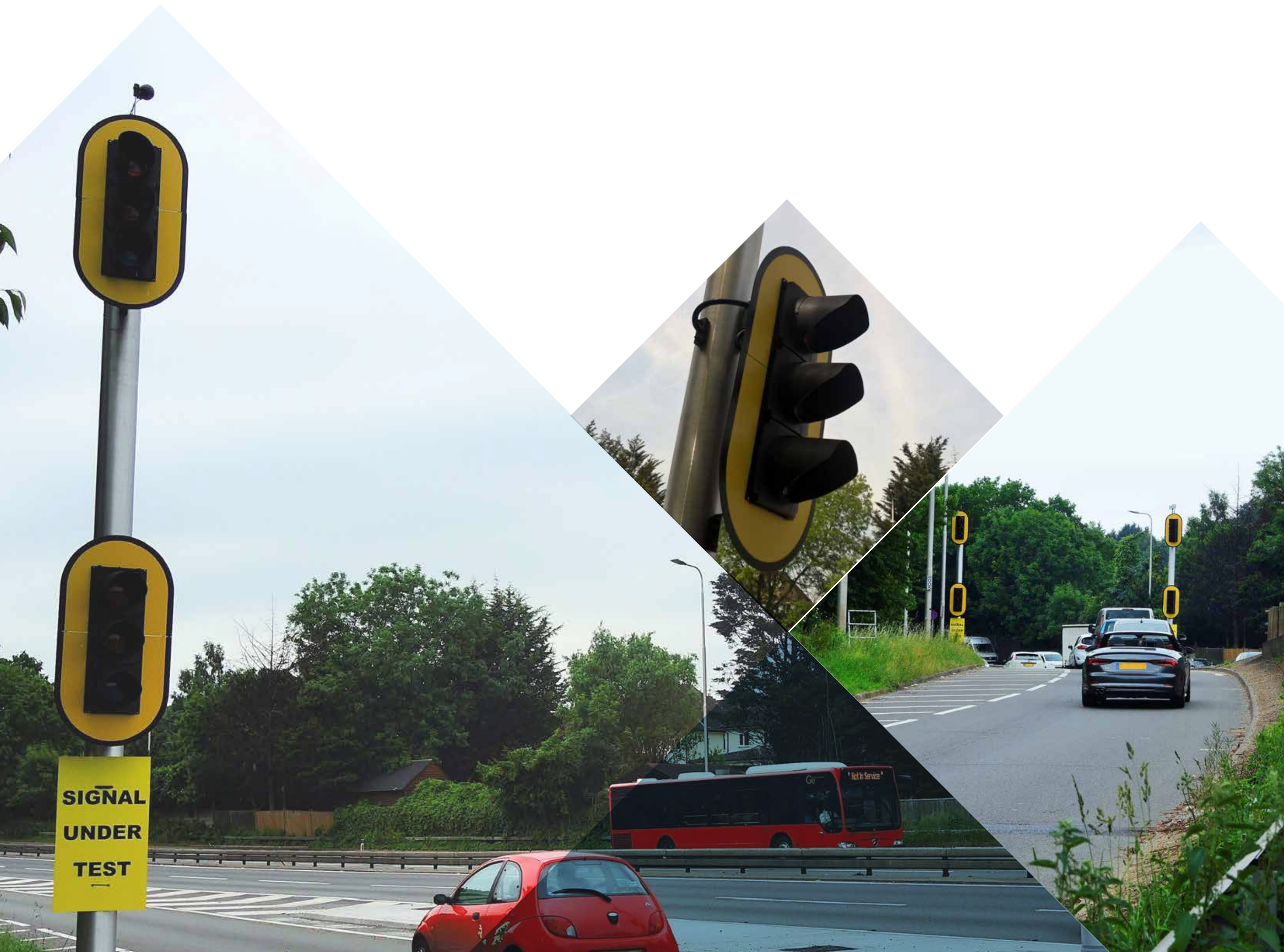
ATKINS

Member of the SNC-Lavalin Group

Evolving and enhancing traffic management

Second Generation Ramp Metering

Dalia Sueiro Ghaderi



Abstract

Ramp Metering is a traffic management system that authorities can use to help slip road traffic merge with the mainline flow in a more controlled manner.

