Assessment Plan Coordinated Ramp-Metering A10-West

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Ministry of Transport, Public Works and Water Management

Directorate-General for Public Works and Water Management

Transport Research Centre (AVV)

Assessment Plan

Coordinated Ramp-Metering A10-West

Report ID 93.304.02/2

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CONTENTS

1. Introduction

To achieve a more efficient use of the existing infrastructure, the Directorate North-Holland of the Ministry of Transport, Public Works and Water Management is implementing a number of traffic management measures. One of those measures is ramp-metering.
Simulation studies, conducted with the programs SATURN and FLEXSYT (references [1] and [2]), have shown that several metering systems on the on-ramps to the A10-West, part of the ringroad around Amsterdam, have a positive effect on the traffic flow on the motorway, although the effects for the urban network can be negative.
As a result of those studies, the decision was made to extend the existing metering system on the ramp S101 (Hemhavens-West) with ramp-metering systems on the ramps S102 (Nieuwe Havens), S104 (Bos en Lommer) and S105 (Geuzenveld). In the framework of the DRIVE-II project EUROCOR it was decided to use coordinated ramp-metering on those ramps.
A map of the situation is shown in Figure 1.

Figure 1. *Survey of the field of study*

The goals of the metering measure can be expressed as follows:

1. Improvement of the traffic flow in the western part of the city of Amsterdam, including the A10-West;
2. Gaining experience with a coordinated metering strategy;
3. Future integration of the metering system with a traffic management system involving the entire ringroad;
4. Priority to Public Transport;

everything under the restriction of causing only limited hindrance for the traffic on the urban network.

The implementation of coordinated ramp-metering is part of the DRIVE-II project V2037: EUROCOR (EUROpean Urban CORridor Control). Within this project the possibilities for the management of corridors with ramp-metering and Variable Message Signs are studied. The test-sites for this project are the Corridor Périphérique around Paris and the A10-West, part of the ringroad around Amsterdam. On the Corridor Périphérique several strategies for ramp-metering, VMS signs and traffic control plans are studied. The A10-West is the test-site for the different metering strategies (see reference [3] for more information about EUROCOR).

The Directorate North-Holland has asked the Transport Research Centre (AVV) to make an assessment plan for the evaluation of the system for coordinated ramp-metering, concerning the aspects related to traffic.
This report contains the approach to do so. Chapter 2 explains coordinated ramp-metering and chapter 3 describes the situations and aspects to be evaluated and the methods to be used. Finally chapter 4 deals with some other aspects of the evaluation.

2. Ramp-metering

2.1. Introduction

Ramp-metering is controlling the access of traffic from an on-ramp to the motorway. The number of vehicles that is allowed to enter the motorway depends on the actual situation on the motorway. That situation is translated to a cycle time for the metering system. In the Netherlands a lot of publications about ramp-metering in general exist. Sufficient further information can be obtained in these publications (references [4], [5], [6], and [7]).

2.2. Coordinated ramp-metering

An unique aspect of this project is that a system for coordinated ramp-metering is used for the first time in The Netherlands. Elsewhere in Europe (Boulevard Périphérique around Paris) some experiments have been carried out, but these experiments are reported insufficient and weak, so that it can be stated that the system for the A10-West will be the first operational one in Europe.
Coordinated ramp-metering implies that a central control unit determines for every ramp the amount of traffic that is allowed to enter the motorway for every time period, depending on the actual situation of both the motorway and the on-ramps. Data is gathered with loop detectors and sent to the central control unit. This unit processes the data and sends the correction on the cycle time to all metering installations.
The metering installations can either operate with or without central control. If the installations operate without central control, a choice can be made between two metering strategies: the Rijkswaterstaat strategy, based on volume and speed, and the ALINEA strategy, based on density (in practise this is occupancy, defined as the fraction of time that a loop detector is occupied). These strategies are discussed in the publications mentioned in the preceding paragraph and in reference [8].
If the metering installations operate with central control, four strategies are possible: ALICEN, RWSCEN, METALINE, developed in the framework of the DRIVE-II- project EUROCOR, and RWSCOR. These strategies are discussed below, but first the coordination is explained.

2.2.1. Coordination

In the first place coordination is focused on switching the metering installations on and off. Given the status of every local installation, the coordinator decides if and which installations must be activated or switched off, based on decision rules.
In the second place the coordinator can adjust the amount of traffic, that is allowed to enter the motorway for a certain installation, based on the situation on the other on-ramps.

2.2.2. The strategies ALICEN and RWSCEN

So there is the possibility that coordination is only concerned with switching on and off the local metering installations. This strategy is called ALICEN if the local installations meter according to the ALINEA strategy and RWSCEN of the local installations meter according to the Rijkswater-staat strategy. These strategies do not adjust the amount of traffic that is allowed to enter the motorway.

