Ramp Metering Study

Scottish Executive

Executive Summary

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SIAS Limited

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RAMP METERING STUDY

Description:

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1 INTRODUCTION

1.1.1 This report is an executive summary of the Ramp Metering Study Report (Final Report) (SIAS ref. 54954). It summarises the main elements of work, the findings and the conclusions of the study.

1.2 What is Ramp Metering?

1.2.1 Ramp metering can be defined as a method by which traffic seeking to gain access to a busy highway (dual-carriageway/motorway) is controlled at the access (merge) point via traffic signals. This control aims to maximise the capacity of the highway and prevent traffic flow breakdown and the onset of congestion. Additionally, ramp metering can affect driver route choice and can be used to encourage alternative routes in corridor networks particularly where complimentary measures such as alternative route signing can be and are applied.

1.2.2 Figure 1.1 presents a schematic diagram of a basic ramp metering highway merge.

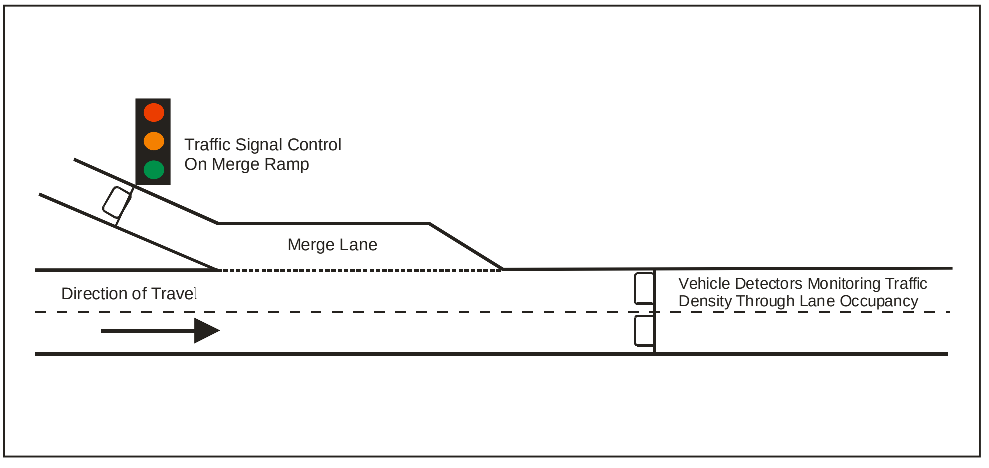

Figure 1.1 : Ramp Metered Highway Merge

1.3 Background

1.3.1 Current ramp metering site evaluation techniques are expensive, involving the installation of on-site equipment, and inflexible, limiting the ability to test specific details such as detector placement and alternative control algorithms.

1.3.2 To assess these issues the Scottish Executive commissioned SIAS in association with Glasgow City Council to undertake a study to develop a generic modelling tool that could be used as an alternative to on-field trials for evaluating ramp metering strategies at existing and potential sites.

1.3.3 For the purposes of the study, the modelling tool was to be developed using SIAS's Paramics traffic microsimulation software and validated against the current live application of the ALINEA ramp metering system on the M8 urban motorway through central Glasgow.

1.3.4 Other applications of ALINEA (Asservissement Lineaire d'entrée Autoroutiere) include both single and multiple ramps on the Boulevard Peripherique in Paris and at the A10 West motorway in Amsterdam.

1.4 Study Objectives

1.4.1 The objectives of the study were as follows:

- To develop a generic and enhanced version of Paramics which includes an a Simple Network Management Protocol (SNMP) data interface, the emerging standard for communication between management centres and remote devices;
- To develop a separate module that implements the ALINEA law on the ramp and communicates with Paramics;
- To build and validate a Paramics model of the existing ALINEA application on the M8 at Junction 16;
- To test the capability of the ALINEA/Paramics software in assessing a potential ramp metering site on the A720 at the Dreghorn Junction.

2 RAMP METERING IN GLASGOW

2.1 Background

2.1.1 Scotland's first ramp metering application was implemented in 1996 at Junction 16 Eastbound on the M8 motorway in Glasgow. It was introduced as one of a range of applications available within the NADICS (National Driver Information and Control System).

2.1.2 The need for ramp metering arose from a substantial realignment of the junction in question, such that the on ramp was changed from a "lane gain" arrangement to a merge. The system implemented in Glasgow was fully integrated within NADICS, and was designed with a high degree of user configurability.

2.1.3 Any particular ramp metering strategy can readily be implemented. However, the ALINEA traffic responsive strategy was chosen, due to its relative simplicity, and previously evaluated implementations.

