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Transportation Research Procedia 8 (2015) 204 – 214

Transportation Research Procedia

www.elsevier.com/locate/procedia

European Transport Conference 2014 – from Sept-29 to Oct-1, 2014

Metering with Traffic Signal Control – Development and Evaluation of an Algorithm

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Abstract

For some on-ramps, which cause congestion on the motorway, it is not possible to install a ramp metering system for geometric or other reasons. But sometimes it is possible to meter traffic with the traffic lights of nearby intersections in such a way that the situation on the motorway improves and on the urban network the situation does not get worse. The research described in this article investigates the use of the traffic lights as metering lights and for this an algorithm was developed. The new control algorithm was tested for a virtual network in a simulation environment. The results show that metering with traffic lights is possible and has potential, but the effectiveness is less compared with regular ramp metering.

Selection and peer-review under responsibility of Association for European Transport

Keywords: metering; traffic signal control; simulation

1. Introduction

In The Netherlands ramp metering is a common traffic management measure to decrease traffic jams on motorways and to improve throughput. Evaluation studies showed that it can be a very effective measure: the capacity of the motorway increased with 0% - 5%, speed on the motorway with up to 20 km/h and delay decreased with 8% - 30%, on average with 11%, as was summarised by Middelham and Taale (2006). But on some locations, where it would be profitable to implement, ramp metering is not possible, because of the geometry of the on-ramp.

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Selection and peer-review under responsibility of Association for European Transport
doi:10.1016/j.trpro.2015.06.055

For example, the on-ramp is too short to buffer traffic on it and blocking back would lead to queues on the urban network or it could be too expensive to implement ramp-metering on that location. Therefore, in the research described in this article we look at the use the traffic signal controllers of nearby intersection to meter traffic heading for the motorway and we test this option with simulation for a theoretical network. The research is part of a development to come to a further integration of traffic management for motorways and urban traffic control. A development which is stimulated in The Netherlands with a field operational test around Amsterdam. Part of this test is to coordinate the operation of ramp metering systems with traffic signal control and to investigate the effects.

The Praktijkproef Amsterdam (Dutch for Field Operational Test Integrated Network Management Amsterdam) aims at gaining practical experience with applying integrated network management in a large-scale regional (urban and motorway) network. It aims to improve the effectiveness of deploying traffic management measures in an integrated and coordinated way as proposed by Rijkswaterstaat (2009). Within this project, the cooperating road authorities have opted for a stepwise implementation of the network control approach. In the first phase of the project the focus is on a motorway stretch (the A10-West, part of the A10 ring road) and its on- and off-ramps and connecting intersections, and one connecting urban arterial with its intersection controllers. All on-ramps to the motorway are equipped with ramp metering systems. In the subsequent phases, larger areas of the Amsterdam network will be considered as described by Hoogendoorn et al. (2014).

One of the main goals of the integrated control strategy is to use the spare capacity (buffer space) in the network. If there is ramp-metering traffic queues on the on-ramp, but normally the on-ramp has a limited space to store traffic. Using other parts of the network to store queues could improve the situation, because then on-ramp space for queues is virtually extended and ramp-metering can operate in the preferred mode for a longer time. These so-called buffers are predefined locations where vehicles can be ‘stored’ for a little while, without causing problems for the rest of the network. The usage of buffers in the network depends on the level-of-service in the network: if traffic conditions worsen, more buffer space can be added to alleviate the problems.

To use this buffer space in an effective way for the combination of a ramp metering system and a connecting intersection a supervisor module was developed. This supervisor (named ST1-Light or ST1L for short) essentially controls the inflow from intersection controllers adjacent to the ramp meter into the on-ramp, in order to prevent the queue on the on-ramp from spilling back onto the urban arterial. In doing so, it extends the storage space for the ramp-meter substantially. In particular for the Dutch situation, since the storage space on the on-ramps in many cases is very limited.

And that brings us to the situation in which the on-ramp has not enough storage capacity to implement an effective ramp metering system. The question then arises if it is possible to use the intersection controller to meter traffic to the motorway directly. This article deals with this topic. First, it describes the original algorithm if a ramp metering system is available and then the adjustments for a situation without ramp metering. After that the simulation setup is given and the results of the runs to test the algorithm. Finally, some conclusions are drawn and directions for further research are given.

2. Control principles

For this research we look at the situation where a bottleneck occurs downstream of the on-ramp. Normally, the ramp meter will restrict the inflow to the motorway to improve the situation there, at the expense of a queue on the on-ramp itself. If the queue grows the urban network can get blocked. To prevent that, the supervisor ST1L is asked to buffer traffic on the available locations in the network to decrease the flow to the on-ramp. In that way the ramp metering system can do its job and the queue on the on-ramp will stay within the limits.

An important issue then is how to distribute the surplus of vehicles between the available buffer locations, taking into account the limits these buffers have. The ST1-Light deals with this issue if there is ramp metering available and the control strategy for that is described in the next paragraph.

2.1. Control strategy with ramp metering

The ST1-Light realises the coordination between the traffic control goals which are set for the motorway and the local controllers on the urban arterials, using the available buffers. Every on-ramp has a feeding urban arterial. For