2.2.3. The METALINE strategy
This strategy is an extension of the ALINEA strategy for local ramp-metering and is based on an optimal occupancy. The strategy tries to keep the occupancy on the motorway near an optimal value, by allowing more or less traffic from an on-ramp to enter the motorway. The amount of traffic that is allowed to enter the motorway is calculated locally and adjusted according to the actual values of the occupancy on all cross-sections where it is measured and which are taken into account by the strategy.

2.2.4. The RWSCOR strategy
This strategy is an extension of the Rijkswaterstaat strategy for local ramp-metering and is based on an optimal usage of the downstream capacity. The amount of traffic that is allowed to enter the motorway is calculated locally, but is adjusted according to the measured speeds near the downstream on-ramps.

2.3. Effects of ramp-metering

At this moment three ramp-metering installations are in operation in The Netherlands. The first one is located on the S101 ramp to the A10-West in the direction of the Coentunnel and operates since 1989. The second one is located on the Delft-Zuid ramp to the A13 in the direction of Rotterdam. This one is in operation since 1990, but has some technical problems. The third one is located on the Zoetermeer ramp to the A12 in the direction of Gouda and Utrecht and is in operation since 1992.
The ramp-metering installations near the Coentunnel and Delft-Zuid were thoroughly assessed twice and the one near Zoetermeer was assessed once. The effects of ramp-metering are reported extensively (see references [4], [9], [10], [11, [12], [13] and [14]) and therefore, for shortness sake, to these publications is referred to.

3. Assessing traffic flow aspects

3.1. Introduction

From the previous chapter it is clear that seven situations can be studied, namely:

- the situation without ramp-metering, except on the S101 (the current situation);
- the situation with ramp-metering with the local ALINEA strategy;
- the situation with ramp-metering with the local Rijkswaterstaat strategy;
- the situation with ramp-metering with the coordinated ALICEN strategy;
- the situation with ramp-metering with the coordinated RWSCEN strategy;
- the situation with ramp-metering with the coordinated METALINE strategy;
- the situation with ramp-metering with the coordinated RWSCOR strategy.

Especially the comparison between the coordinated strategies is important for the EUROCOR project. For the determination of the aspects that are to be assessed, use has been made of the previous evaluation studies and of the aspects that are recommended in [3]. After the stock-taking the following aspects were chosen:

- traffic volume motorway;	(veh/hr)
- capacity motorway;	(veh/hr)
- traffic volume on-ramps;	(veh/hr)
- traffic volume urban network;	(veh/hr)
- speed on the motorway;	(km/hr)
- travel time;	(min/veh)
- delay;	(min/veh)
- quality standard traffic flow;	(%)
- distance travelled;	(veh*km/hr)
- route choice;	(veh/hr)
- length of queues on the motorway;	(m)
- size of queues on the motorway;	(veh*km)
- length of queues on the on-ramps and urban network;	(m)
- red-light obedience;	(%)
- weather conditions;	
- incidents and accidents.	

All the aspects mentioned will be discussed in the next paragraphs. At the same time it will be indicated which methods for measurement must be used.

3.2. Traffic volume motorway

3.2.1. Description

The traffic volume on the motorway is the number of vehicles per hour that passes a cross-section, during a measure period. Mostly a measure period of a quarter of an hour is used. The effects of ramp-metering on these volumes must be determined.

3.2.2. Method for measurement

Traffic volumes can be measured in different ways: visually or automatically. In this case automatic measurement is chosen, because of the availability of measurement equipment. In the first place the metering installations themselves can be used as measurement equipment. Every installation has a set of loop detectors upstream and downstream of the ramp at it's disposal. The data of these loop detectors is recorded in files per measure period (one minute). For every day the metering installation makes a file containing the data of the motorway (volume and smoothed speed per measure period and per lane), volume on the on-ramp and data about the functioning of the installation (metering times and error messages). The Transport Research Centre (AVV) has software at it's disposal with which the files can be processed and transformed into status reports, tables with hourly volumes and red-light obedience and plots of fundamental diagrams, the course of motorway volumes and speed and the course of cycletimes and on-ramp volumes. Examples of these output are added in the appendices. The use of this software is not compulsory.
Furthermore, the fixed measuring locations, of the network for measurements on the Dutch motorways, can be used. On the A10-West three fixed measuring locations are located. A periodical counting location, which gives volumes per hour, near kilometre 22.8. A periodical 24-hours count is done near kilometre 25.4 and a permanent hour count is done near kilometre 28.8, just before the Coentunnel. The data of the last counting location mentioned, can be obtained from the division BG (Basic Data) of the Transport Research Centre (AVV). If data from the other counting locations are necessary, then further agreements with the division BG have to be made.

There are also loop detectors in the Coentunnel itself. These can be used for data check and for calculating the capacity of the tunnel, among other things.

3.2.3. Locations

The exact positioning of the loop detectors can be found in the drawings that are part of the specifications for the metering installations.