2.2 Operational Detail

2.2.1 Features implemented include full user configuration of the main ALINEA strategy parameters.

2.2.2 To address a desire for minimisation of platoons presented at the actual merge point, an algorithm was devised which, for a desired ramp flow rate, minimises the platoon allowed to progress through the ramp meter signals during each green stage. This feature helps optimise the actual merge process.

2.2.3 Under the auspices of the EU Fourth Framework ITS project, TABASCO (Telematics Applications in Bavaria, Scotland and Others), the scheme was evaluated and demonstrated significant overall network benefits (i.e. considering both motorway and urban elements). To achieve this overall network benefit, the ramp metering application was operationally integrated with both Variable Message Signing and Urban Traffic Control.

2.2.4 The success of this first implementation identified ramp metering as a suitable tool for possible implementation elsewhere on the motorway network around Glasgow and on the wider Scottish strategic network.

3 SOFTWARE DEVELOPMENT

3.1 Introduction

3.1.1 The development of the software component of this project followed two related parallel threads – the addition of a generic Simple Network Management Protocol (SNMP) based interface to the Paramics microsimulation package and, using this, the development of a software simulator of the ALINEA law based Ramp Metering Controller itself.

3.2 Paramics SNMP Interface

3.2.1 SNMP was a natural choice as an interface to Paramics as it is rapidly becoming a de-facto standard for networked device monitoring and control software with applications ranging from office printer control through to, in the transportation industry itself, on-street detector, VMS signage and signal control.

3.2.2 The implemented Paramics SNMP Interface allows rapid development of external controllers with access to a rich set of simulation data coupled to detailed control over signal timings and turn priorities as well as overall simulation control.

3.2.3 Separating the control logic completely from the simulation software permits the independent development of controllers utilising proprietary or experimental algorithms. Whilst this particular project was developed by SIAS, the developer of Paramics, such controllers can now be developed and marketed by third parties with little or no involvement by SIAS and with no risk to the integrity of the simulation.

3.2.4 Developing an actual controller in parallel to the interface was ideal for both sides as it provided an immediate test-bed for the interface whilst ensuring that the needs of the controller were fully addressed from the outset.

3.2.5 The top-level architecture of the interface is shown below in Figure 3.1.

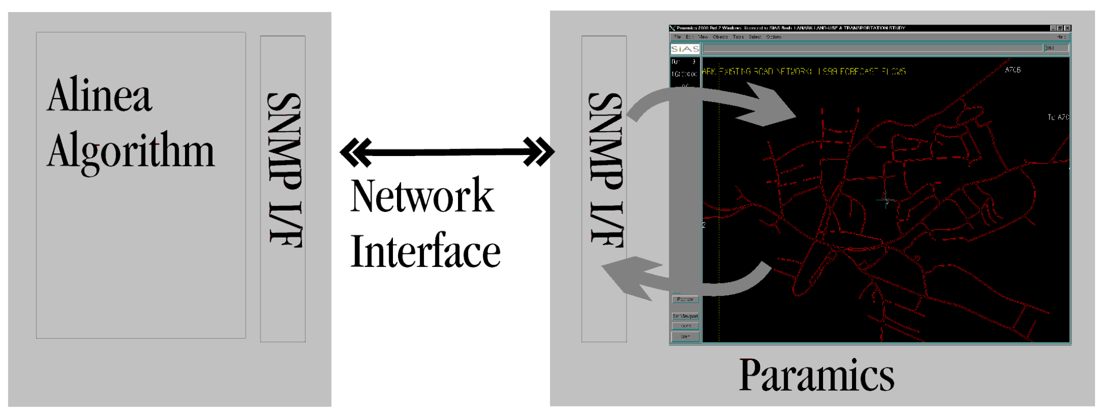

Figure 3.1 : ALINEA/Paramics Software Design Architecture

3.2.6 The SNMP interface within Paramics reaches into the simulation to extract and modify data in a running simulation, for example the vehicle detector loops and signal timings. The ALINEA controller uses SNMP to request data and to make signal timing changes within the running model, via the Paramics SNMP interface. Since SNMP is a network protocol, the ALINEA controller and the Paramics simulation may be co-located on one computer or the tasks may be distributed between two computers.

3.3 ALINEA Controller

3.3.1 The controller was developed to be a model-independent simulation of the ALINEA system, collecting detector data directly from the running simulation and applying the actual ALINEA law algorithms in order to determine signal timings to achieve optimum platoon sizes. These signal timings were then fed immediately back to the simulation to control the merging of simulated traffic from the ramp onto the motorway.

3.3.2 As well as providing complete control over all normal variable parameters available within the real system, the simulation permits these values to be set to “out-of-range” values to allow the testing of alternative strategies. In addition control over values normally considered constants within the real system was also provided.

