Simulating Variable Message Signs

Influencing dynamic route choice in microsimulation

N.D. Cohn, Grontmij Traffic & Transport, nick.cohn@grontmij.nl

P. Krootjes, International School of Breda, pronos@ricardis.tudelft.nl

J.C. Zee, Grontmij Traffic & Transport, jaap.zee@grontmij.nl

Contribution to Colloquium Vervoersplanologisch Speurwerk 2004,

25 and 26 november 2004, Zeist

Table of contents

1. Introduction **3**

2. VMS In the Netherlands **3**

Systems *3*

Observed effects of VMS *4*

3. New route choice in Paramics **6**

4. VMS In Paramics **8**

VMS implementation *8*

Paramics VMS Module *8*

5. Conclusions **11**

Samenvatting

DRIPS Simuleren; Het beïnvloeden van routekeuze in microsimulatie

Dynamische Route Informatie Panelen worden al meerdere jaren in veel verschillende landen toegepast. Zij vormen een efficiënt hulpmiddel voor verkeersbeheersing en optimalisering van het wegennet. DRIP-systemen komen voor in veel verschillende vormen en hun werking hangt af van hun configuratie, lokale kenmerken en het bestuurdersgedrag. Recente ontwikkelingen in microsimulatie maken het mogelijk om DRIP-systemen expliciet te simuleren. Het nauwkeurig voorspellen van het effect van DRIPS is niet alleen afhankelijk van technische mogelijkheden maar ook van daadwerkelijke informatie van de bestuurdersreactie. Wij hebben een nieuwe toepassing ontwikkeld om DRIP-systemen in S-Paramics te simuleren. De aanleiding hiervoor komt voort uit de nieuwe ontwikkelingen van Paramics. Het vernieuwde routekeuze systeem stelt de gebruiker in staat om de dynamische routekeuze van bestuurders op specifieke locaties tijdens een simulatie direct te beïnvloeden. Dit is in het bijzonder van toepassing op het modelleren van DRIP's. Met de aangepaste routekeuze kunnen DRIP's samen met de waargenomen reactie van de autogebruikers op een goede manier gesimuleerd worden. Een test met een simulatiemodel van de stedelijke ring van Maastricht heeft de functionaliteit van de toepassing aangetoond. Met behulp van deze toepassing kunnen locatiegebonden routekeuze beïnvloedingssystemen (zoals DRIP's) expliciet gemodelleerd worden.

Summary

Simulating Variable Message Signs; Influencing route choice in microsimulation

Variable Message Signs (VMS) have been used for a number of years in many different countries. They constitute an effective tool for traffic management and the optimization of road network use. VMS-systems take many forms and their effectiveness depends on their configuration, local characteristics and driver behaviour. Recent developments in microsimulation have made it possible to simulate VMS-systems within the framework of traffic models. At the same time, accurate forecasting of the effectiveness of VMS is not only dependent on software capabilities but on information about actual driver response. We have developed a new tool for simulating VMS-systems in Paramics simulation models. The stimulus for this came from new developments in the Paramics software. The new assignment process allows the user to directly influence the dynamic route choice of drivers at specific locations during a simulation. This is of particular practical use for modelling VMS-systems as they exist on road networks today. The new VMS tool incorporates elements of existing Dutch VMS systems as well as observed driver response to these systems. A test of the new tool made with a simulation of the urban ring of the city of Maastricht showed that it is functional. The module allows the modeller to determine that all drivers have a specific type off route information at a specific location and to determine the response of the drivers in the simulation.

1. Introduction

Variable Message Signs (VMS) have been used for a number of years in many different countries. They constitute an effective tool for traffic management and the optimization of road network use. VMS-systems take many forms and their effectiveness depends on their configuration, local characteristics and driver behaviour. Recent developments in microsimulation have made it possible to simulate VMS-systems within the framework of traffic models. At the same time, accurate forecasting of the effectiveness of VMS is not only dependent on software capabilities but on information about actual driver response.

The purpose of the work described in this paper was to develop a new VMS-module that can be used to simulate VMS-systems in Paramics (1) for road networks in the Netherlands. New developments in the Paramics software made it possible for us to program a VMS module incorporating information from local VMS systems. The new module is based on these elements:

1. The Dutch queue detection system now in place on the motorways (2).
2. Data about observed driver response to VMS-information in Rotterdam (3).
3. New dynamic route choice processes in Paramics software (1).
4. Programming using Standard Network Management Protocol (1).
5. Testing of the tool based on a microsimulation of an incident on the urban ring road of Maastricht.

This paper presents each of these elements and provides conclusions about the applicability of the new VMS tool for use with Paramics.

2. VMS In the Netherlands

Systems

There are three main types of VMS information provided by systems in use today in the Netherlands:

1. Queue lengths: these systems provide information on the number of kilometres of queues on the actual route and on alternative routes.