Since 2006, Highways England have benefited from deploying ramp metering at suitable junctions on motorways and trunk roads across their network.

In the intervening period, the current (first generation) ramp metering systems have remained unchanged. The technology has become outdated, is dependent on specific roadside infrastructure, and has become increasingly difficult to maintain.

Additionally, with network improvements and changing traffic behaviours over time, traffic management systems need to be able to adapt to more dynamic environments.

Highways England commissioned Atkins and Dynniq to specify, develop and trial a new generation of ramp metering; one that is better adapted for the current and future traffic environment and facilitates more collaboration between different traffic systems and traffic authorities.

An overview of the project plus experience from its development and first year of operation is shared.

ATKINS
Member of the SNC-Lavalin Group

Ramp metering, what is it and why have it?

With increasing levels of traffic flows on motorways, efficient traffic network operation is essential for maintaining safe and congestion-free roads. Junctions and merges are hotspots for congestion and National and Local Highways Authorities have a duty to manage traffic effectively using suitable technical approaches.

Ramp metering is an internationally accepted technology for congestion management at merges where the slip road traffic is a significant factor to flow breakdown.

Ramp metering is a traffic management system that can help regulate the merging of slip road traffic with the mainline flow more efficiently. Using traffic signals on the on-slip, the flow of merging traffic is broken it into smaller platoons enabling traffic to merge in a more orderly manner. This can avoid the merge going over capacity, prevents shockwaves, and minimises flow breakdown. It can also support flow recovery.

Image 1 - Second generation ramp metering deployed at the A3 in Guildford.

ATKINS
Member of the SNC-Lavalin Group

Introduction to the second generation ramp metering trial project

Through the Highways England Innovation Fund, and as part of the Collaborative Traffic Management Programme, Atkins and Dynniq were commissioned to develop and deploy a second generation ramp metering trial which provides enhanced functionality over the current ramp metering system.

Second generation ramp metering introduces several improvements and functionality, including:

- Use of a hosted system architecture from where individual ramp metering sites are controlled and managed. The system has an increased processing power, allowing for more complex algorithms.
- Introduction of new algorithms which adapt more efficiently to traffic conditions, reducing the need for on-going manual recalibration works.
- Flexibility to easily deploy and test new algorithms, future-proofing the system.
- Capability for data sharing with third party systems (UTC, UTMC, etc) through cloud technology and web connectivity.
- Capability to influence the operation of adjacent ramp metering sites (i.e. corridor linking) using centralised system intelligence.
- Less reliance on roadside infrastructure, with flexibility on type of sensors to be used.
- Infrastructure design that is compatible with current standards, improved configuration management and easier and safer to maintain.
- Improved fault reporting and remote system monitoring.

Image 2 - Second generation ramp metering deployed at the A3 in Guildford.

Two sites have been commissioned as initial trials to develop the system and confirm its functionality:

- M25 Junction 13 northbound slip road, near Staines.
- A3 Dennis Roundabout southbound slip road, in Guildford.

The system uses the latest technology, enabling it to be more flexible and future proof; supporting better connectivity between cloud-based traffic management systems and easier implementation at non-motorway sites.

Soon, the second generation ramp metering system will be sharing data with the local junctions through UTMC, using a VPN connection. Longer term, this flexibility can support the development of new technology such as innovation in algorithms, use of different data sources, or connectivity with vehicles and other systems.