3.3.3 During each simulation run all of the simulation data, intermediate calculated values and resulting signal timings can be collected for validation, calibration and analysis. A significant amount of additional data, not used in simulating the ALINEA law, was also included to assist in statistical scheme performance analysis.

3.3.4 The user interface was designed with a main “front page” allowing the entry and selection of the main control parameters, activation scheduling and immediate feedback on critical calculated values as they become available. Further pages allow the entry of detailed configuration parameters, viewing and saving of historical data and the selection and viewing of “fake data”.

3.3.5 This “fake data” page was used in the development of the system in order to prove the accuracy of the controller. By separating it from the simulation and forcing it to use real-world data in its algorithms, the results obtained from this were then checked directly against the matching real-world data. Any discrepancies were quickly identified and cured prior to using the controller with the simulation.

3.3.6 One aspect of the controller that was not in the original specification was Queue Dissipation, whereby additional detectors are used to monitor queues building on the ramp and the ALINEA calculations adjusted or overridden in order to mitigate the queues. A complete simulation of this aspect of the system was added and is available for model tests.

3.3.7 The only aspect of the real world system not implemented within the controller was the concept of intra-cycle timing adjustments whereby the actual platoon sizes are monitored and small adjustments to the green phase are made in an attempt to force the desired platoon sizes. Simulating to this level of detail would have had an impact on both the development timescale and the resulting simulation performance that would have far outweighed any minor improvements to the accuracy of the simulation.

3.3.8 Although access to all variables and constants was provided through the interface, it was recognised that changes to the underlying algorithms, or a need to test alternative algorithms, could result in a need to modify the controller at the source code level. The controller was therefore developed using Microsoft Visual Basic 6.0 with fully documented and commented code in order to allow rapid ongoing development of the controller by the client or their representatives.

4 M8 MODEL

4.1 Introduction

4.1.1 A Paramics microsimulation model of the M8 through central Glasgow was developed and validated against the recognised standards set out within the Design Manual for Roads and Bridges (DMRB), Volume 12. Figure 4.1 shows the study area.

4.1.2 The model was developed for the PM peak period (15:00 – 19:00) based on the most robust data available from the NADICS traffic database. Information for the average Wednesday in June 2001 proved the most reliable traffic data set.

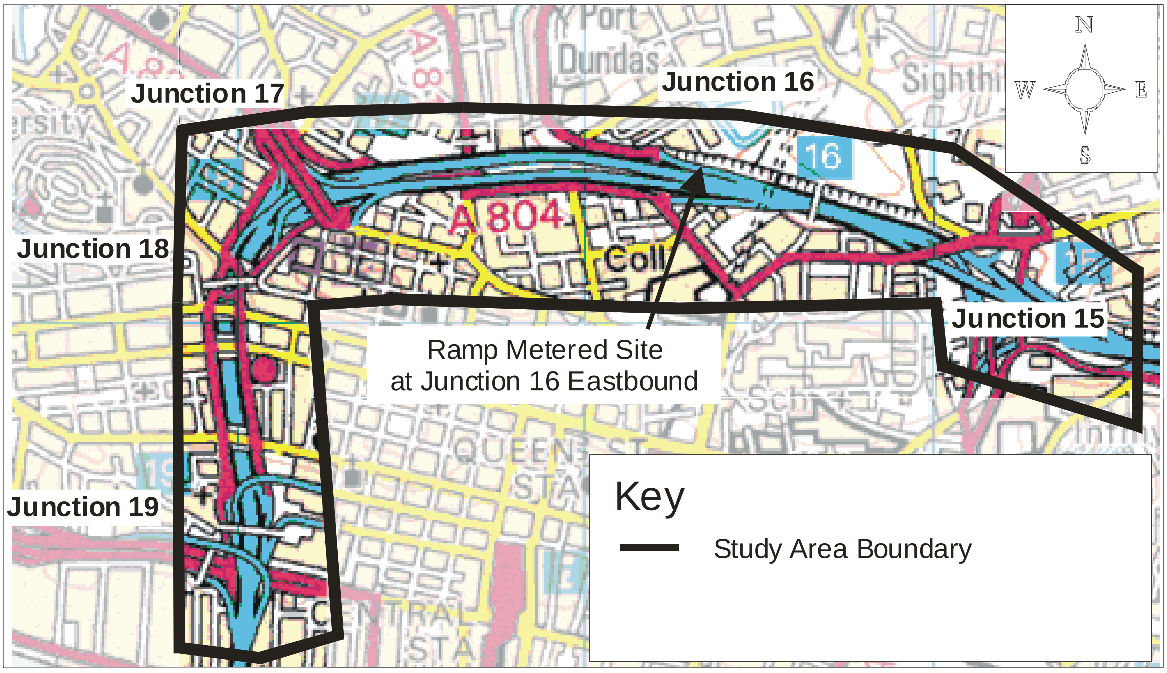

Figure 4.1 : M8 Study Area

4.2 Model Validation

4.2.1 Observed to modelled comparisons included traffic flows at 15 minute intervals, lane usage on the M8 through Junction 16 and vehicle detector occupancy on the M8.