3.3. Capacity motorway

3.3.1. Description

A definition of the capacity that is commonly used, does not exist. The Highway Capacity Manual (1985) defines the capacity as follows:

> *In general, the capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse through a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions.*

This definitions is not precise enough, because it is not clear what is understood by 'reasonably expected'. Therefore other definitions of the capacity are also used, for example: the capacity is the 95 percent value of the measured volumes. That means that 95 percent of the measured volumes is lower than that value. For the assessment of the ramp-metering installations Delft-Zuid and Zoetermeer-Oost use has been made of survival analysis. This method estimates the chance distribution of the capacity for a certain congestion criterium (for example: speed must be lower than 80 km/hr).

3.3.2. Method for calculation
The capacity has to be calculated from the measured volumes. If sufficient volume data (per quarter of an hour) are available, survival analysis is the most appropriate way to calculate capacity. Commonly used is the product-limit method of Kaplan-Mayer.

3.3.3. Locations
The capacity has to be calculated only for every measuring location upstream of the on-ramp, because, the upstream location is also the downstream location of another on-ramp.

3.4. Traffic volume on-ramps

3.4.1. Description
From the assessment of the ramp-metering installation on the S101 on-ramp it was clear that traffic from this on-ramp shifted to the on-ramps upstream. It is to be expected that again traffic will divert from certain on-ramps to other on-ramps. Therefore the number of vehicles per hour that uses a certain on-ramp has to be measured.

3.4.2. Method for measurement
All on-ramps, including the S106 ramp have to be measured. For the on-ramps with ramp-metering the volume is automatically measured and stored in files. That is the number of vehicles per measure period (one minute). For the S106 ramp automatic counting devices have to be placed, that count the number of vehicles per quarter of an hour.

3.5. Traffic volume urban network

3.5.1. Description
One of the effects of ramp-metering on route choice, except choosing another on-ramp, could be the choice for another tunnel: IJtunnel or Zeeburgertunnel. To investigate this, it is necessary to measure the volumes in these tunnels and on a number of intersections in the city. These intersections are Basisweg-Einsteinweg, Kabelweg-Basisweg and Haarlemmerweg-Radarweg. On these intersections the decision for a certain route is taken.

3.5.2. Method for measurement
The volumes in the IJtunnel and Zeeburgertunnel can be measured automatically. The Dutch measuring network for the motorways has a permanent measuring location near the Zeeburgertunnel (km 9.5 of the A10-East). The data from this location can be obtained from the division BG of the Transport Research Centre (AVV). For the data from the IJtunnel arrangements have to be made with the municipality of Amsterdam.
The volumes on the intersections can not be measured automatically. Options are using counting equipment or human observers. The division for Spatial Organization of the Municipality of Amsterdam has pointed out the possibility that she can take care of the measurements on the intersections.
For this aspect only the situations without and with ramp-metering are important. For this aspect the comparison between the different strategies is not important.

3.6. Speed on the motorway

3.6.1. Description
The average speed is an important assessment criterion. For this aspect a comparison between the current situation and the different situations with ramp-metering and the comparison between the average speed on different cross-sections are important.

3.6.2. Method for measurement
The smoothed speed per measure period (one minute) is automatically measured and stored in files by the metering installation.

3.6.3. Locations
The exact positioning of the loop detectors can be found in the drawings that are part of the specifications for the metering installations.

3.7. Travel time

3.7.1. Description
For the assessment of the ramp-metering installation on the S101 ramp the travel times from the different on-ramps to a location downstream the Coentunnel were measured. These measurements have to be done also for this assessment.

3.7.2. Method for measurement
The travel time has to be measured by recording licence-plate numbers and passage times (in seconds) on several locations by observers. It is not possible to record all vehicles, so that, for example, only the white vehicles are recorded. Using the passage times of the vehicles the travel times for the different routes can be calculated. Furthermore the total travel time (vehicle hours per hour) and the maximum travel time can be calculated from the volumes and the measured travel times. These aspects are important for the EUROCOR project.

3.7.3. Locations
The observers have to be positioned at the beginning of every on-ramp. Furthermore observers are needed for the A10-West. If on an on-ramp a queue is formed that reaches the urban network, the observer has to record the times that the queue starts and ends to block the urban network.

3.8. Delay

3.8.1. Description
Delay is defined as the difference between the measured travel time and the free travel time. The free travel time is the travel time of a vehicle that travels through the network unhindered. For the free travel time several definitions are possible.

3.8.2. Method for calculation
For the assessment of the ramp-metering installation on the S101 ramp the following method is used: the travelled, average speed is calculated from the measured travel times and the distances; bases upon these average speeds the 95-percent value is taken as the free travel speed, from which the free travel time can be obtained. The difference between this free travel time and the measured travel times is defined as delay.

So the delay must be calculated in the described way for the routes for which the travel time is measured. From these delays and the volumes the total delay (vehicle hours per hour) and the maximum delay can be obtained. These aspects are important for the EUROCOR project.

3.9. Quality standard traffic flow

3.9.1. Description
A quality standard is chosen comparable with the congestion chance from the Second National Structure Plan, namely the chance that, with a certain reliability, a vehicle can travel a route with a certain speed.