2. Travel time: these systems provide information on travel time in minutes to specific motorway interchanges or destinations.
3. Qualitative information: these systems provide general qualitative information about the condition of the road ahead and are generally used for non-motorway situations. Information such as ‘delay on the A9’ or ‘no delay’ is provided.

The first type of VMS is the currently the most common in the Netherlands. The information displayed by VMS systems that display queue lengths is automatically generated at the traffic control centre(s). Information about the traffic volumes on the road network is collected automatically using a system of detection loops.

Many of the VMS systems in the Netherlands are based on the Automatic Incident Detection (AID) system (2). AID consists of a loop detection system linked to a warning system for road users. The loops detect speeds by lane at approximately every 400m. When speeds cross specific thresholds (for example, 35kph) advisory speeds are provided using automated signs on gantries. The same detected information is used to determine queue locations and lengths. This queue length information is in turn used for messages on VMS signs in several regions in the Netherlands (see Figure 1).

Observed effects of VMS

A study completed by Transpute provides clear information about the relationship between VMS information and route choice (3). In this study, the difference in congestion delay (queue length) between two alternative routes (the stimulus for route change) and the change in the ratio between the traffic flows on the two routes (the response) were examined.

Figure 2 below shows an example of this. Assume that both route 1 and route 2 can be used to reach a given destination. In an average congestion-free situation, the route choice split percentage for route 1 is calculated as:

$$split_{normal} = \frac{volume_{route1}}{volume_{route1} + volume_{route2}}$$

For the example situation without congestion, split = 60% for route 1, leaving 40% for route 2. This is referred to as the ‘normal’ split percentage for route 1.

The response to a difference in queue lengths between the two routes is a change in the split percentage. This means that there is a ‘desired’ split percentage in the modelling of congested situations. This split percentage is ‘desired’ by the modeller in order to recreate the observed behaviour of drivers (from the Transpute study) when provided with VMS information:

$$split_{desired} = split_{normal} + a_{response} \times (queuelength_{route1} - queuelength_{route2})$$

Note that queue lengths are stated in kilometres in this paper.

The Rotterdam study (3) showed that $a_{response}$ was approximately 1%. This means that if, in the example, the VMS indicates that there is a 3km queue on route 1 and a 10km queue on route 2, the desired split becomes 67% for route 1. This effect was found to be consistent across different locations on the Rotterdam motorway network. If the queue on route 1 becomes longer than the queue on route 2, the desired split becomes smaller than the normal split for route 1.

The exact level of driver response depended on the time of day (peak/off-peak) and the form in which the information was given on the VMS signs.

In summary:

- Normal split = route split percentage in free-flow conditions without VMS information
- Current split = route split percentage at a given moment (in reality or in a microsimulation)
- Desired split = route split percentage that is achieved by providing VMS information about queue lengths
- In free-flow conditions, the normal split is equal to the current split. According to the Transpute study, when providing VMS information, the current split will become equal to the desired split.

We used this behaviour directly in our new VMS module.

3. New route choice in Paramics

The new route choice modeling in Paramics is described in detail by Boris Johanssen (1). Paramics route choice has been designed to reflect actual travel behavior throughout a complete journey. A set of travel costs is maintained for all possible destinations for every network link in a given model. These generalized costs are based on distance, predicted time and any toll. The costs can be calculated differently for familiar and unfamiliar drivers, high occupancy vehicles, heavy goods vehicles or other user-specified classes.
Paramics allows the user to incorporate 'route feedback' in the choice process, providing dynamic route information during a simulation. It also allows for inaccuracy in drivers' perception of time and distance when making route choices ('route perturbation').

Experience with microsimulation models and an understanding of real driver behaviour has shown that the previous Paramics route choice modelling was not always adequate for long-distance journeys with a large route choice set. In order to improve route choice for these situations and to provide new capabilities for simulating ITS systems, SIAS has added a second level to the dynamic assignment process in Paramics (1):

> *A long journey may be delineated by a set of waypoints, the trip between each being treated as a short journey in its own right. On long journeys, drivers' routing decisions are based on the best route to the next waypoint, i.e. to the start of the next stage of the journey. Waypoints form a macro level network, while the components of the journey between them remain at the micro level.*

Two important benefits of this routing system are:

- Route choice in larger simulation models is more realistic. In the past it was possible to obtain long-distance routes which included, for example, unnecessary detours through town centres as part of regional origin-destination movements. This happened when such routes fell within the perturbation margin used to establish the set of possible routes. By using waypoints, long routes are divided into shorter segments whereby, given the same perturbation margins, routes with unnecessary detours fall outside the choice set. It is also possible to specify the perturbation margin separately for the ‘macro level’ (for the entire route from origin to destination) and the ‘micro level’ (between waypoints).