4.2.2 Figure 4.2 shows the modelled and observed traffic flows for the Junction 16 Eastbound merging ramp at 15 minute intervals.

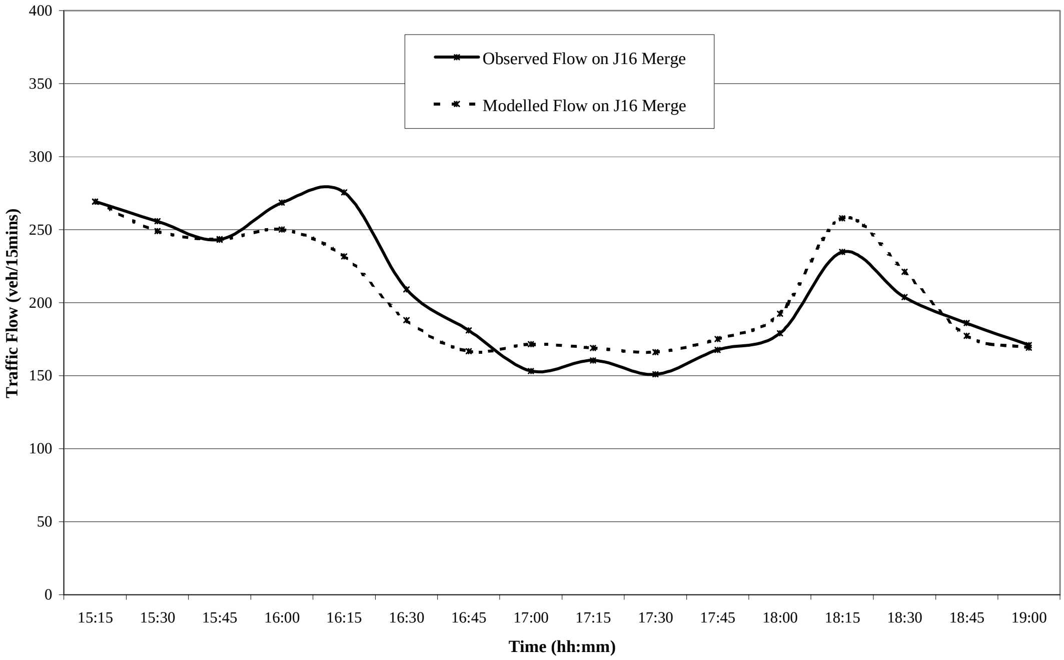

Figure 4.2 : M8 Observed and Modelled Traffic Flow Profiles at Junction 16 On Ramp

4.2.3 The traffic flow on the Junction 16 merge within the model is controlled by the interface between the Paramics and ALINEA software. This made it a key factor in assessing the ability of the traffic model to simulate typical observed conditions. The comparison presented in Figure 4.2 show that the model was able to provide a good representation of observed data.

4.2.4 Figure 4.3 shows how the recorded motorway occupancy from the model compares to that collected from the in-situ loop on the M8 at Junction 16. Critical motorway occupancy defines the boundary above which the ALINEA strategy will begin to control traffic. It will seek to achieve this occupancy level during its period of operation.