3.9.2. Method for calculation
The chance mentioned above has to be calculated, for the evening rush-hour and for all measuring locations, for a speed of 80 km/hr; that is the number of observations for which the average speed is larger than or equal to 80 km/hr, divided by the total number of observations.

3.10. Travelled distance

3.10.1. Description
For the assessment of the ramp-metering installation on the S101 ramp it is established that, caused by the new distribution of traffic to the on-ramps, the total number of travelled kilometres has decreased for the urban network and has increased for the A10-West. For the current assessment this aspect is also of importance, especially for the EUROCOR project.

3.10.2. Method for calculation
The total distance travelled on the A10-West itself, can be calculated, for the several sections between the on-ramps, from the traffic volumes and the length of those sections. Further conclusions with regard to the total distance travelled have to be drawn from the volumes on the motorway, the on-ramps and the urban network.

3.11. Route choice

3.11.1. Description
The implementation of ramp-metering on several on-ramps to the A10-West motorway could effect the route choice of drivers. This effect can demonstrate itself in two different ways: drivers choose one of the other on-ramps or drivers choose one of the other tunnels.

3.11.2. Method for determination
The effects mentioned above must be determined by measuring the traffic flows of all on-ramps and the other tunnels, completed by measuring volumes on three important intersections of the urban network. By analyzing the possible shifts in traffic volumes, it is possible to state something about route choice behaviour.

3.12. Length of queues on the motorway

3.12.1. Description
At this moment congestion occurs frequently before the Coentunnel in the northern direction in the evening rush-hour. In 1992 the KLPD (traffic police) reported 221 queues. To determine the effects of ramp-metering on the length of queues, it is necessary to measure this using observers. A queue is defined as slow going traffic (speed lower than 30 km/hr) or stationary traffic.

3.12.2. Method for measurement
The position of the heads and the tails of the queues have to be recorded every five minutes, with a precision of 100 metres, by the observers. From these data the length and the duration of the queues can be calculated with a precision of five minutes. A comparison with the data from the files of the metering installations and the data of KLPD (traffic police) in Driebergen is necessary for accuracy.

3.12.3. Locations
The observers have to be posted at strategic locations. Possibly these measurements can be combined with the recording of licence plate numbers.

3.13. Size of queues on the motorway

3.13.1. Description
The size of queues is defined as the total number of vehicle kilometres that are travelled under congested conditions. This aspect is assessed for both the ramp-metering installations near Delft and Zoetermeer.

3.13.2. Method for calculation
The size of the queues can be calculated by multiplying the queue length with the traffic flow at that time.

3.14. Length of queues on the on-ramps and urban network

3.14.1. Description
One of the effects of ramp-metering is the shifting of delay from the motorway to the on-ramp. That means that the urban or rural network suffers extra delay and longer queues and that can cause the blocking of intersections. The extra delay is determined with the aspect ’delay’, but it is also necessary to determine the effects on the length of queues.

3.14.2. Method for measurement
The length of the queues on the on-ramp and the directions of the intersections that lead to the on-ramp are recorded by observers every five minutes.

3.14.3. Locations
The observers have to be posted at the beginning of every on-ramp and at strategic locations on the intersections. The length of the queues can be recorded with the aid of a map.

3.15. Red-light obedience

3.15.1. Description
The inverse of the red-light obedience (red-light violation) is defined as the number of vehicles that drove through red light divided by the total number of vehicles that was metered.

3.15.2. Method of measurement
The red-light violation is measured by the ramp-metering installations. From the files of the metering installations, with the AVV programs, the number of red-light violators and the percentage can be obtained.

3.16. Weather conditions

3.16.1. Description
It is known that weather conditions have a great influence on traffic flow. To make the various situations comparable, it is necessary to take the weather conditions into account.

3.16.2. Method for determination
The consultant has to record the weather conditions, that is: the type of weather (dry, rain, snow, fog, etc.) and the conditions of the road surface (dry or wet) on the days that observers are measuring the aspects mentioned above. It is possible to obtain rain data (millimetres rain) with the Dutch Royal Meteorological Institute (KNMI) for the entire measuring period.

3.17. Incidents and accidents

3.17.1. Description
Incidents are all the events that disturb the traffic flow, for example: accidents, hight detection before the Coentunnel, lost cargo, broken down vehicles, etc.
The measuring period is to short to make well-founded statements about the effects of ramp-metering on the number of accidents, but these data are necessary for making a good comparison, which means for selecting comparable days.

3.17.2. Method for determination
Observers have to record incidents and accidents, their nature and their duration, that occur within their area. These data have to be completed with data of the police and the traffic control centre in Oostzaan (CBO).

4. Other aspects of the assessment

4.1. Introduction

This chapter deals with a number of other aspects related to the assessment. To begin with it is indicated which work has to be done in the framework of the EUROCOR project and which not. Then something is said about the measuring period and also something about presentation. Finally a global time schedule is given.