- Waypoints allow the user to determine where route information is applied to drivers. Using VMS in Paramics, it is possible to modify the information about the costs of reaching specific waypoints and provide this information to drivers at specific locations (for example, VMS locations). This may result in a change in driver route choice at specific network locations during the simulation.

Depending on user settings, vehicles in the microsimulation are informed of delay on their route and will use this information to change their route. This process is referred to as feedback. With the advent of waypoints and the distinction of macro and micro level route choice, the feedback process has been refined. The amount of feedback the drivers use in their route choice depends on their aggression and awareness characteristics. This is important for the effects a VMS system will have on drivers in a microsimulation.

It is possible to directly change the behaviour of drivers at VMS locations. Using the example with two routes shown above, we can send drivers passing the VMS to a waypoint on route 1 or to a waypoint on route 2. We can change these instructions constantly during the course of the simulation, depending on the actual and desired split percentages achieved at any given moment. These capabilities have been used directly in developing the new VMS module.

These capabilities greatly increase the value of microsimulation for testing traffic management strategies. In particular the testing of VMS systems in microsimulation can be particularly useful because the iterative effects in a congested network with a given origin-destination distribution can now be calculated within a microsimulation in a very practical way.

4. VMS In Paramics

VMS implementation

Given the workings of the Dutch queue detection system, the information about observed driver response and the new Paramics route choice, the next step in the development of the VMS module was to program it. This was done using Visual Basic and the Standard Network Management Protocol (SNMP). SNMP is a standard protocol adopted by urban traffic control systems for the management of signals detectors and other transport control devices. The SNMP interface allows all aspects of signals control (e.g. timing, stage sequences, red and green times etc.) to be linked to road traffic conditions via real or simulated control systems. Through SNMP interfaces, microsimulation can be used to test and evaluate the effect of proposed network management control systems and is a powerful tool when used under constantly changing route choice conditions.

VMS signs can be implemented in Paramics, but in order to control them dynamically, the SNMP interface has to be used. Because the controller runs outside Paramics, strategies and actions can be tailor-made. This means that it is possible to implement different kinds of VMS messages (queue lengths, travel times, incident warnings) as well as specific driver responses (route choice). It is also possible to implement dynamic lane restrictions (use of the hard shoulder, for example) or set lane speeds dynamically based on specific VMS algorithms.

Using SNMP it is possible to influence a wide variety of behaviour during a simulation, including:

- Vehicle speed.
- Route choice.
- Awareness.
- Aggression.

These parameters can be influenced according to vehicle classification, destination or other dimensions.

Paramics VMS Module

We have developed a VMS-module for Paramics based on the Dutch VMS-systems and behaviour described above. This module uses intensities and speeds to determine the VMS-response based on the AID detection system. The effect of the system on driver choices is modelled based on the results from the Rotterdam study.

The VMS module works as follows:

- First the module determines what the ‘normal’ route choice split percentage is (as described above) for normal conditions at a given location where route alternatives exist. This is done by recording and smoothing split percentages over a number of different congestion-free moments (possibly the warm-up period in the simulation).
- The module then adjusts the ‘response’ to the VMS information about queue lengths until the current split percentage in the simulation is equal to the desired split (see also above). When linking the VMS module to the simulation model, the user defines the destination zones for which the response is to be adjusted. This must be done based on local knowledge or observed origin-destination route patterns. In practice it is not yet known how much the response must be adjusted in order to reach the desired split. The VMS module determines this iteratively in the context of the simulation. In the meantime, the desired split may change during the simulation as the queue lengths on the different routes change. The module iteratively tries to achieve the same response to the VMS as found in the Rotterdam study (3). Note that the module does not try to optimise network performance. Research done by S. Hoogendoorn (4) shows that a higher response rate is necessary to reach an optimum situation.

Practical application of the module

When applying the VMS module in a microsimulation, the following steps must be made:

1. Define two (or more) routes which are alternatives for each other; these may be, for example, two directions on a ring-road. A VMS-board is located at the point at which these routes diverge.
2. Designate the area of influence in the model. The area of influence consists of traffic zones (destination zones) for which drivers passing the VMS can use either of the alternative routes.
3. Create detection loops on both of the routes to detect delays based on the standards of the AID detection system. The module has automated this process for the user.
4. Start the simulation model; the VMS will communicate with Paramics (by way of SNMP).

The module will perform the following routines:

5. Read the speeds and volumes detected by the loop system and convert them to AID-codes for the VMS system.
6. Determine the difference in congestion between the two routes.
7. Calculate the normal and current route choice split percentages.
8. Calculate the desired route choice split percentages.
9. If the desired split percentages differ from the current percentages, the response of traffic passing the VMS-sign is changed (the amount of vehicles for which the route choice is changed).

Steps 5 through 9 are repeated iteratively until the desired split is achieved.