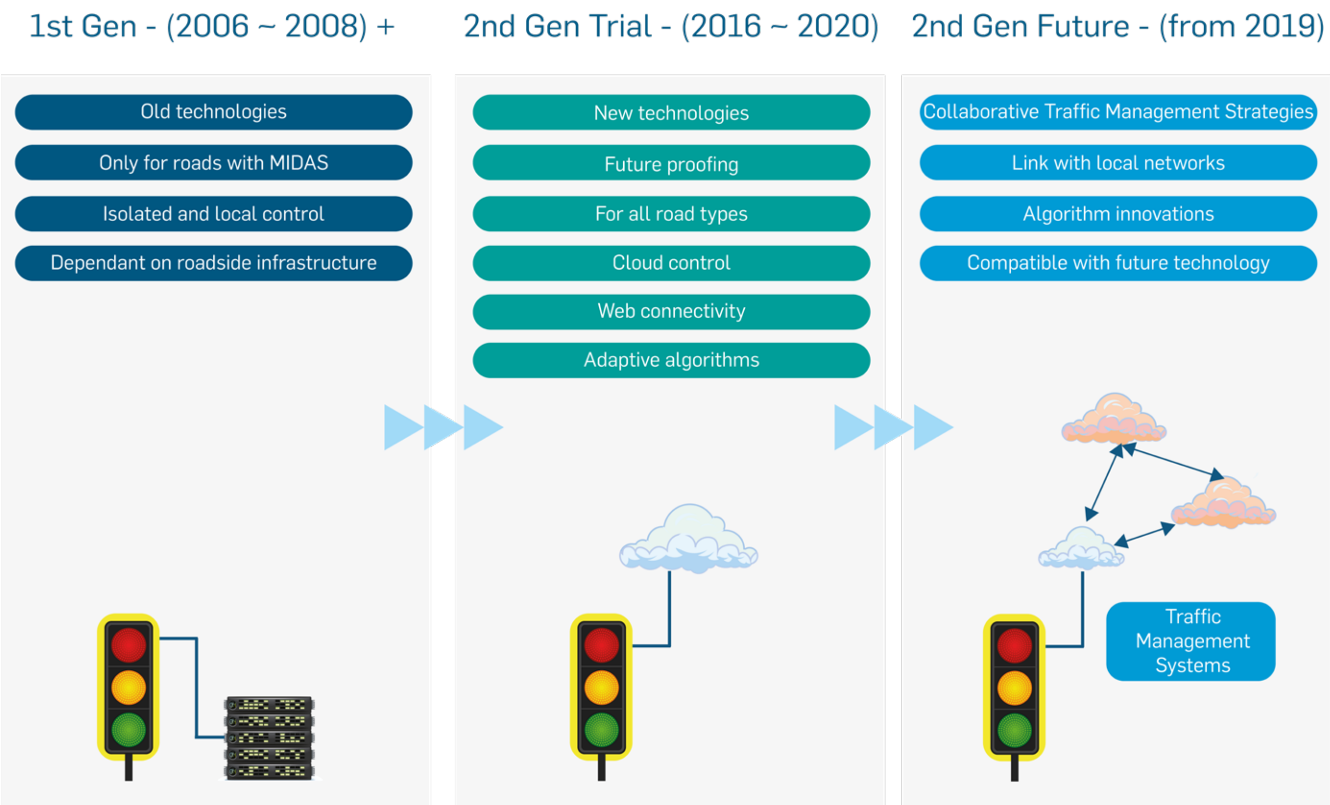


Figure 1 - Development of the second generation ramp metering system

ATKINS
Member of the SNC-Lavalin Group

Evolving the Ramp Metering Control System

The ramp metering uses a feedback loop control system:

- The traffic conditions at the merge and the slip road are monitored using detectors.
- Based on these traffic conditions and how far they deviate from optimal conditions, several algorithms estimate the flow of vehicles that should be released from the slip into the main carriageway.
- The system then selects the green and red timings that should provide the flow requested by the algorithms.
- The new traffic conditions at the merge and the slip road are monitored, feeding back revised data and completing the loop.