4.2. Relations with the EUROCOR project

A distinction has to be made between the assessment necessary for the EUROCOR project and the assessment for the Directorate North-Holland. This distinction must be made, because the time schedule for the EUROCOR project is fixed. The following tables, from the 'annex to feasibility study' [3], show the relevant aspects for EUROCOR

Scenarios and criteria to be used in the 2 test-sites

Scenarios	Criteria	Total Travel time	Maximum Travel time	Travel Distance	Total Waiting time	Maximum Waiting time	Time spend in congestion	Queue lengths and frequency
No control	on-line	+ ●	+	+ ●	+ ●	+	●	+
	off-line	+ ●	+ ●	+ ●	+ ●	+ ●	●	+ ●
Local control[1,2]	on-line	+ ●	+	+ ●	+ ●	+	●	+
	off-line	+ ●	+ ●	+ *	+ ●	+ ●	●	+ ●
Coordinated (corridor) control[3]	on-line	+ ●	+	+ ●	+ ●	+	●	+
	off-line	+ ●	+ ●	+ *	+ ●	+ ●	●	+ ●
Normal traffic[4]	on-line	+ ●	+	+ ●	+ ●	+	●	+
	off-line	+ ●	+ ●	+ ●	+ ●	+ ●	●	+ ●
Incident	on-line	●		●	●		●	
	off-line	●	●	●	●	●	●	●

1. Applied to each controllable on-ramp individually (C.P.)
2. Off-line: only for two on-ramps (A10-West)
3. Two types of Coordinated control: RWS-strategy versus METALINE (A10-West)
4. Taking into account the surface intersections constraints

\+ A10-West: Amsterdam test-sit
● C.P.: Corridor Périphérique in Paris

Scenarios and criteria to be used in the 2 test-sites (continued)

Scenarios	Criteria	Total time[5] Delay of Vehicles diverted	Traffic Distribution	Travel Distance	Number of Vehicles served	Speed	Fuel Consump-tion	Diversion estimation
No control	on-line			+ ●	+ ●	+ ●		+ ●
	off-line	●	●	+ ●	+ ●	+ ●	●	●
Local control[1,2]	on-line			+ ●	+ ●	+ ●		+ ●
	off-line	●	●	+ *	+ ●	+ ●	●	●
Coordinated (corridor) control[3]	on-line			+ ●	+ ●	+ ●		+ ●
	off-line	●	●	+ *	+ ●	+ ●	●	●
Normal traffic[4]	on-line			+ ●	+ ●	+ ●		+ ●
	off-line	●	●	+ ●	+ ●	+ ●	●	●
Incident	on-line		●	●	●	●		●
	off-line	●	●	●	●	●	●	●

1. Applied to each controllable on-ramp individually (C.P.)
2. Off-line: only for two on-ramps (A10-West)
3. Two types of Coordinated control: RWS-strategy versus METALINE (A10-West)
4. Taking into account the surface intersections constraints
5. Total time delay of vehicles diverted (or not) along a long route compared to the route duration of vehicles on the main route. (Included is the subcriterion routing the flow which is actually diverted by the VMS.)

+ A10-West: Amsterdam test-sit
● C.P.: Corridor Périphérique in Paris

So for the EUROCOR project a number of aspects is of importance, namely: total travel time, maximum travel time, total distance travelled, total and maximum delay, the length and frequency of queues, the traffic volume and the speed, as shown in the tables above. Therefore these aspects have to be analyzed and reported first.

4.3. Measuring period

4.3.1. Introduction

After the completion of the implementation, the best thing to do is to let the system operate for three weeks with the lights switched off. In those three weeks the current situation can be measured and errors that can occur can be mended. After that the system has to meter every week with a different metering strategy. In the ideal case for every situation at least 10 measuring days are necessary to get significant results. This means that at least a measuring period of 14 weeks is necessary. Taking into account unforeseen circumstances, holidays, etc. it boils down to a measuring period of 21 weeks, so 3 to 5 months. If the measuring period does not start in March, that means that the measuring period is not united. It also means that the costs for visual observations are very high. Therefore the measuring period has to be shortened. For this a distinction is made between automatic measurements and visual observations.

4.3.2. Automatic measurements

As soon as the implementation is completed, the ramp-metering installations can be used for measurements. Data have to be collected during the entire measuring period, from March up to and including June. It is not necessary to collect data for the entire 24 hours, only the period from 14:00 until 20:00 hrs. is of importance. All other automated data collectioning must use the same periods.

4.3.3. Visual observations

Visual observations are done to determine travel time, the length and duration of queues and possibly traffic volume on the urban network. For every situation eight days have to be measured, so that means that 56 measuring days are necessary. These measuring days fall into the period March up to and including June. During a day observations have to be done from 15:00 until 19:00 hrs. Possibly these times can be adjusted, depending on the time of appearance and disappearance of congestion.

4.4. Video observations

For presentational purposes, within DRIVE and conferences, both the situations before and after the implementation of ramp-metering have to be recorded, for every on-ramp. Therefor the camera must take a masked and high position, for example in an electric standard, as it was done for the assessment of the ramp-metering on the S101 on-ramp.