As in reality, the VMS messages are refreshed once per minute. Step 5 is also repeated once per minute. Steps 6 through 9 are recalculated every 20 seconds in the VMS module. This is done to help ensure that the iterative process is rapidly completed.

Test of the module

The VMS module has been programmed to apply route choice behavioural effects based on the Automatic Incident Detection protocol and driver response behaviour from the Rotterdam study. As such we expect that it should provide generally realistic results when applied. Due to a lack of other VMS evaluation studies with detailed data, we completed a test of the module’s functionality using a microsimulation of the urban ring road of the city of Maastricht.

In order to be able to examine the workings and effects of the module as clearly as possible, we completed simulations without any feedback in the route choice. When testing a VMS for an actual situation, the modeller must consider the general knowledge of drivers in the study area and the availability information on current traffic conditions. Awareness and aggressiveness are of great importance in terms of the effects of a VMS in reality and must be taken into account in the modelling process as well.

Figure 8 shows the test situation used. The ring road, the selected destination zones of the vehicles to be influenced by the VMS, the location of the VMS, the location of the simulated incident and the alternative route are indicated.

Table 1 contains the travel times for the northern and southern ring road, showing the differences between the reference situation and the simulation with the VMS module activated.

In the test, the travel time on the northern ring road begins to worsen as the traffic flow increases during the morning peak. The VMS module then begins to send more traffic to the southern ring road. This results in improvement on the northern ring relative to the situation without VMS, though the queue is reduced as opposed to being eliminated. The southern ring travel times do not worsen significantly until 8:00 because it has adequate capacity available for the additional traffic. After 8:00, the southern ring also begins to slow and the VMS cannot achieve as much improvement as earlier in the simulation period. This is because the response diminishes along with the diminishing difference in queue length between the two routes.

5. Conclusions

The VMS module created for use in Dutch microsimulation works logically and provides clear results. The module allows the modeller to determine that all drivers have a specific type of route information at a specific location and to determine the response of the drivers in the simulation. A validation using an observed situation before and after the implementation of a VMS is necessary before applying the module in studies. Sensitivity tests are also required to ensure that feedback, awareness and aggression levels reflect local conditions when combined with a VMS. Once this work has been completed, the VMS module should provide added value for simulating traffic management systems prior to implementation.

References

Johansson, Boris. *Dynamic Traffic Assignment in SIAS Paramics*. Proceedings for the seminar Dynamic Traffic Assignment for Reliability Studies, Delft, TRAIL Research School, April 2004.

Grontmij Traffic Management. *Optimalisatie parameterinstellingen AID*, for the Netherlands Ministry of Transport AVV, De Bilt, May 2002.

Transpute. *Dynamische route informatie panelen rond de Ring van Rotterdam* (vervolgonderzoek), for the Netherlands Ministry of Transport South Holland, Gouda, March 1998.

Hoogendoorn, S.P. *De waarde van de perfecte reisinformatie, marktpenetratie en de invloed van collectieve verkeersinformatie*, DVM Symposium, Rotterdam, April 2001.

List of tables and figures

TABLE 1 VMS module test results
FIGURE 1 AID General Schematic
FIGURE 2 AID linked to simulation by way of SNMP
FIGURE 3 Example route choice situation
FIGURE 4 VMS Module flow chart of queue length
FIGURE 5 VMS module flow chart showing determination of split percentage and response
FIGURE 6 VMS Module user interface
FIGURE 7 VMS response monitoring screen
FIGURE 8 Test simulation model of Maastricht city ring road

TABLE 1 VMS module test results

Travel times in minutes, per time period	**6:00 - 6:30**	**6:30 - 7:30**	**7:00 - 7:30**	**7:30 - 8:00**	**8:00 - 8:30**	**Mean**
Ringroad North reference	0:06:05	0:06:58	0:07:46	0:08:22	0:08:38	0:07:34
Ringroad North with VMS	0:06:05	0:07:02	0:07:30	0:07:45	0:08:25	0:07:21
	0%	**0.9%**	**-3.6%**	**-8.0%**	**-2.6%**	**-2.9%**
Ringroad East / South reference	0:06:16	0:06:22	0:06:20	0:06:18	0:06:26	0:06:21
Ringroad East / South with VMS	0:06:16	0:06:21	0:06:17	0:06:16	0:06:28	0:06:20
	0%	**-0.3%**	**-0.8%**	**-0.5%**	**+0.5%**	**-0.3%**