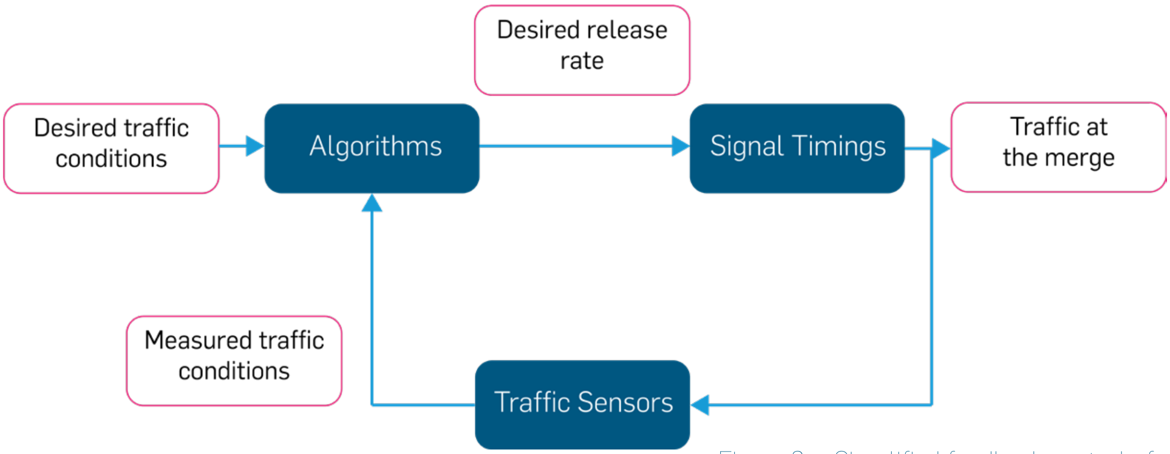


Figure 2 – Simplified feedback control of ramp metering

The first generation ramp metering system has a ramp metering controller housed in a cabinet near the signals. It uses a Pentium processor where the algorithms estimate the required release rate of vehicles on the slip road. The traffic conditions on the slip road and the main carriageway are the inputs to the algorithms in the controller, necessitating the deployment of loops for traffic detection on the slip road and connection to at least two MIDAS outstations on the main carriageway (upstream and downstream of the merge). The ramp metering controller interfaces with the traffic signals controller through an I/O card and it interfaces with MIDAS using legacy RS485 communications. The user can access a web user interface of each individual ramp metering controller through an IP connection and modify the algorithm parameters.

The current system is operating well at many junctions in the UK, however, the technology has become outdated and is not compatible with the latest Highways England traffic management or fault reporting systems; replacement parts are not readily available, and the processing power is limited so, the algorithms require manual recalibration on a periodic basis.

The second generation ramp metering system that has been developed evolves this concept further. The ramp metering controller uses a distributed architecture, with the main control algorithms running in the cloud and a Network Interface Unit in the outstation.

This architecture has several benefits:

- The increased processing power (central and roadside) allows for developing smarter and more sophisticated algorithms which can adapt better to traffic conditions, with less need for manual recalibration.
- The cloud architecture permits the user to control all ramp metering outstations from a single web interface, with the ability to perform software updates and deploy new algorithms simultaneously to all sites, download input and output data, and view live and historical performance and fault reports.
- The new system uses IP communications throughout, complying with Highways England current standards, and is compatible with Highways England traffic management and asset management systems.
- The cloud system can interface with other systems through an API and VPN connection.

When it comes to detection, second generation ramp metering has been developed to use wireless magnetometers which are battery powered, reducing the dependence on loops technology and MIDAS infrastructure. Furthermore, it remains compatible with MIDAS but now uses IP communications.

ATKINS
Member of the SNC-Lavalin Group

Enhancing the Ramp Metering Algorithms

After 10+ years of operating ramp metering there was an interest in improving the algorithms and reducing the costs and time on periodic recalibration.