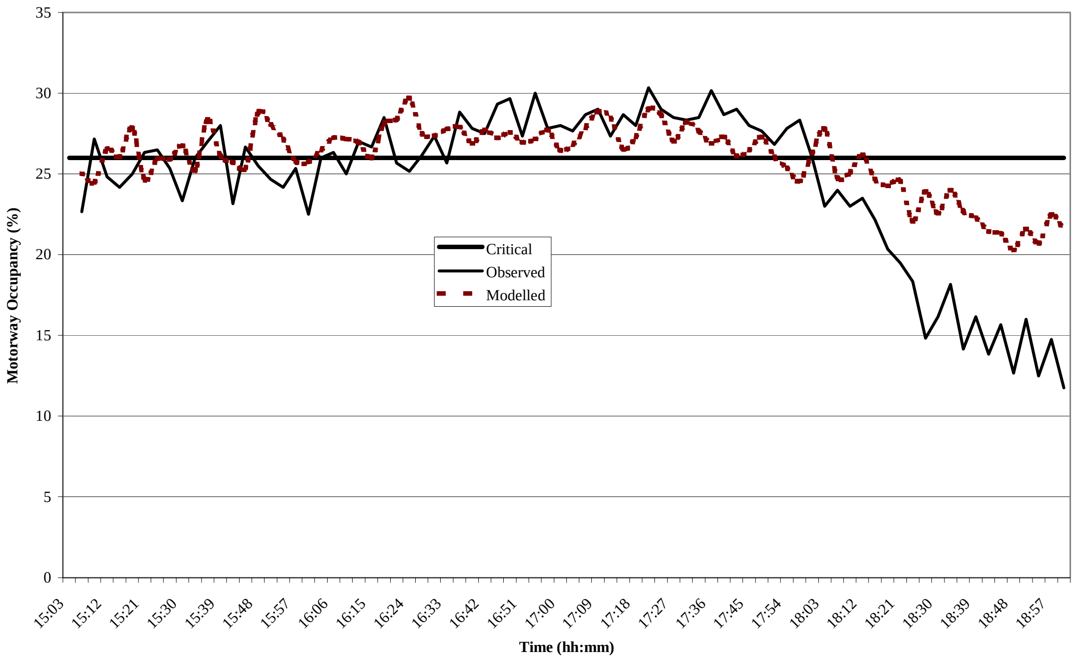

Figure 4.3 : M8 Observed and Modelled Motorway Occupancies at Junction 16

4.2.5 The definition of motorway occupancy is expressed as the percentage of time that a loop is indicating presence. This is evaluated every measurable period (currently one minute) at the site and this is simulated within the model.

4.2.6 Figure 4.3 shows that the modelled motorway occupancy is replicating observed motorway occupancy figures well. The only exception being the decay period after 18:00 when the distribution of traffic between the monitored motorway occupancy lanes is over estimated.

4.2.7 Overall the model produced a high level of accuracy, and comparisons between observed and modelled outputs showed the model adequately met the DMRB validation criteria.

4.2.8 The results confirmed that the ALINEA/Paramics software is suitable for modelling ramp metering. Furthermore, using the outputs from Paramics, it is possible to conduct operational, economic, and environmental assessments and compare the before ramp metering and after ramp metering scenarios in fine detail prior to any field trials.

4.2.9 Screen captures from the modelling software at Junction 16 of the M8 are shown in Figure 4.4.

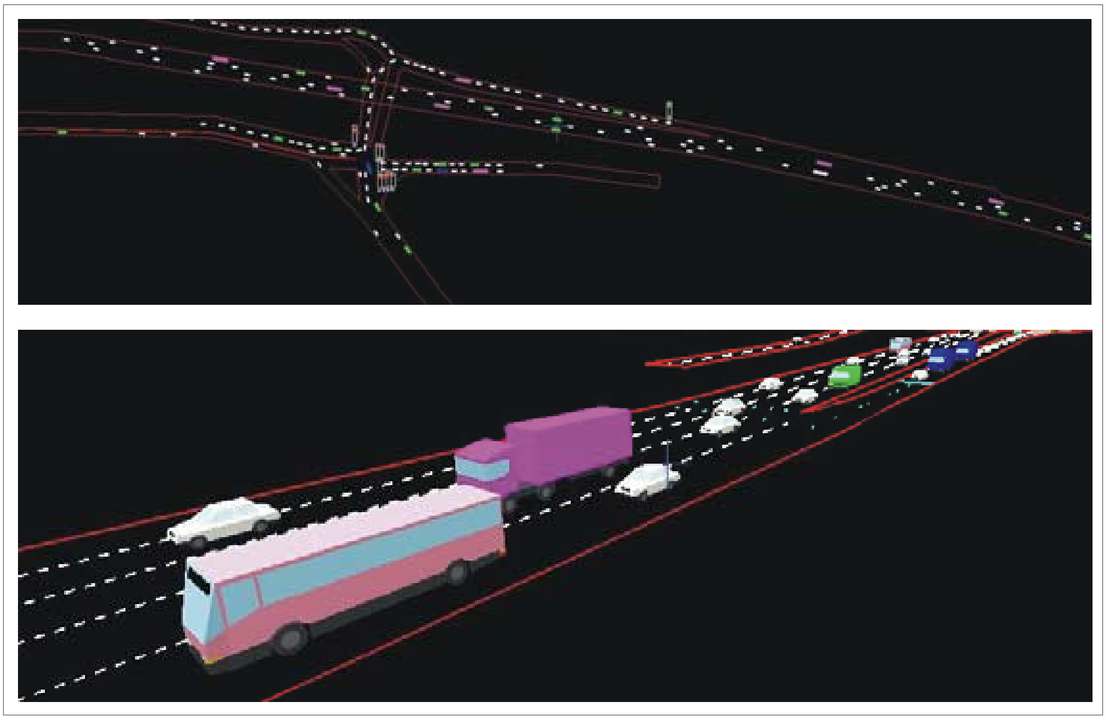

Figure 4.4 : Image Captures from ALINEA/Paramics Software

5 A720 MODEL

5.1 Ramp Metering Infrastructure

5.1.1 Using the M8 as a guide, the A720 ramp metering control infrastructure was modelled with traffic signals on the merging Dreghorn ramp, a motorway occupancy loop detector west of the Dreghorn merge and ramp flow rate loop detectors on the ramp at the signal stopline.