FIGURE 1 AID General Schematic

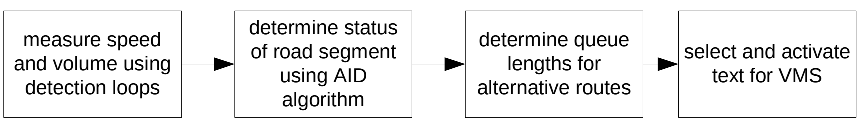

FIGURE 2 AID linked to simulation by way of SNMP

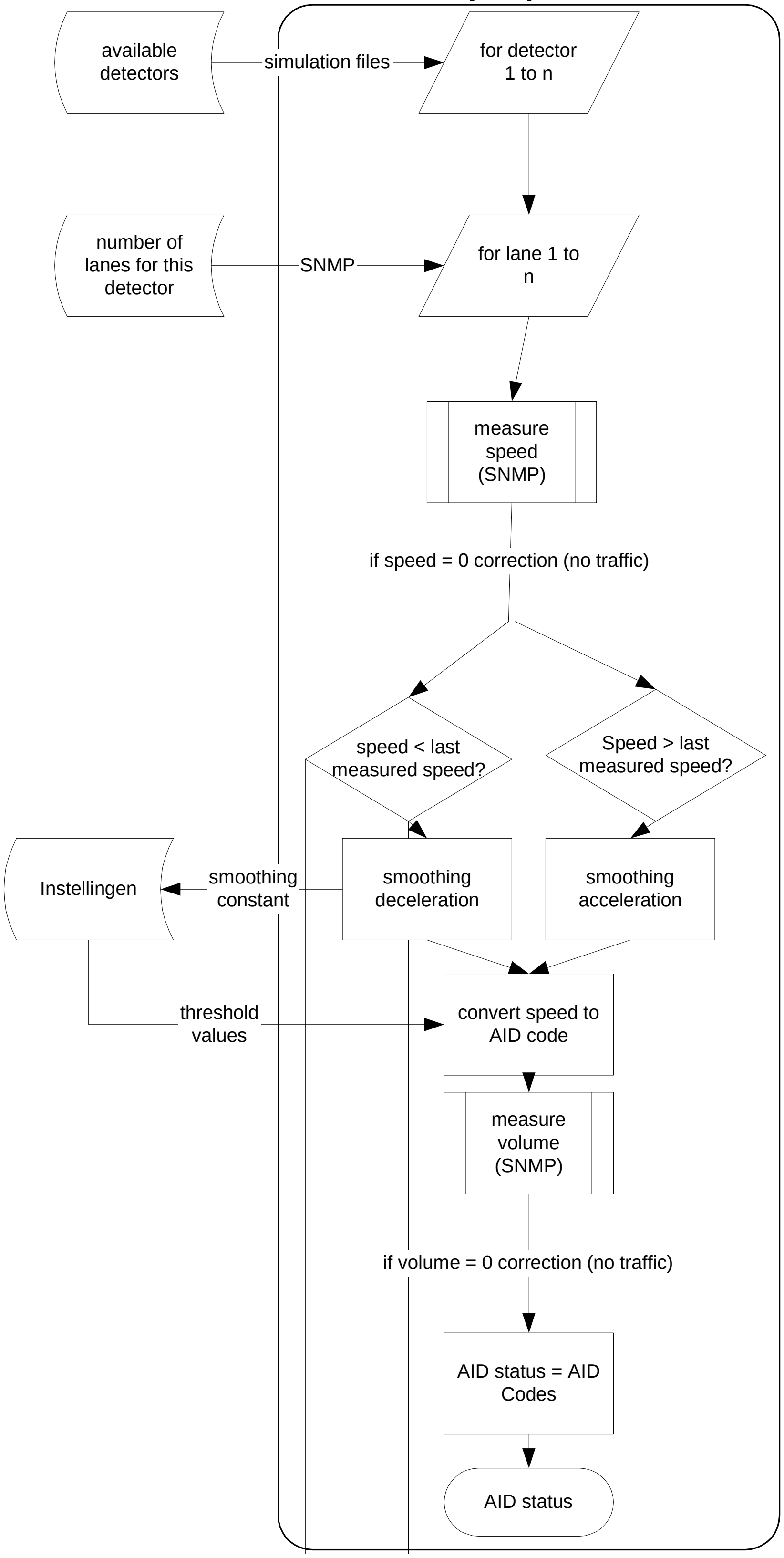

FIGURE 3 Example route choice situation