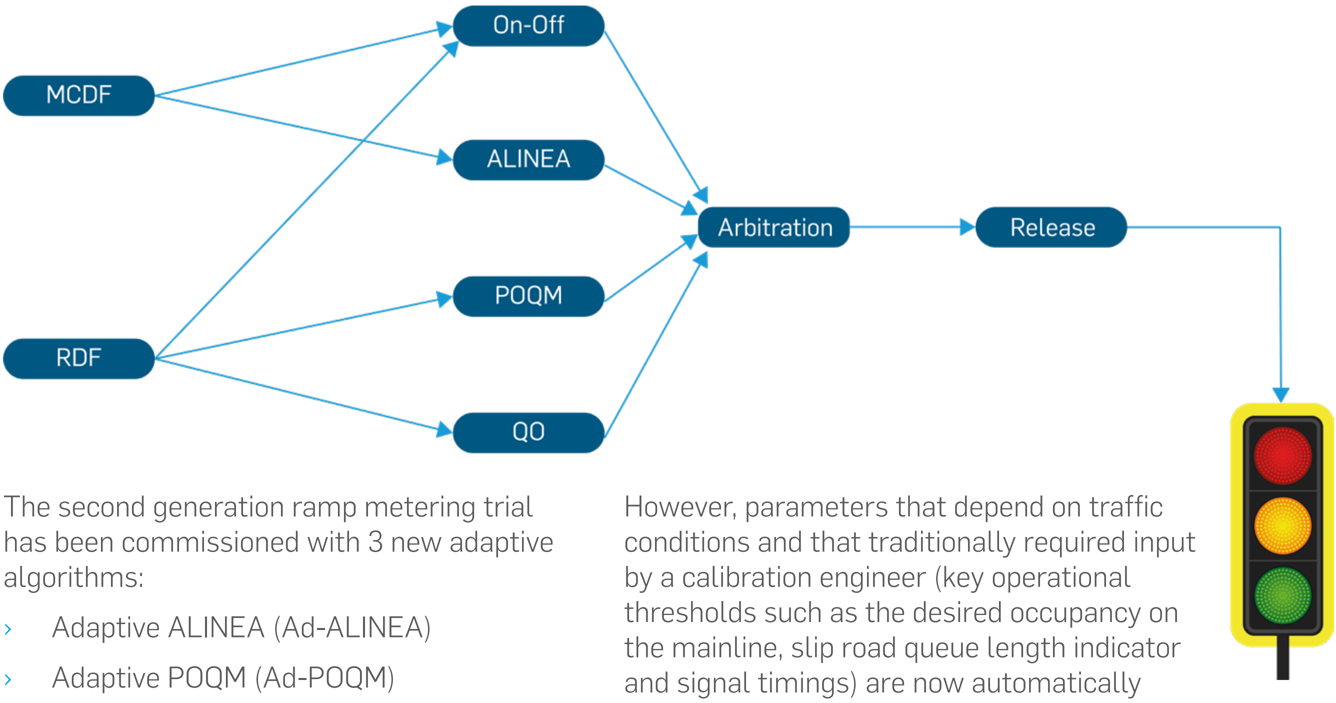
The first generation controller was limited in its capacity for expansion and could not accommodate more complex algorithms or extensions for coordinated algorithms with neighbouring signalised junctions or ramp metering systems.

During this development, the opportunity was taken to add considerable flexibility which allows the modification or addition of algorithms using Python language and JSON format. As traffic control systems improve, authorised users can easily modify the algorithm files or upload new ones through the web user interface.

1GRM Ramp metering in the UK operates the following algorithms:

- Data filtering algorithms (MCDF and RDF): filter the sensor data from the mainline and the slip road respectively to avoid a noisy reading for the operation of the algorithms.
- Switch on/off algorithm (On-Off): controls the switching on and off of the ramp metering signals based on the real time traffic conditions.
- Main carriageway algorithm (ALINEA): requests a vehicular flow rate from the slip road to maintain the main carriageway occupancy where capacity is maximised.
- Queue Management algorithm (POQM): requests a quantity of vehicles to be released from the slip to maintain a manageable queue length on the slip road.
- Queue Override algorithm (QO): requests a maximum flow rate of vehicles to be released from the slip when the queue on the slip is threatening to interfere with the local junction.
- Arbitration algorithm: selects the dominant requested vehicular release rate requested by the algorithms above.
- Release algorithm: translates the requested vehicular flow rate into a 'release level' category which determines the signal cycle times observed on street.

