either electronic or hardcopy format, can be used to express the benefits of ramp meters prior to and during construction. The local media should be notified of program goals, objectives, and benefits well in advance of when meters are expected to be turned on. This will help form a working relationship with the media that will be needed to publicise the benefits of ramp meters later on. Although the media can aid in acquiring public support, the media can also be obstructive if not handled properly. If the benefits of ramp metering are oversold and unrealistic, credibility of the implementing agency can be questioned.

3.4.1.3 Cost / Benefit Analysis

The objective of cost benefit analysis is to extrapolate the findings from analysis of selected implementations to provide estimates of the system-wide benefits and costs of the ramp metering system. The ramp metering system's capital investment, operating, and maintenance costs are quantified, and compared against the system's benefits.

The following cost and benefits are typically considered:

Costs

- Investment
- Central control system and communications
- Equipment supply and installation
- Marking and placement of road signs
- Traffic management during implementation
- Calibration, evaluation and driver information
- Operation
- Data transmission
- System supervision, monitoring and fine-tuning
- Maintenance

Benefits

- Increased mainline capacity
- Increased mainline speeds
- Reduction in overall travel times
- Reduction in the number of Personal Injury Accidents
- Ease of traffic merging manoeuvres
- Vehicle operating costs
- Emissions / environmental costs (cost of damage to vegetation caused by emissions; land / vegetation lost due to the ramp metering installation and emissions of carbon dioxide to the environment)

There are various methods used throughout Europe to analysis the costs and benefits of ramp metering.

Cost benefit analysis of three ramp metering projects was undertaken as part of the evaluation of the EURAMP project[10]. This study found that in all cases where benefits could be achieved they led to cost benefit ratios between 2.2 and 10.3. Details of the evaluation can be found in EURAMP Deliverable 6.3.

[10] European Ramp Metering Project: EURAMP - http://www.euramp.org/

4 Annex A: Compliance Checklist

4.1 Compliance checklist "must"

#	Requirement	Fulfilled?		If no – quote of insurmountable reasons
		Yes	No	
Functional requirements				
None				
Organisational requirements				
None				
Technical requirements				
TR1	Whenever road operators have to exchange data requiring interoperability between two or more different organisations, they **must** enable their system to use DATEX II.			
Common look & feel requirements				
None				
Level of Service requirements				
None				

4.2 Compliance checklist "should"

#	Requirement	Fulfilled?		If no – explanation of deviation
		Yes	No	
Functional requirements				
None				
Organisational requirements				
OR1	Inter- and Intra-Agency Coordination - agreements and cooperation **should** be established between all authorities / operators when implementing ramp metering from one network to another (e.g. city authority urban roads to motorways or from one regional operator to another)			
OR2	Public Information Campaign - formal public information campaign **should** be instigated in areas where ramp metering is new.			
Technical requirements				
None				
Common look & feel requirements				
CL&FR1	Traffic signals **should** be positioned sufficiently far from the merging point to ensure drivers can accelerate enough to reach the speed of the main carriageway and to maximise the storage space on the on ramp.			
CL&FR2	Ramp metering traffic signals **should** be installed at the metered on-ramps at a low level to face drivers at the beginning of the queue			
CL&FR4	At least one set of ramp metering traffic signals **should** be installed per lane			
CL&FR5	Fixed or variable warning pre-signs **should** be installed on the on-ramp sufficiently upstream of the traffic signals or the on-ramp entrance			
CL&FR6	The display of signs/pictograms on VMS or other end-user devices **should** be in accordance with prevailing national road codes and where applicable be in line with the requirements of the EW-DG for Variable Message Signs Harmonization VMS-DG01: • MS which ratified the 1968			

	Convention MUST respect the 1968 Convention and SHOULD consider the Consolidated Resolution on Road Signs and Signals (R.E.2); • MS which did sign but not ratify the 1968 Convention SHOULD follow the 1968 Convention and also consider the R.E.2.			
CL&FR7	Ramp metering signals **should** be distinguishable from regular junction signals.			
CL&FR8	The traffic signals **should** operate a "Green – Amber – Red" cycle			
CL&FR9	At locations where ramp metering has a fixed release time to allow a fixed number of vehicles to pass during each release phase; the number of vehicles released **should** be communicated to the driver using a sign; i.e. "x car(s) per green" / "(x) Fahrzeug(e) bei Grün"			
Level of Service requirements				
LoSR1	Given that pre-deployment surveys / evaluations provide the necessary evidence to proceed with the deployment, the minimum and optimum LoS **should** respect the Level of Service to Operating Environment mapping table.			

4.3 Compliance checklist "may"

#	Requirement	Fulfilled?		If yes –remarks
		Yes	No	
Functional requirements				
None				
Organisational requirements				
None				
Technical requirements:				
None				
Common look & feel requirements				
CL&FR3	Traffic lights **may** additionally be installed at a high level			
Level of Service requirements				
None				

5 Annex B: Bibliography

[1. **S. Bradner, (Network Working Group).** Key words for use in RFCs to Indicate Requirement Levels. *The Internet Engineering Task Force (IETF).* [Online] March 1997. http://www.ietf.org/rfc/rfc2119.txt.]