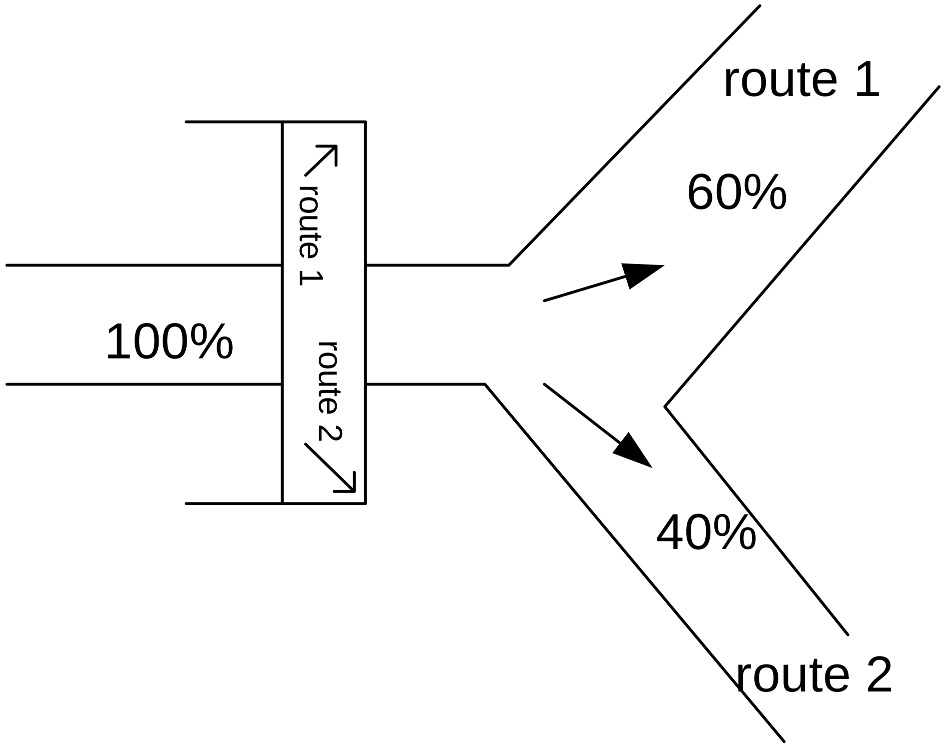

FIGURE 4 VMS Module flow chart of queue length

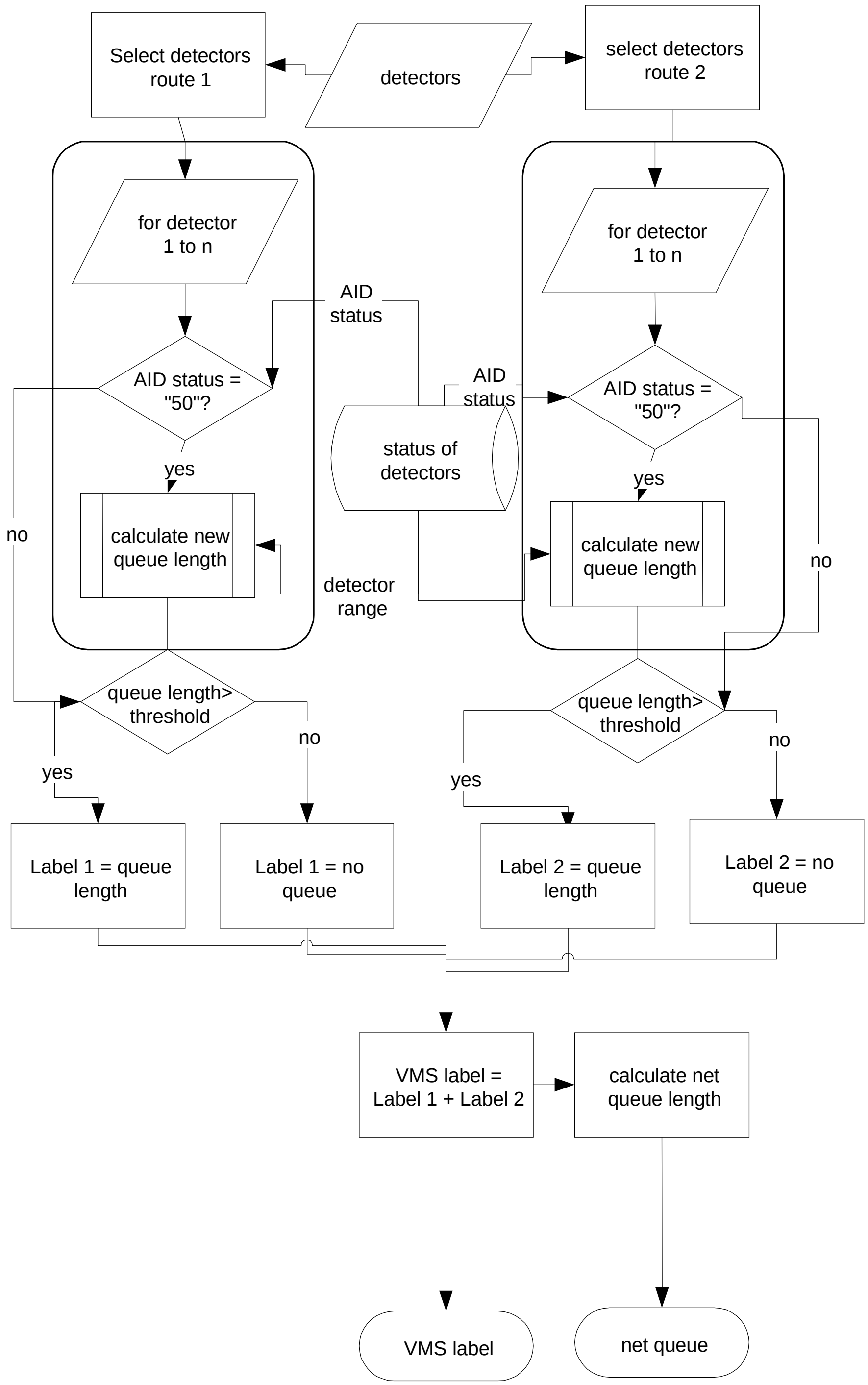

FIGURE 5 VMS module flow chart showing determination of split percentage and response