Figure 3 – Standard ramp metering algorithms



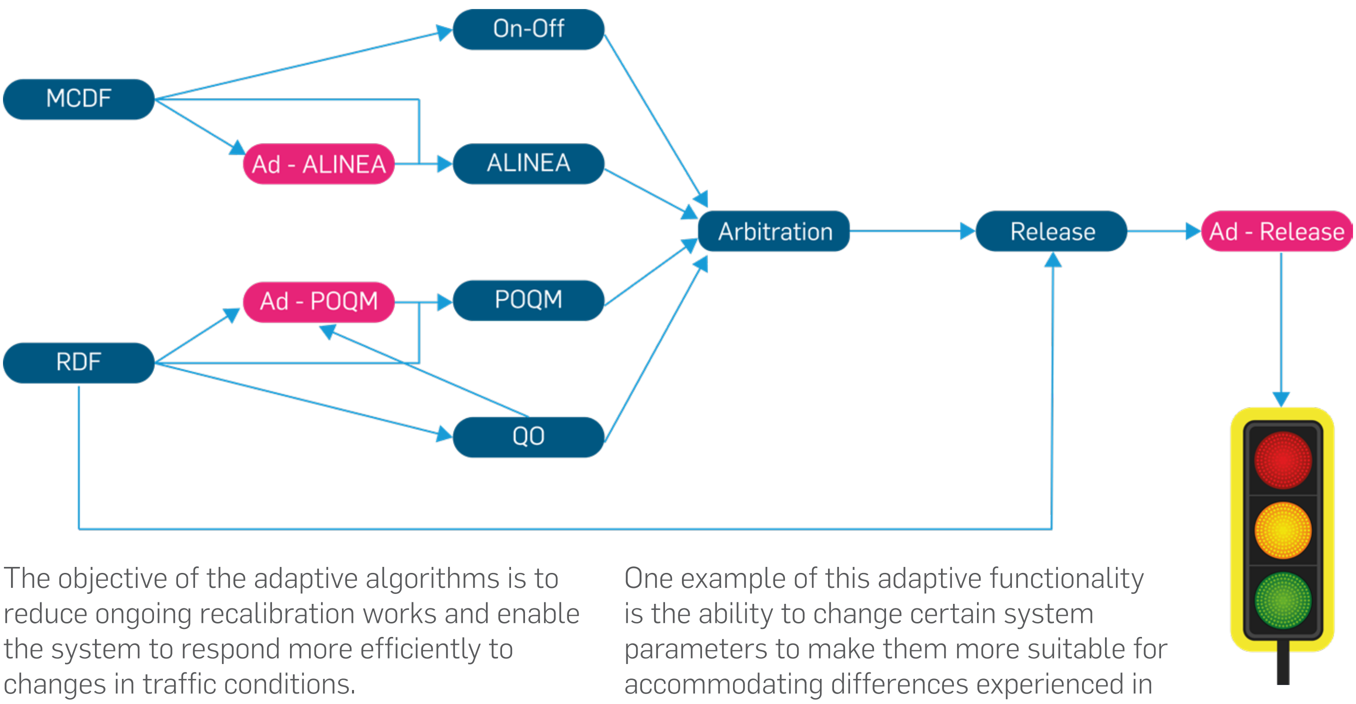
The second generation ramp metering trial has been commissioned with 3 new adaptive algorithms:

- Adaptive ALINEA (Ad-ALINEA)
- Adaptive POQM (Ad-POQM)
- Adaptive Release (Ad-Release)

These new algorithms work in parallel with the existing ramp metering algorithms.

However, parameters that depend on traffic conditions and that traditionally required input by a calibration engineer (key operational thresholds such as the desired occupancy on the mainline, slip road queue length indicator and signal timings) are now automatically calculated and adjusted based on the actual traffic events and conditions.

Figure 4 – Introduction of additional algorithms



The objective of the adaptive algorithms is to reduce ongoing recalibration works and enable the system to respond more efficiently to changes in traffic conditions.

One example of this adaptive functionality is the ability to change certain system parameters to make them more suitable for accommodating differences experienced in traffic profiles, such as between morning and afternoon peaks or different day types.

Introducing new detection options

Ramp metering requires measurements of speed, flow and occupancy on the main carriageway and slip road. Traditionally this has involved using existing MIDAS loops on the main carriageway and cutting new loops on the slip road.

In order to broaden the potential application of ramp metering, second generation ramp metering was specified with both motorway and non-motorway junctions in mind. MIDAS may not be available in all cases and introducing loop infrastructure requires roadside cabinets and power supplies. Second generation ramp metering has been developed to allow the use of differing technologies including magnetometers.

Magnetometers are quicker to install than loops, thereby reducing disruption to traffic and improving safety by reducing site worker's exposure to risks. They are self-powered and they use wireless communications, reducing the need for trenching and cabling.

The use of magnetometers for ramp metering had not been tried before and has proven successful as part of the commissioning of the two second generation ramp metering trial sites. Since they use a different connection method to those already implemented in other highways applications; Dynniq made use of a stretch of the Bruntingthorpe test track and implemented a trial based on the A3 site design.

The test included testing access points, magnetometer units and repeater units, replicating the detection solution for the A3 site.

Image 3 – Testing the magnetometers for ramp metering at Bruntingthorpe test track

The A3 site in Guildford is an example of how the architecture with magnetometers and wireless communications allows for a wider set of conditions where ramp metering can be deployed. The A3 is a busy and constrained trunk road without sufficient space for the installation of MIDAS loops or power ducting and trenching. The use of magnetometers overcame these challenges.