4.5. Time schedule

In the following table a global time schedule for the assessment is presented. The schedule is based on the assumption that measurements can start April/May 1994. The assessment is divided into three phases: a measuring phase, an analyzing phase and a reporting phase.

	1994									1995			
months	04	05	06	07	08	09	10	11	12	01	02	03	04
measuring phase	X	X	X	X		X	X	X					
analyzing phase								X	X	X	X		
reporting phase										X	X	X	X
analyzing phase EUROCOR								X	X	X	X		
reporting phase EUROCOR										X	X	X	

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[10] **Ramp-metering near the Coentunnel (Dutch)**, F. Middelham, Verkeerskunde, Volume 40, no. 4, April 1989

[11] **Pilot project ramp-metering Coentunnel, first evaluation (Dutch)**, BGC, reportno. RWE/-797/08/Bn, February 1990

[12] **A closer look at Coentunnel data (Dutch)**, BGC, reportno. RWE/969/08/Mn, August 1991

[13] **Ramp-metering on-ramp Delft-Zuid A13 (Dutch)**, Grontmij, report, November 1990

[14] **Second evaluation pilot project ramp-metering on-ramp Delft-Zuid A-13 (Dutch)**, Grontmij, DVK reportno. CXR91102.rap, November 1991

Appendices

```
930116 13:50:30  COMMUNICATIE FOUT

930127 09:19:52  GEEL_MIN_6              0.5
930127 09:19:52  GROEN_MAX_5             7.0
930127 09:19:52  GROEN_MAX_6             7.0
930127 09:19:52  GROEN_MIN_5             0.5
930127 09:19:52  GROEN_MIN_6             0.5
930127 09:19:52  HIAAT_UIT                 5
930127 09:19:52  I_BTR_R_AF_2            1.0
930127 09:19:52  I_BTR_R_AF_3            1.0
930127 09:19:52  I_BTR_R_AF_4            1.0
930127 09:19:52  I_BTR_T_AF_5            1.0
930127 09:19:52  I_BTR_T_AF_6            1.0
930127 09:19:52  I_BTR_R_OP_1            1.0
930127 09:19:52  I_BTR_R_OP_2            1.0
930127 09:19:52  I_BTR_R_OP_3            1.0
930127 09:19:52  I_BTR_T_OP_5            1.0
930127 09:19:52  I_BTR_T_OP_6            1.0
930127 09:19:52  I_DR_IN                4400
930127 09:19:52  I_DR_R_IN              3200
930127 09:19:52  I_DR_T_IN              1100
930127 09:19:52  I_DR_R_UIT             3000
930127 09:19:52  I_DR_T_UIT             1000
930127 09:19:52  I_DR_UIT               4200
930127 09:19:52  I_FACT_R_OP_1           0.5
930127 09:19:52  I_FACT_R_OP_2           0.5
930127 09:19:52  I_FACT_R_OP_3           0.5
930127 09:19:52  I_FACT_T_5              1.0
930127 09:19:52  I_FACT_T_6              1.0
930127 09:19:52  I_FIX_T                1300
930127 09:19:52  KNIP_GEEL_IN             15
930127 09:19:52  LOG_DAG_1           0111110
930127 09:19:52  LOG_DAG_2           0000000
930127 09:19:52  MEETPER                  60
930127 09:19:52  MINIMUM_IN                5
930127 09:19:52  MINIMUM_UIT               5
930127 09:19:52  NA_FILE                 180
930127 09:19:52  ONDER_GEDRAG_D1.1         0
930127 09:19:52  ONDER_GEDRAG_D1.2         0
930127 09:19:52  ONDER_GEDRAG_D2.1         0
930127 09:19:52  ONDER_GEDRAG_D2.2         0
930127 09:19:52  ONDER_GEDRAG_D2.3         0
930127 09:19:52  ONDER_GEDRAG_D2.4         0
930127 09:19:52  ONDER_GEDRAG_D3.1         0
930127 09:19:52  ONDER_GEDRAG_D3.2         0
930127 09:19:52  ONDER_GEDRAG_D3.3         0
930127 09:19:52  ONDER_GEDRAG_D3.4         0
930127 09:19:52  ONDER_GEDRAG_D4.3         0
930127 09:19:52  ONDER_GEDRAG_D4.4         0
930127 09:19:52  ONDER_GEDRAG_D5.1         0
930127 09:19:52  ONDER_GEDRAG_D5.2         0
930127 09:19:52  ONDER_GEDRAG_D5.3         0
930127 09:19:52  ONDER_GEDRAG_D5.4         0
930127 09:19:52  ONDER_GEDRAG_D5.5         0
930127 09:19:52  ONDER_GEDRAG_D5.6         0
930127 09:19:52  ONDER_GEDRAG_D6.1         0
930127 09:19:52  ONDER_GEDRAG_D6.2         0
930127 09:19:52  ONDER_GEDRAG_D6.3         0
930127 09:19:52  ONDER_GEDRAG_D6.4         0
930127 09:19:52  ONDER_GEDRAG_D6.5         0
930127 09:19:52  ONDER_GEDRAG_D6.6         0
930127 09:19:52  ROOD_GAR_5              2.0
930127 09:19:52  ROOD_GAR_6              2.0
930127 09:19:52  S_DBOG                07:30
930127 09:19:52  S_DOS_MAG_AAN_1       15:00
930127 09:19:52  S_DOS_MAG_AAN_2       00:00
930127 09:19:52  S_DOS_MAG_UIT_1       15:00
930127 09:19:52  S_DOS_MAG_UIT_2       00:00
930127 09:19:52  STRAF_5                 2.0
930127 09:19:52  STRAF_6                 2.0
930127 09:19:52  S_LOGGEN_1            14:00
930127 09:19:52  S_LOGGEN_2            00:00
```