5.1.2 The occupancy of the motorway was measured across both lanes of the A720 with the average applied in the ALINEA law. Figure 5.1 shows a schematic diagram of the model infrastructure specified at the Dreghorn junction.

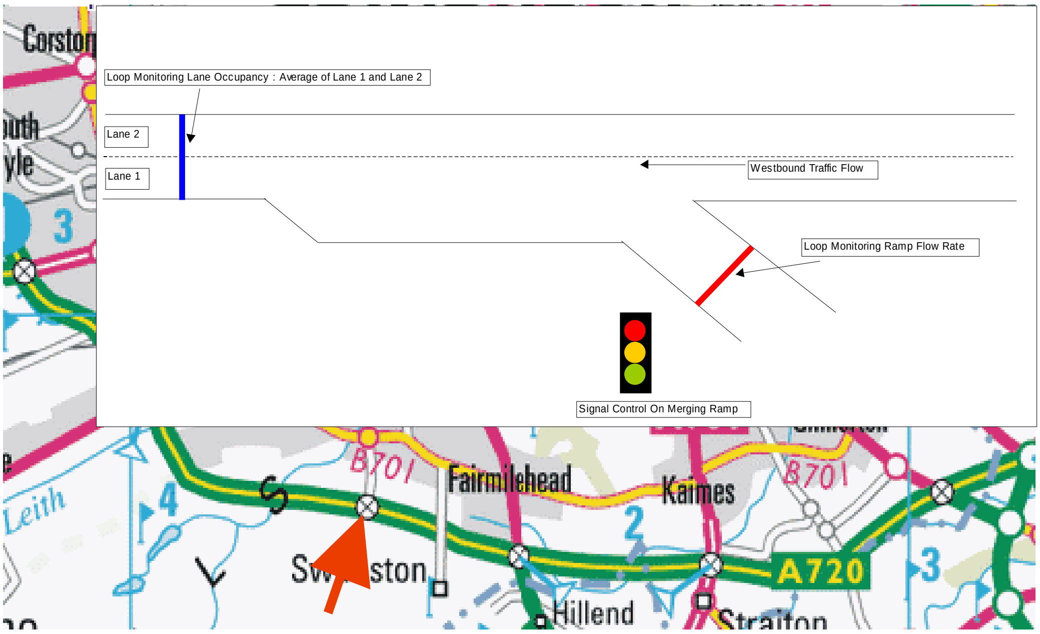

Figure 5.1 : A720 Ramp Metering Infrastructure at Dreghorn

5.2 Modelling

5.2.1 In order to establish the critical occupancy trigger value for ALINEA at this site, model runs were completed and the occupancy value on the dual carriageway monitored over the flow breakdown period. Further to this analysis the critical motorway occupancy was adopted as 20. Figure 5.2 plots modelled motorway occupancy against the critical occupancy over the model period.