In addition, the M25 Junction 13 provided a good example of a typical motorway layout, but with use of different detector types at the same time, with MIDAS on the mainline and magnetometers on the slip road.

Image 4 & 5 – Clearview Intelligence magnetometer used in the A3 site

ATKINS
Member of the SNC-Lavalin Group

Further Research and Development

The two trial sites were successfully commissioned with the A3 site operating since October 2018 and the Junction 13 site operating since January 2019.

The sites are currently being monitored by Atkins to confirm and evaluate the performance of the system and its new functionality, and to identify any further developments required.

Highways England are currently studying the possible rollout of second generation ramp metering to either upgrade existing sites that are becoming difficult to maintain or to deploy the system at new sites.

Meanwhile, Highways England have commissioned Atkins to undertake further research and development works through the Innovation Fund to study the further expansion of the system. Some of the work currently being undertaken includes the following:

Algorithm Development

Due to the constraints of the first generation systems, many algorithms have not been trialled or tested in the UK and second generation ramp metering provides the facilities to unlock this.

Research is being conducted on the potential improvements to existing algorithms and new algorithms that could be implemented using different logic, parameters or data sources.

ATKINS
Member of the SNC-Lavalin Group

Junction Linking

Linking between ramp metering and a local signalised junction has been implemented before, where the ramp metering sends queue status messages to the local traffic signal controller through a physical connection. These data bits are used to influence the operation of the traffic signals and are implemented using special conditioning logic programmed into the traffic signal controller.

The second generation ramp metering cloud architecture allows the ramp metering system to interface with other systems through an API and VPN connection. This includes sharing data and commands with UTMC systems, allowing for the development of highly flexible strategies. In practice, this enhances the ramp metering system's ability to share data and / or control instructions with single or multiple controllers, junctions, SCOOT regions, VMS, other ramp metering sites or other traffic systems. It is also cost effective since no new infrastructure needs to be deployed once the API connection between systems is implemented.

The junction linking activities seek to specify and deploy the linking between the second generation ramp metering system and Highways England UTMC system.

Corridor linking

Since second generation ramp metering has a centralised platform which controls the algorithms of all the outstations, it can run complex algorithms where the parameters of one ramp metering site inform another ramp metering site, allowing for coordinated control across a corridor of junctions with ramp metering.

Atkins are undertaking an assessment on the feasibility of using corridor linking to deliver a more strategic traffic management approach, able to better target congestion.

Use of Floating Vehicle Data

Atkins are undertaking an assessment on the potential for using Floating Vehicle Data in place of some or all roadside detectors to provide input to the algorithms. This would reduce both commissioning and maintenance costs and other associated risks by reducing roadside infrastructure.

Image 6 – Second generation ramp metering deployed at M25 Junction 13

ATKINS
Member of the SNC-Lavalin Group

Conclusion

Highways England commissioned Atkins and Dynniq to specify, develop and trial a new generation of ramp metering that uses updated technology and architecture; is better adapted for the current and future traffic environment and, will facilitate greater collaboration between different traffic systems and traffic authorities.

Two second generation ramp metering trial sites have been deployed and have been operating for more than 6 months, successfully proving the design and system technology. Future innovations, enabling the system to exploit its full capabilities are currently being researched and developed.

Image 7 - Second generation ramp metering deployed at the A3 in Guildford.

Acknowledgements

Paul Canning and Robin Magraw, project sponsors from Highways England.

Peter Kirby, Kevin Picot, Martin Cummings, Jill Hayden, Peter Davies and team from Atkins for the project delivery and technical advice.

Lisa Williams, Alan Hindley, Nancy Bunyan, Allison Parry and team from Dynniq for the system development and delivery.

Kier, Connect Plus Services and Carnell for the site design, preparation and civils works.

ATKINS

Member of the SNC-Lavalin Group

Dalia Sueiro Ghaderi
dalia.sueiroghaderi@atkinsglobal.com
Transport Technology Consultant
Intelligent Mobility and Smart Motorways
Atkins
Woodcote Grove
Ashley Road
Epsom
Surrey KT18 5BW

atkinsglobal.com