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930127 09:19:52  TEGENHOUDEN_5           8.0
930127 09:19:52  TEGENHOUDEN_6           8.0
930127 09:19:52  TIJD_AFVALLEN_5        25.0
930127 09:19:52  TIJD_AFVALLEN_6        12.0
930127 09:19:52  TIJD_OPKOMEN_5          0.0
930127 09:19:52  TIJD_OPKOMEN_6          4.4
930127 09:19:52  TIJD_RIJDEN_5           2.1
930127 09:19:52  TIJD_RIJDEN_6           2.1
930127 09:19:52  UIT_TIJD                  3
930127 09:19:52  VAST_GEEL_IN              5
930127 09:19:52  VAST_ROOD_IN              5
930127 09:19:52  V_BOVEN_DR               70
930127 09:19:52  V_BTR_AF_2              1.0
930127 09:19:52  V_BTR_AF_3              1.0
930127 09:19:52  V_BTR_AF_4              0.0
930127 09:19:52  V_BTR_OP_1              0.0
930127 09:19:52  V_BTR_OP_2              1.0
930127 09:19:52  V_BTR_OP_3              1.0
930127 09:19:52  V_DR_AF_IN               75
930127 09:19:52  V_DR_AF_UIT              80
930127 09:19:52  V_DR_DIR_UIT             20
930127 09:19:52  V_DR_IN_NA_UIT           45
930127 09:19:52  V_DR_OP_IN               75
930127 09:19:52  V_DR_OP_UIT              80
930127 09:19:52  V_ONDER_DR                0
930127 17:20:20  DOSEREN AAN
930127 17:28:20  DOSEREN UIT

930128 16:33:11  DOSEREN AAN
930128 16:41:11  DOSEREN UIT

930202 12:34:29  TOERIT LUS D5.5 GESTOORD
930202 12:34:30  TOERIT LUS D5.6 GESTOORD
930202 12:34:30  TOERIT LUS D5.5 STORING OPGEHEVEN
930202 12:34:31  TOERIT LUS D5.6 STORING OPGEHEVEN
930202 16:49:37  DOSEREN AAN
930202 17:00:38  DOSEREN UIT
930202 18:00:38  DOSEREN AAN
930202 18:07:38  DOSEREN UIT
930202 18:18:38  DOSEREN AAN
930202 18:23:38  DOSEREN UIT

930203 15:56:45  DOSEREN AAN
930203 16:02:45  DOSEREN UIT
930203 17:05:45  DOSEREN AAN
930203 17:14:45  DOSEREN UIT
930203 17:19:45  DOSEREN AAN
930203 17:24:45  DOSEREN UIT
930203 17:25:45  DOSEREN AAN
930203 17:35:45  DOSEREN UIT
930203 17:40:45  DOSEREN AAN
930203 18:03:46  DOSEREN UIT
930203 18:10:45  DOSEREN AAN
930203 18:15:45  DOSEREN UIT