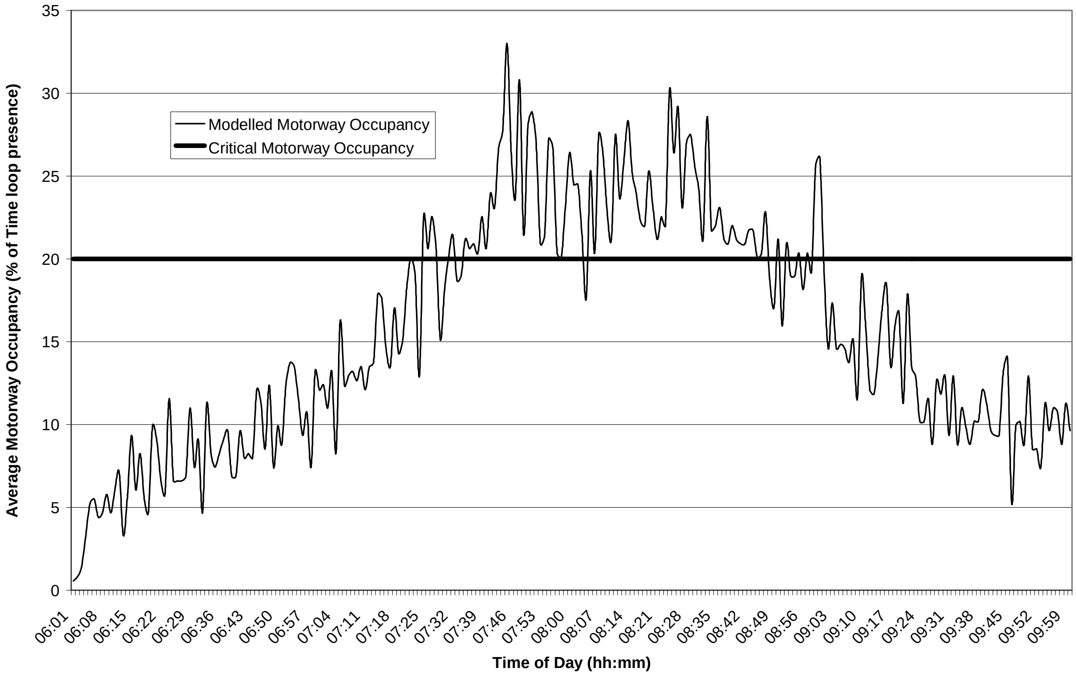

Figure 5.2 : A720 Modelled Motorway Occupancy at Dreghorn

5.2.2 It is evident from Figure 5.2 that flow starts to break down at Dreghorn around 07:30, at this point ALINEA will begin to control the ramp flow via the traffic signals. The period of control effectively runs from 07:30 through until 09:00.

5.2.3 Figure 5.3 shows the resultant flow rate control being applied by ALINEA via the traffic signals.

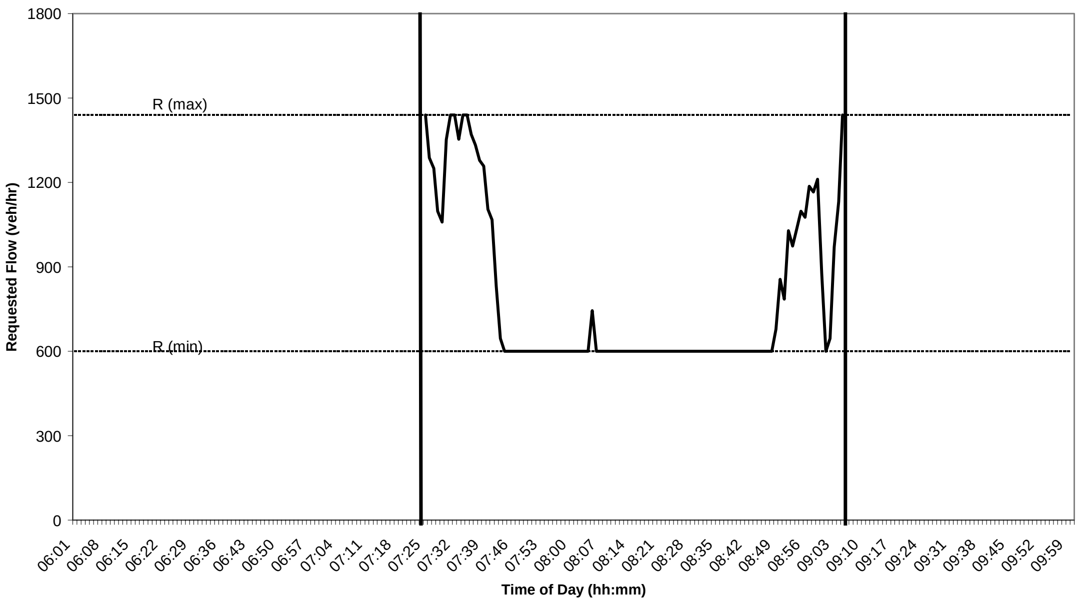

Figure 5.3 : A720 Modelled Requested Flow Rate (Veh/hr) at Dreghorn

5.2.4 It can be seen that before and after the peak congestion period, ALINEA has shoulder periods of control. Between 07:30 and 07:50 the ramp flow rate is steadily reducing as motorway congestion increases. Likewise between 08:50 and 09:00 ALINEA begins to increase the rate of flow for the on-ramp as motorway congestion eases.

5.3 Scheme Assessment

5.3.1 Using outputs from the Paramics model, operational, environmental and economic assessments were undertaken to evaluate the potential of ramp metering at the A720 Dreghorn junction.

5.3.2 The results of all the assessments indicated overall benefits with ramp metering. As an example, Figure 5.4 shows a comparison of traffic flow profiles on the Dreghorn ramp and on the A720 prior to the Dreghorn ramp with and without ramp metering.