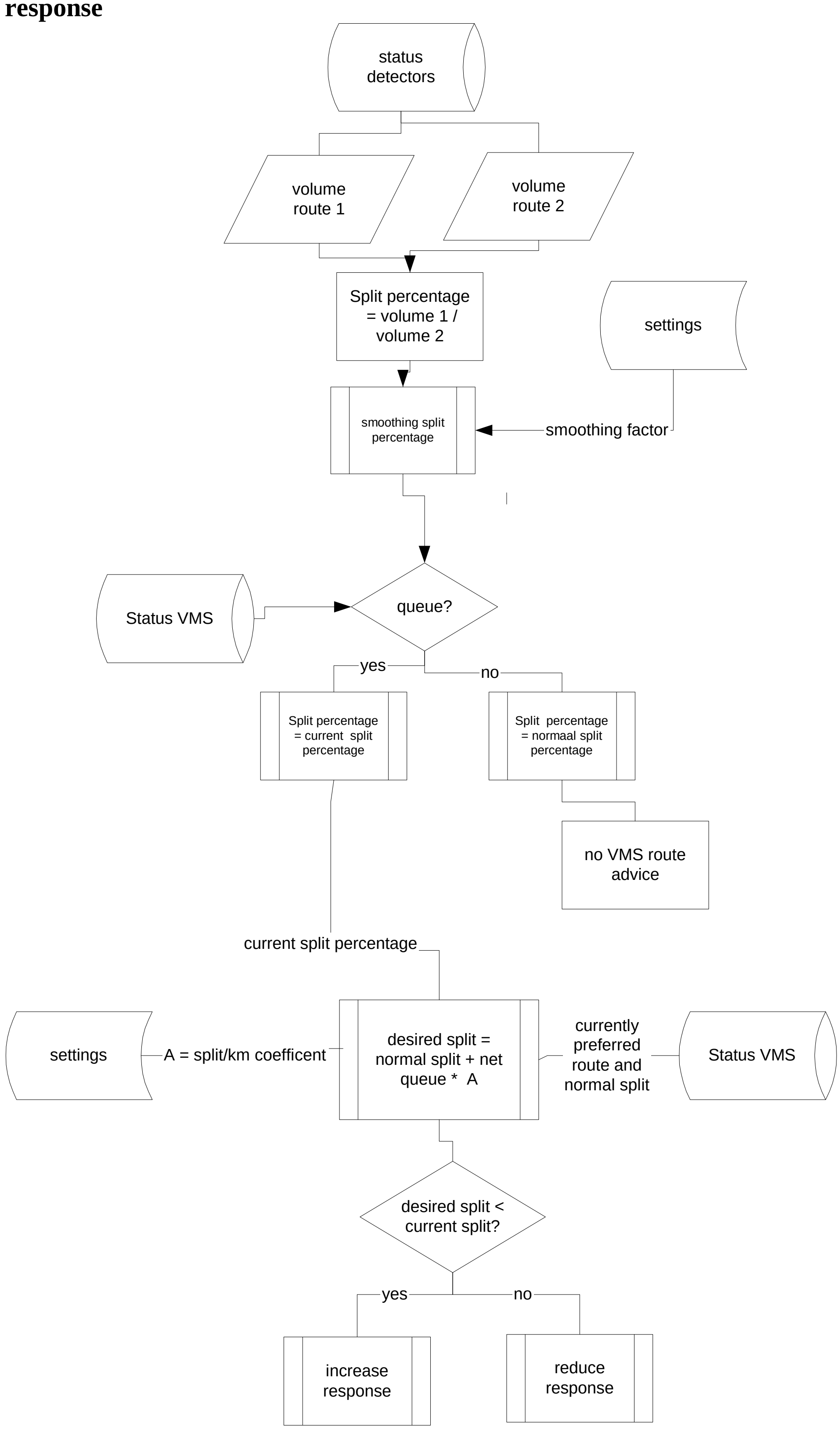

FIGURE 6 VMS Module user interface

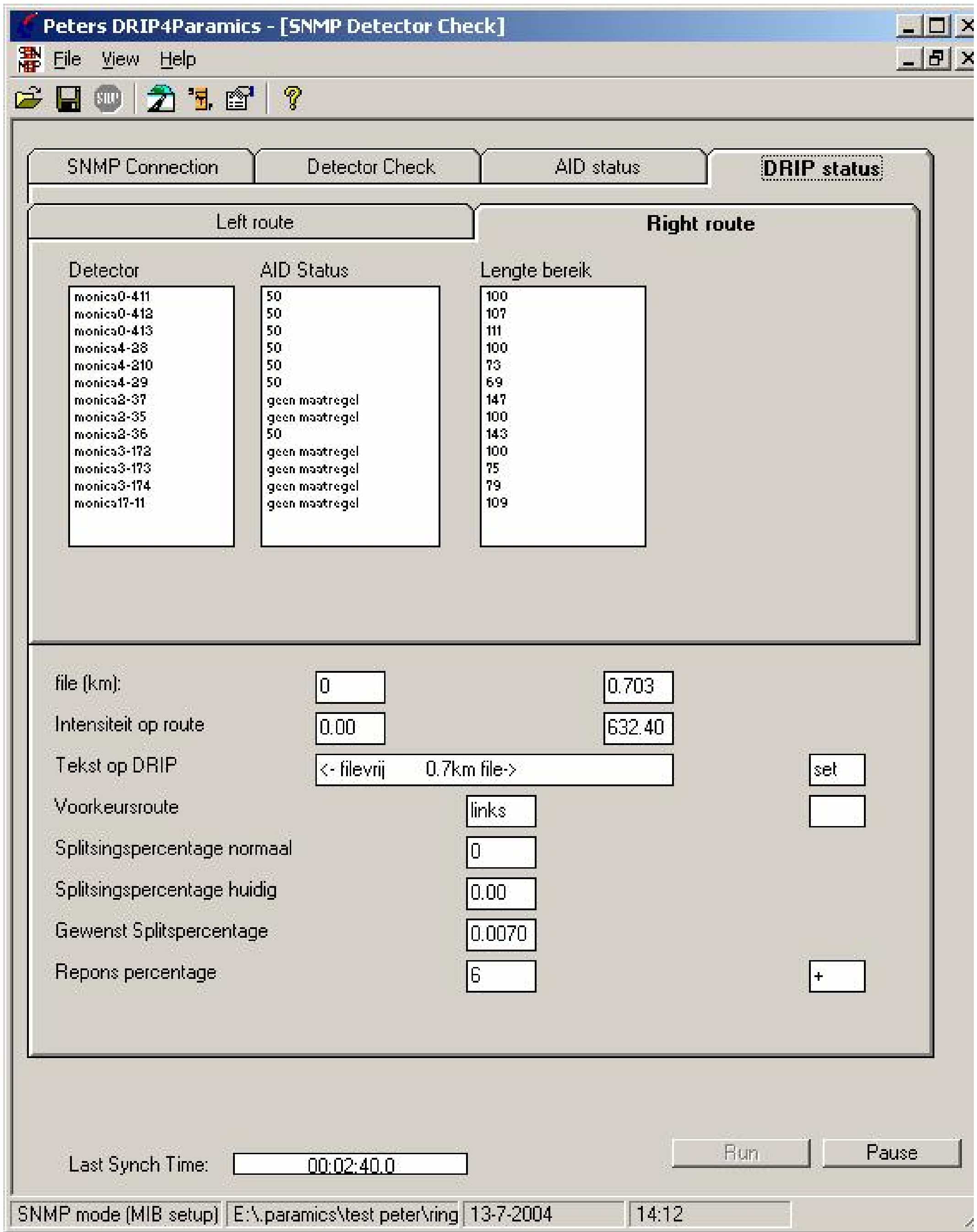

FIGURE 7 VMS response monitoring screen

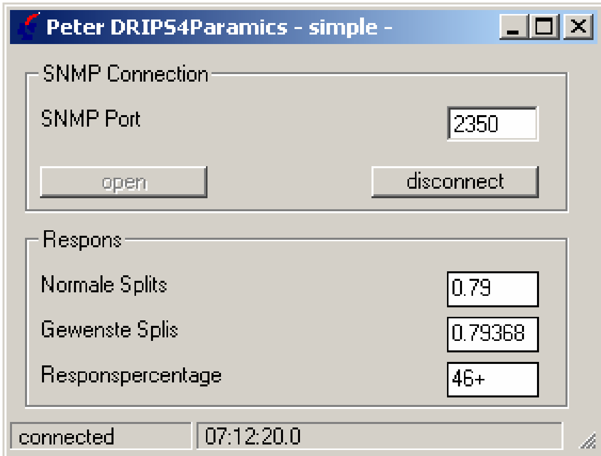

FIGURE 8 Test simulation model of Maastricht city ring road