930205 17:30:59  DOSEREN AAN
930205 17:38:59  DOSEREN UIT

930208 16:18:21  DOSEREN AAN
930208 16:27:21  DOSEREN UIT

930209 16:19:13  DOSEREN AAN
930209 16:32:12  DOSEREN UIT
930209 17:06:12  DOSEREN AAN
930209 17:15:12  DOSEREN UIT

930210 14:24:51  TOERIT LUS D6.1 GESTOORD
930210 14:24:51  TOERIT LUS D6.2 GESTOORD
930210 14:24:52  TOERIT LUS D6.1 STORING OPGEHEVEN
930210 14:24:52  TOERIT LUS D6.2 STORING OPGEHEVEN
930210 16:09:17  DOSEREN AAN
930210 16:19:17  DOSEREN UIT
```

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930201	14:00-15:00	9	499	701	1209	185	443	628	1837	616	914	273	1803	41	588	629	0	0	0	***
930201	15:00-16:00	68	1079	910	2057	287	588	875	2932	1295	1228	343	2866	85	827	912	0	0	0	***
930201	16:00-17:00	116	1619	1124	2859	398	696	1094	3953	1940	1532	443	3915	96	1032	1128	0	0	0	***
930201	17:00-18:00	84	1435	1086	2605	457	791	1248	3853	1803	1546	449	3798	109	1176	1285	0	0	0	***
930201	18:00-19:00	49	862	801	1712	229	545	774	2486	1079	1101	281	2461	69	725	794	0	0	0	***
930201	19:00-20:00	6	216	502	724	117	283	400	1124	277	658	164	1099	33	380	413	0	0	0	***

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930202	14:00-15:00	28	604	764	1396	204	460	664	2060	732	999	269	2000	70	631	701	0	0	0	***
930202	15:00-16:00	92	1152	901	2145	345	584	929	3074	1452	1223	363	3038	118	858	976	0	0	0	***
930202	16:00-17:00	139	1764	1089	2992	446	744	1190	4182	2120	1603	471	4194	183	1030	1213	19	12	31	14
930202	17:00-18:00	100	1404	1012	2516	438	788	1226	3742	1844	1491	440	3775	103	1167	1270	0	0	0	***
930202	18:00-19:00	88	1027	865	1980	251	491	742	2722	1298	1147	309	2754	117	634	751	12	21	33	16
930202	19:00-20:00	11	276	514	801	99	353	452	1253	387	677	174	1238	17	448	465	0	0	0	***

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930203	14:00-15:00	26	598	737	1361	226	501	727	2088	751	980	303	2034	89	678	767	0	0	0	***
930203	15:00-16:00	102	1182	920	2204	329	628	957	3161	1474	1277	378	3129	123	856	979	8	4	12	16
930203	16:00-17:00	126	1632	1089	2847	399	704	1103	3950	1994	1472	445	3911	115	1032	1147	4	3	7	14
930203	17:00-18:00	94	1601	1129	2824	427	754	1181	4005	1938	1606	571	4115	408	794	1202	46	92	138	15
930203	18:00-19:00	58	1118	861	2037	233	513	746	2783	1333	1172	322	2827	74	690	764	10	10	20	17
930203	19:00-20:00	5	285	519	809	84	317	401	1210	361	648	165	1174	16	391	407	0	0	0	***

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930204	14:00-15:00	25	586	724	1335	226	441	667	2002	712	967	276	1955	66	631	697	0	0	0	***
930204	15:00-16:00	91	1166	879	2136	326	605	931	3067	1448	1224	349	3021	107	854	961	0	0	0	***
930204	16:00-17:00	153	1694	1110	2957	421	711	1132	4089	2082	1554	431	4067	84	1074	1158	0	0	0	***
930204	17:00-18:00	92	1394	1084	2570	418	807	1225	3795	1795	1518	444	3757	93	1170	1263	0	0	0	***
930204	18:00-19:00	52	831	791	1674	265	499	764	2438	1027	1107	295	2429	77	717	794	0	0	0	***
930204	19:00-20:00	12	271	518	801	124	304	428	1229	373	675	153	1201	30	406	436	0	0	0	***

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930205	14:00-15:00	57	856	862	1775	271	569	840	2615	1075	1113	347	2535	98	782	880	0	0	0	***
930205	15:00-16:00	127	1300	969	2396	387	605	992	3388	1634	1327	368	3329	115	915	1030	0	0	0	***
930205	16:00-17:00	141	1553	1110	2804	387	696	1083	3887	1912	1522	419	3853	115	1015	1130	0	0	0	***
930205	17:00-18:00	114	1359	1022	2495	427	677	1104	3599	1702	1469	410	3581	171	976	1147	13	11	24	17
930205	18:00-19:00	37	832	817	1686	262	514	776	2462	1010	1115	298	2423	56	737	793	0	0	0	***
930205	19:00-20:00	14	343	580	937	167	413	580	1517	462	826	215	1503	40	555	595	0	0	0	***

		UPSTREAM								DOWNSTREAM										
		MOTORWAY				RAMP				MOTORWAY				RAMP			RED-LIGHT			
DATE	TIME	L	M	R	TOT	L	R	TOT	SUM	L	R	W	TOT	L	R	TOT	L	R	TOT	%
930208	14:00-15:00	19	523	703	1245	180	463	643	1888	621	925	289	1835	48	611	659	0	0	0	***
930208	15:00-16:00	91	1103	887	2081	297	579	876	2957	1282	1245	364	2891	66	832	898	0	0	0	***
930208	16:00-17:00	112	1608	1125	2845	439	685	1124	3969	1970	1528	485	3983	169	993	1162	9	17	26	14
930208	17:00-18:00	78	1419	1096	2593	455	790	1245	3838	1782	1552	454	3788	122	1166	1288	0	0	0	***
930208	18:00-19:00	47	805	813	1665	266	504	770	2435	1017	1110	301	2428	69	730	799	0	0	0	***
930208	19:00-20:00	8	244	510	762	110	313	423	1185	322	668	172	1162	22	404	426	0	0	0	***

Wednesday 3 February 1993

A12 ZOETERMEER–OOST