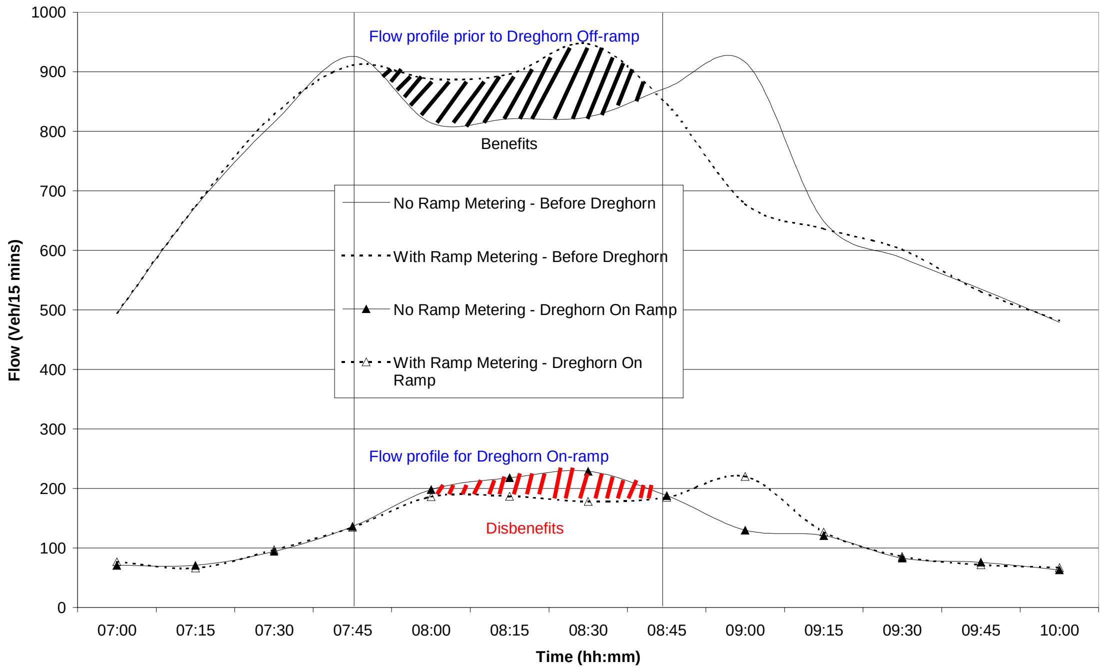

Figure 5.4 : A720 Traffic Flow Profiles at Dreghorn

5.3.3 Figure 5.4 demonstrates the improved flow through Dreghorn on the A720 with ramp metering, the shaded areas highlighting larger benefits to the strategic traffic on the A720 compared with the smaller disbenefits to the local traffic joining the A720 at the Dreghorn junction.

6 FINDINGS AND CONCLUSIONS

6.1 Findings

6.1.1 The software written to interface with the Paramics microsimulation package showed that it was possible to mimic the complexities and responses of the ramp metering ALINEA law within a modelled environment.

6.1.2 The results from the M8 model confirmed that the ALINEA/Paramics software linked via the SNMP interface can provide a high level of model validation. From traffic flow comparisons at 15-minute intervals to detailed ALINEA output comparisons of motorway occupancy, the model simulates the M8 ramp metering site well.

6.1.3 The A720 model demonstrated the ability of the ALINEA/Paramics software to be transferred to an independent site to assess the potential for ramp metering.

6.2 Conclusions

6.2.1 As an essential part of the software design, the ALINEA/Paramics software permits fully interactive user control over all key configuration parameters required to assess detailed installation criteria within the confines of the ALINEA strategy, prior to field installation.

6.2.2 As demonstrated by the A720 model, the software can be fully transferred and readily applied to evaluate potential ramp metering sites and strategies without recourse to expensive on field trials.

6.2.3 While in this instance the SNMP interface has been used specifically to closely reproduce ALINEA, its range of applications can interface with urban traffic control (UTC) tools from SCOOT to SCATS, and the potential to develop totally new network management control devices.

6.3 Future Work

6.3.1 If ramp metering on the A720 at Dreghorn were to be progressed, further model optimisation and site engineering would be required prior to implementation. In particular, the modelling exercise would have to consider the potential re-routing of traffic over a wider area and potential complimentary and ameliorative measures.

6.3.2 This commission has shown that model accuracy could be further enhanced with more detailed observations and studies of driver behaviour on motorways, particularly with respect to:-

- Merging / diverging traffic
- Weaving / lane changing
- Lane speeds and usage

These studies would not only enhance modelling and assessment capabilities but would also improve understanding and knowledge for the design of motorway sections and junctions.